Wild West Frisia : the role of domestic and wild resource exploitation in Bronze Age subsistence
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5. Animal husbandry

5.1 INTRODUCTION

Small-scale mixed subsistence farming, as is postulated for the West Frisian Bronze Age (Chapter 3), consists of crop and animal husbandry, the latter of which is the subject of research in this chapter. For the investigation of animal husbandry practices, the old and new available data are re-evaluated similar to hunting in the previous chapter: first, previous research of animal husbandry in West Frisia is reviewed, after which the main components are distilled from the current model. These main components are challenged in this chapter. The numbers behind each of the main components are restated in the methods section (section 5.2) where the methods used to challenge each main component are further explained.

5.1.1 Previous research

Animal husbandry is defined as: "controlled cultivation, management, and production of domestic animals, including improvement of the qualities considered desirable by humans by means of breeding." – Encyclopaedia Britannica (2016).
The above definition shows the complexity of animal husbandry practices and the multitude of aspects which need to be researched in order to understand its organisation. A previous, elaborate attempt towards researching animal husbandry in West Frisia was performed by IJzereef (1981). He created an elaborate model for animal husbandry in West Frisia during the Bronze Age based on a large bone assemblage uncovered during one of the large-scale West Frisian excavations, at Bovenkarspel Het Valkje. His model can be summarized in the following main components. The excavation at Bovenkarspel yielded the domestic animal remains of cattle, sheep, goat, pig, dog, and horse, and these animals seem to be the basic domestic animals kept in the Bronze Age throughout West Frisia. Cattle are the dominant species found, based on both number and weight of bones (IJzereef 1981, 25), which seems to underline their importance for subsistence (1). A further indication of the special character of cattle in the Bronze Age, and animal husbandry practices in general, is that seemingly specialisation in the use of livestock seemed to be occurring. Based on ratios of age at slaughter and sex of cattle, different specialisations of their use through time were identified (2) (IJzereef 1981, 195). In the Middle Bronze Age, a dominance of remains of male cattle was observed in Bovenkarspel, apparently signifying the importance of bulls and oxen as draught-animals and meat suppliers (2a). In the Late Bronze Age, remains of cows were more dominant in the assemblage, indicating that milk production became more important during this time (2b). Inherent to the previous statement, milk consumption by humans after being weaned was therefore assumed for the Bronze Age (3). In addition to the use of the cattle herd, IJzereef has also identified possible original herd sizes for West Frisian households based on the size of the barn (4) (IJzereef 1981, 177). West Frisian houses do not show any indications for a barn section of the house. However, based on a comparison of these houses with contemporary barn-houses from the east of the Netherlands, IJzereef assumes that barns in West Frisia could have contained, and therefore households would have possessed 10-30 cattle, with 50-30% cows, respectively (5) (IJzereef 1981, 183).

The current model therefore indicates the importance of animal husbandry for the households and settlements in Bronze Age West Frisia based on the domestic animal remains uncovered at Bovenkarspel Het Valkje, with cattle forming the most dominant and widely exploited domestic animal species.

5.1.2 The proxies and the sites

The main components of the current animal husbandry model, and by extent the model itself are re-evaluated in this chapter by, similar to the previous chapter, (re-)analysing both old unpublished data as well as data from more recent excavations. Again,

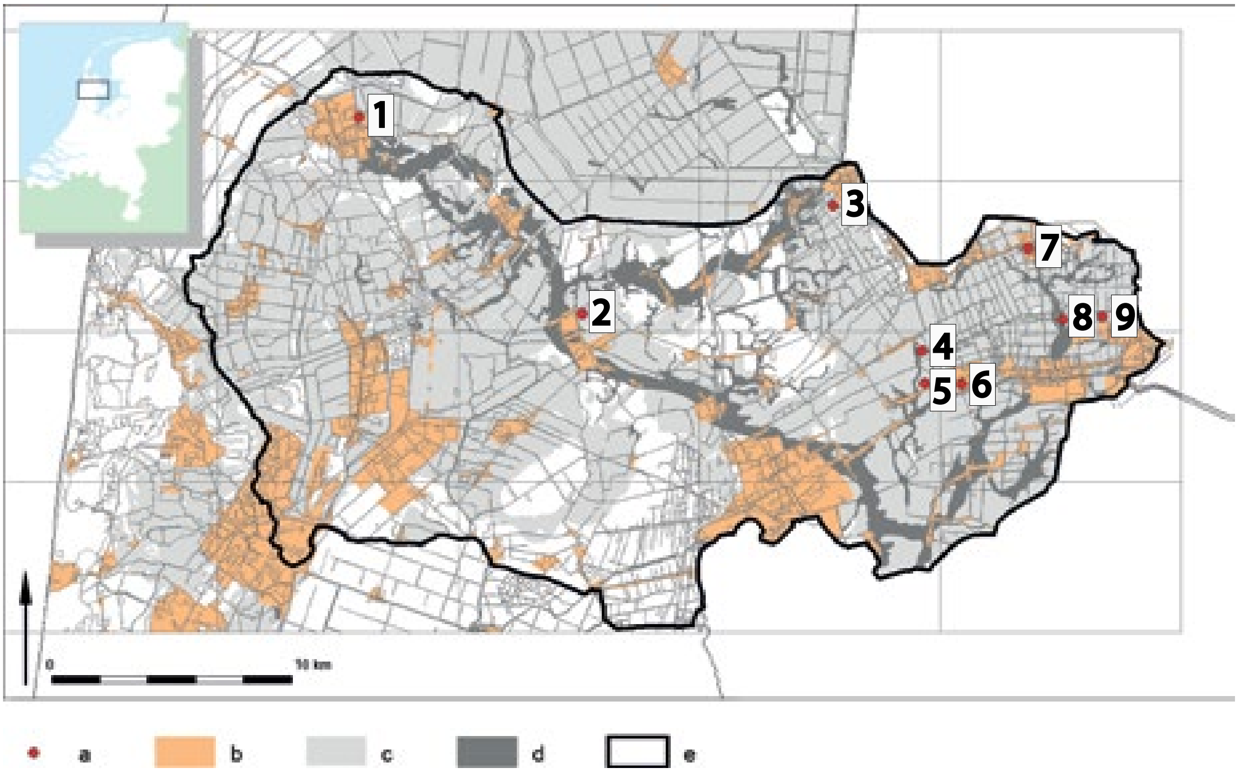


Figure 5.1. Overview of the sites of West Frisia that yielded domestic animal remains. 1: Schagen de Hoep-Noord; 2: Hoogwoud Opmeer; 3: Medemblik Schepenwijk II; 4: Zwaagdijk 1961 and Zwaagdijk Oost; 5: Westwoud; 6: Hoogkarspel Tolhuis and Hoogkarspel Watertoren; 7: Andijk Zuid and Noord; 8: Bovenkarspel Het Valkje; 9: Enkhuizen Kadijken; a: location of an excavated site; b: present-day urban areas; c: tidal marsh deposits; d: creek deposits; e: outline of present-day West Frisia.

several different proxies (*i.e.* ethnography, biology, biochemistry, archaeology, and statistics) are used for the creation of an expectation of the role and praxis of animal husbandry in a small-scale mixed farming community, as well as for the analysis of the West Frisian data (section 5.2, 5.3, and 5.4). A thorough assessment of the impact of different processing techniques affecting a bone assemblage is also included in this chapter (section 5.4.7), an aspect which is also reflected in the new programme Faustitas which is created for the improved construction and interpretation of mortality profiles (section 5.4.2 and Appendix A1.7). The new results obtained from this programme as well as the results from other analyses made in this chapter form a new model for animal husbandry in West Frisia in the Bronze Age.

The information on the sites yielding domestic animal remains is summarized in Figure 5.1 and Table 5.1, including location, name, date, dating method, and applied sieving mesh size.

Throughout the text, site names are addressed by their first name only, unless further specification is necessary to avoid confusion between different sites from the same location.

5.1.3 Main current model components

The main components of the current animal husbandry model, which are challenged in this chapter, are as follows:

(1) Cattle was the dominant domestic animal species in West Frisia and was most important for subsistence.

Table 5.1. Information on the sites of West Frisia used for the analysis of animal husbandry.

Site location	Toponym	Excavated	Date	Dating method	Sieving mesh size	Reference(s)
Andijk	Zuid and Noord	1973	1500-1100 cal BC	14C-dating and pottery typology	unknown	Mensch & IJzereef 1975 (mammals) Aal 2016 (mammals)
Bovenkarspel	Het Valkje	1974-1978	1500-800 cal BC	14C-dating and pottery typology	1.0-2.0 mm	IJzereef 1981
Enkhuizen	Haling	2012	1500-800 cal BC	14C-dating and pottery typology	not sieved	van der Jagt 2014
Enkhuizen	Kadijken	2007-2009	1500-800 cal BC	14C-dating and pottery typology	4.0 mm	Zeiler & Brinkhuizen 2011, 191-216
Hoogkarspel	Watertoren	1973-1978	1500-800 cal BC	14C-dating	unknown	Clason 1967
Hoogkarspel	Tolhuis DEF	1964-1969	1500-800 cal BC	14C-dating and pottery typology	unknown	Smits 1978 Suwijn 1981
Hoogwoud	Opmeer	2004	1300-1100 BC	pottery typology	4.0 mm	van Dijk 2005, 36-43
Medemblik	Schepenwijk II	2007	1450-800 cal BC	14C-dating and pottery typology	1.0 and 4.0 mm	Groot 2010b, 83-104
Schagen	de Hoep-Noord	2003-2004	2200-1600 cal BC	14C-dating	1.0, 2.0, 5.0 mm	Zeiler *et al.* 2007
Westwoud	1988	1988	1400-800 cal BC	AMS-dating	0.5-1.0 mm	Buurman 1996
Zwaagdijk	1961	1961	1500-1100 cal BC	14C-dating and pottery typology	unknown	Clason 1964

(2) Animal husbandry in the West Frisian Bronze Age was characterized by specialisation towards specific uses of cattle:

(2a) In the Middle Bronze Age, animal husbandry was specialized towards meat production and draught power.

(2b) In the Late Bronze Age, animal husbandry shifted towards milk production.

(3) Milk was consumed by people in West Frisia during the Bronze Age.

(4) Herd size can be related to the (reconstructed) size of a barn of a house.

(5) Bronze Age households in West Frisia possessed 10-30 cattle, consisting of 50% cows in the case of 10 cattle, and 30% cows in the case of 30 cattle.

5.2 METHODS

In order to investigate whether the role and organisation of animal husbandry in Bronze Age West Frisia presented in the current model is plausible, the available data was analysed by multiple methods, which are presented here. As has become apparent from the above definition of animal husbandry (section 5.1.1), a lot of time and effort is required for its many integrated activities in order to successfully operate. Therefore, these different activities are translated into general aspects related to animal husbandry (Table 5.2), which are first researched and discussed separately, before they are re-integrated in an attempt to understand animal husbandry in its entirety.

Each of the aspects summarized in Table 5.2 is the starting point for creating an expectation of animal husbandry practices (section 5.3), as well as for analysis of the West Frisian data (section 5.4). To achieve this, five main disciplines are used: ethnography, biology, biochemistry, archaeology, and statistics. For the analysis and interpretation of the West Frisian data, each basic animal husbandry aspect is discussed separately for the different domestic animal species concerned (*i.e.* cattle, sheep, goat, and pig) (section 5.4). Dog and horse, although both domestic animal species, are not treated in much detail, since they are not assumed to have been major livestock species contributing to the subsistence economy in relation to consumption. Their potential other roles are, however, discussed in section 5.4.7.4. Furthermore, in the analysis of the data, it is taken into account that the small-scale mixed farms in Bronze Age West Frisia are assumed to be of limited scale, as introduced in Chapter 3, which may affect the praxis and organisation of the required activities.

Finally, as shortly mentioned above, the development and application of a new programme called Faustitas is introduced in this thesis (section 5.4.2/Appendix A1.7), which allows for a more accurate construction and interpretation of mortality profiles. With this programme a more detailed understanding of past human practices regarding animals is created by diminishing the effects of internal and external biases on bone data.

5.2.1 Ethnography

A general idea of the importance of animal husbandry in small-scale mixed farming communities was obtained through the employment of the ethnographical work by Murdock (1981). A selection was made of the cultures described in his work to most closely resemble the assumed Dutch Bronze Age situation (cf. Chapter 4, section 4.2.1). This selection was the same as that employed for the other chapters on subsistence (Appendix A1.4), so that the

Table 5.2. Basic aspects related to animal husbandry

Animal husbandry aspects	Relates to:
a. Herd/flock size and composition	owned livestock
b. (In)breeding	produced livestock
c. Use	purpose of livestock
d. Handling and related locations	moving and keeping livestock
e. Nutrition and related locations	feeding requirements of livestock
f. Seasonality	extra seasonal activities related to livestock

role of each food strategy for subsistence could be compared on an equal basis. More specific parallels for the aspects related to animal husbandry practices in West Frisia were found in detailed ethnographic material on modern-day small-scale mixed farming communities, which are elaborated upon in each respective section. Especially information on herd size and composition, use, and breeding of livestock provided great insight into these practices performed by small-scale farmers. By researching communities from several locations in the world, an attempt was made to understand consistent animal husbandry practices regardless of geography, time period or climate.

5.2.2 Biology

Biological information was employed to study several aspects of animal husbandry. First of all, population genetics were consulted to estimate the effect of inbreeding on small populations of livestock. An effective population size was furthermore calculated based on the West Frisian data in order to gain insight into the minimum size of herds required to sustain a healthy livestock population. Since subsistence economies are self-sustaining units, it is assumed that each settlement possessed herds which were large enough to be self-reproducing. Information on the breeding and birthing behaviour of cattle, sheep/goat and pig was used to assess the seasonality of specific animal husbandry practices.

Grazing behaviour and grazing experiments performed in partly forested areas (Putman 1986; Baéte & Vandekerkhove 2001) provided information on the probable size of pasture (both grassland and woodland) required to sustain the herds and flocks of West Frisian households.

5.2.3 Biochemistry

Information from ancient DNA (aDNA) research in combination with dental calculus analysis of Bronze Age individuals has yielded detailed indications for the probability of animal milk consumption by adults during this time. Strontium isotope analysis has been applied to teeth to investigate the origin of West Frisian cattle and sheep/goat (Brusgaard 2014), and nitrogen isotope analysis has been applied to charred cereal grains to evaluate the application and role of manure in West Frisia (Appendix A1.11; Chapter 6).

5.2.4 Archaeology

Archaeological finds from Bronze Age north-western Europe at large, as well as West Frisia in particular, has revealed evidence for several aspects related to animal husbandry practices, including the use of cattle and sheep, animal health, as well as possible configurations of livestock in the barn.

5.2.5 Statistics

The discipline of statistics was consulted to improve the current methods used for the interpretation of age at slaughter (*i.e.* Chaplin 1971) and subsequent interpretation on the use of livestock (*i.e.* Payne 1973). These methods were proven to be statistically flawed, after a careful re-interpretation of their employed assumptions and calculations and their resulting outcome in comparison with known data (Appendix A1.7). The re-evaluation of these current methods for determining essential aspects of a herd and its use has resulted in an online programme called Faustitas. This programme can be applied to cattle and sheep/goat data and is not specific for the Bronze Age, enabling a wide applicability to zooarchaeological data in general (Appendix A1.7).

5.3 CREATING AN EXPECTATION OF ANIMAL HUSBANDRY PRACTICES

In this thesis, Bronze Age West Frisian farms are postulated to practice small-scale animal husbandry based on the presence of indications for mixed farming and its inherent limited scale (cf. Chapter 3, section 3.3). Similar to the analysis of hunting in the previous chapter, the role of animal husbandry in such communities was investigated with the use of the study performed by Murdock (1981). The analysis of these relatively modern small-scale farming communities has revealed that on average, animal husbandry aids subsistence by 29% (Appendix A1.4). Similar to what was stated in Chapter 4 (section 4.3), it is unclear what Murdock specifically means by this addition to subsistence, but it is clear that animal husbandry on its own contributes more than a quarter, underlining its importance in these subsistence economies.

More specific ethnographical examples of these types of communities are discussed below in the appropriate sections on each of the aspects of animal husbandry.

Note that the general term herd is used throughout the text for groups of livestock including either cattle, sheep/goat or pig, unless further specification is required.

5.3.1 Herd size and composition

Information on the size and composition of herds is of the utmost importance when analysing (small-scale) farming communities, since it informs about the possibilities and limitations of the researched (subsistence) economy in West Frisia. The size of the herd and its composition can have major consequences on the possible breeding schemes and uses of the herd, as well as the required amount of shelter and nutrition for all the owned animals. Information on both these important herd characteristics is therefore critical to establish before attempting further investigation into other animal husbandry practices.

When small-scale subsistence farming is considered for different parts of the world, it is seen that families or small villages indeed only produce what is needed for their survival (Moorosi *et al.* 2001; Schwalbach *et al.* 2001; Lehloenya *et al.* 2007; Ndebele *et al.* 2007). Small-scale mixed subsistence farms inherently possess herds of limited size. These herds often also consist of smaller sized animals to increase manageability on the settlement, as well as combinability with other activities related to subsistence: such possession of small herd sizes in small-scale mixed farming communities is a global phenomenon (Long *et al.* 1975; Troxel & Simon 2010, 6; Pica-Ciamarra *et al.* 2011, 7). Another consistent aspect of animal husbandry within such communities is the concurrent possession of multiple species of livestock, of which cattle, buffalo, goat, sheep, pig, horse, and chicken are the most prevalent (Schiere & Kater 2001, Ch 4; Kagira *et al.* 2010, 868; Karimuribo *et al.* 2011; Pica-Ciamarra *et al.* 2011, 9; Kongolo 2012, 105). For West Frisia, only cattle, sheep, goat and pig are considered to have been potential livestock species[6] and are discussed further below, with minor additional discussions on dog and horse.

Cattle

Within small-scale mixed farming systems, cattle are mostly kept in small herds. Herd sizes range from 2-10 cattle per household in western, central, and eastern Europe (Crijns & Kriellaars 1987, 64; Bieleman 1992, 57,186; Laski 2007, 6), 3-4 cattle in Asia (Pica-Ciamarra *et al.* 2011 , 6-7), and 4-10 cattle in Africa (Sandford 1982; Moorosi *et al.* 2001, 3; Schwalbach *et al.* 2001, 200; Lehloenya *et al.* 2007, 221; Ndebele *et al.* 2007, 4).

The composition of such herds ranges from 42-78% adult females, 18-25% calves, and 8-22% males (Moorosi *et al.* 2001, 3; Schwalbach *et al.* 2001, 201; Kongolo *et al.* 2012, 106).

One specific quantitative research (Lehloenya *et al.* 2007, 220-1) provides an example of the general composition of a cattle herd owned by a small-scale mixed farming household in terms of age and sex, and this information is summarized in Figure 5.2.

Although variation exists in the composition of a herd, a consistent factor is that male animals are only present in low amounts. This low amount of males could be related to the fact that not many bulls are needed to sustain a viable herd; on average only 1 bull for every 25 cows is recommended (Agricultural Extension Services 2005; Hayes 2008, 62). The requirement of only a few males in combination with the small herd sizes present at small-scale mixed farms means that in such communities, not every household necessarily owns a bull. In fact, in many small-scale farming societies, communal use of bulls is a common practice (Rocha *et al.* 1991; Moorosi *et al.* 1999, 5; Schwalbach *et al.* 2001, 201). When bulls are obtained from other areas further away, this potential fresh supply of bulls can aid in the prevention of inbreeding (Ndebele 2007,6; Troxel & Simon 2010, 2).

Bulls are however not the only type of male cattle which could occur on a settlement. Oxen can also comprise a variable part of the herd, ranging from not being present at all (Schwalbach *et al.* 2001, 201), present in only low numbers (0,6%, Moorosi 2001, 3), or indeed as a substantial part of the subsistence economy (10-11%, Moorosi 2001, 3; Kongolo 2012, 106). This large range in the possible presence of oxen seems to be linked to their use for traction power, being absent in areas where arable land is scarce (Schwalbach 2001, 201). Still, alternative pairs of cattle for ploughing exist, such as combinations of bulls, steers (*i.e.* young bulls), cows or heifers (*i.e.* young cows) (nb. bulls and cows or heifers do not form a traction pair). These examples are known from many different countries (Hajnalová & Dreslerová 2010, 185; Bakx 2011, §8.2). Therefore, oxen are not necessarily components of small-scale farming systems. Furthermore, oxen are very expensive for a farmer, since they no longer function as a breeding animal, but do require large(r) amounts of feed in order to remain healthy (Oschinsky 1971, 331; Bakx 2011, §8.2).

Thus, cattle herds within small-scale mixed farming systems usually consist of a limited number of animals,

6. Livestock being defined here as domestic animals that are reared as suppliers of (red) meat, milk, fibre, and labour. Although dog and horse may also have been consumed, it is not assumed that they were kept especially for this purpose.

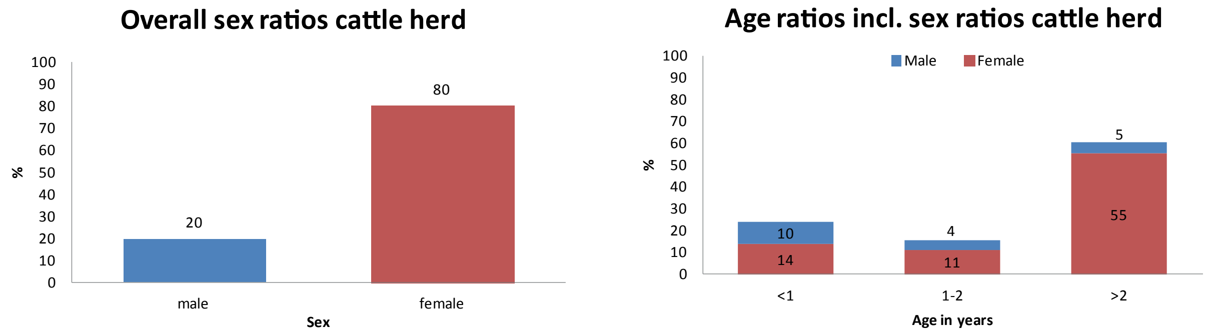


Figure 5.2. Example of the general composition of a small-scale living cattle herd in South Africa in terms of age and sex (after: Lehloenya *et al*. 2007, 220-1). This study forms one of the very few examples wherein this type of detailed quantitative information on small-scale herds in mixed farming communities is taken into consideration.

which range from 2-10 individuals per household. On average, a herd size of 5-8 cattle per household was most frequently observed in the researched examples, and this is the applied expected herd size here. Females usually outnumber males by as much as 78%, followed by 18-25% of youngstock. Males are often scarce on a settlement, since few are needed to sustain a herd. The presence of oxen in small-scale mixed farming systems varies and is not a necessity, since either bulls or cows can form replacements for pulling the plough. Oxen, when present, are considered very valuable due to their uselessness for breeding purposes and high nutritional demands.

Sheep

In Africa, small-scale subsistence economies contain sheep flocks that are of small to medium size, ranging from 2-30 animals, and on average 5-15 animals (Panin & Mahabile 1997, 11-2; Abebe *et al.* 2000; Lehloenya 2007, 222; Poku 2009, 155). In Romania, a small-scale mixed farmer possesses 15 sheep (Page & Popa 2013, 12).

Sheep flocks on average consist of 65-73% females, and 10-30% males; 25% of the total flock typically consists of lambs, of which at most 10% is male, since surplus males are unwanted and culled before they reach maturity (Cribb 1987, 382; Ndamukong *et al.* 1989, 133; Lehloenya 2007, 222; Abebe 2013, 329). The male portion of the flock consists mostly of lambs and males older than 1 year, and, for a smaller part of castrated individuals (*i.e.* wethers), which only comprise around 1-17% of the males in the flock (Ndamukong *et al.* 1989, 133; Abebe *et al.* 2000). The specific quantitative research consulted for cattle also provided an example of the general composition of a sheep flock (Lehloenya *et al.* 2007, 220-1), which is summarized in terms of age and sex in Figure 5.3.

The recommended ratio of breeding male to female in a sheep flock is around 1:50 (Hinton 2006, 64). This means that, similar to cattle, not all small-scale farmers would own breeding males, and might have to use their neighbours' ram for breeding purposes (Abebe *et al.* 2013, 330). The low amount of breeding males is the result of slaughter or castration of males at a young age (Abebe *et al.* 2013, 330). Castrated sheep (*i.e.* wethers) are sometimes preferred to uncastrated individuals due to their better fattening properties.

In general, small-scale sheep flocks usually consist of a limited number of animals within small-scale mixed farming systems, which range from 2-30 individuals per household. A sheep flock of 5-15 individuals is used as the expected size for West Frisia, since it covers all the different flock sizes observed in the ethnographic parallels. Around two-thirds of a flock normally consists of female animals, which also includes most of the 25% of lambs present in the flock. Most males are unwanted and are therefore slaughtered at a young age or castrated, ensuring only a few males are kept in a herd.

Goats

Goats can be kept as a separate herd or as part of a mixed flock with sheep (Dahl & Hjort 1976; Panin &

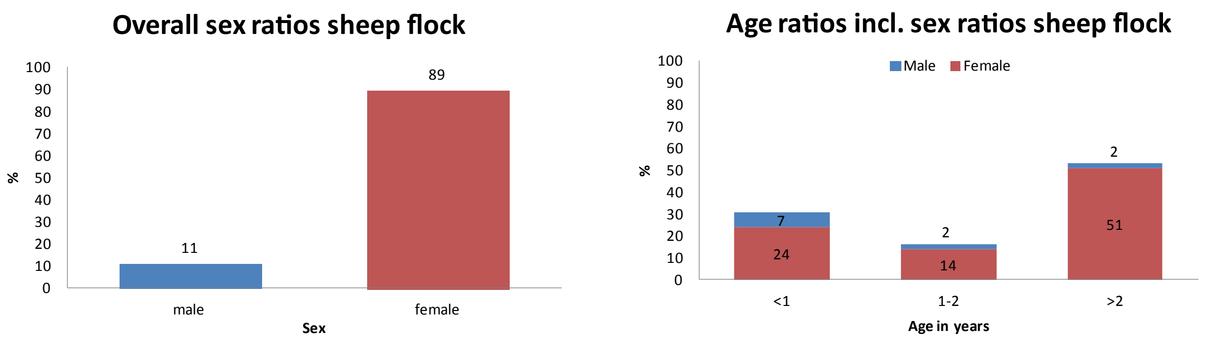


Figure 5.3. Example of the general composition of a small-scale living sheep flock in South Africa in terms of age and sex (after: Lehloenya *et al.* 2007, 220-1). This study forms one of the very few examples wherein this type of detailed quantitative information on small-scale herds in mixed farming communities is taken into consideration.

Mahabile 1997, 12). Information on herd composition of goats kept by small-scale mixed farmers is limited, since many recorded goat herds concern pastoral nomads. However, some ratios for age and sex of goats from small subsistence farmers' herds were found (Peters 1987; Kapa *et al.* 2001 (Indonesia); Gizaw *et al.* 2010, 13). On average, herd size ranges from 2 to 20 animals (Wilson 1983; King *et al.* 1984; Peters 1987, table 1; Kapa *et al.* 2001, 6; Poku 2009, 155; Gizaw *et al.* 2010, 13), consisting of 66-75% females, and 50% breeding females. Additional flock components include 6-15% breeding males, 3-8% castrated males, and 20-60% young goats (*i.e.* kids), of which only 25% is male (Wilson 1983; Ndamukong *et al.* 1989, 133; Gizaw *et al.* 2010, 13).

Since the exact sex differentiation in each age group is unknown, no general overview of a goat herd composition is provided here.

In a goat herd, the ratio of breeding male to female should be 1:25 to 1:50 (Poku 2009, 157; Sikosana & Senda 2011, 14). Again, exchange or use of breeding males from other farmers seems necessary.

Zoologically, sheep and goat are hard to distinguish based on bone remains, so it is unclear what past ratios between sheep and goat were on a settlement. Therefore, it is assumed here that a mixed flock of sheep and goat existed, with the assumed size of 5-15 individuals. Since sheep are often more prevalent in temperate areas of the world than goats, an assumed ratio of 25% goats and 75% sheep is applied as the expected ratio of animals within the flock.

Pigs

Pig herds in small-scale farming systems are also often small. The herd size ranges from 1-8 individuals, with a mean of 3 animals per household (Rekwot *et al.* 2003, 36; Ajala *et al.* 2007, 185; Lemke and Valle Zarate 2008; Kagira *et al.* 2010, 867; Karimuribo *et al.* 2011, 3-4). An example of the general herd composition for pigs based on sex and age ratios is shown in Figure 5.4 (after: Karimuribo *et al.* 2011, 3-4). The male:female ratio within pig herds is often more balanced than in the ruminant herds and flocks; males and female are often present in comparable numbers in the herd (Karimuribo *et al.* 2011), although females still outnumber the males in most age groups. Pigs are usually kept for consumption purposes, which is reflected by growing or fattening individuals consistently forming the largest part of the herd (Kagira *et al.* 2010, 867; Karimuribo *et al.* 2011), and higher age groups becoming increasingly smaller in size (Figure 5.4). However, besides the example shown in Figure 5.4, examples of ratios of adult animals which follow the trends seen in cattle and sheep also exist. In these herds, adult male pigs are present at only very low numbers, often resulting in the need to borrow boars from neighbours (Lemke & Valle Zarate 2008, 209; Kagira *et al.* 2010, 867, 871). This observations is underlined by the recommended male:female breeding ratio for pigs of 1:15-1:18 (Roese & Taylor 2006, 2).

Overall, pig herds seem to be more variable in their composition with regard to males than ruminant herds and flocks. Non-breeding boars can still function as meat producers, and can therefore be fattened

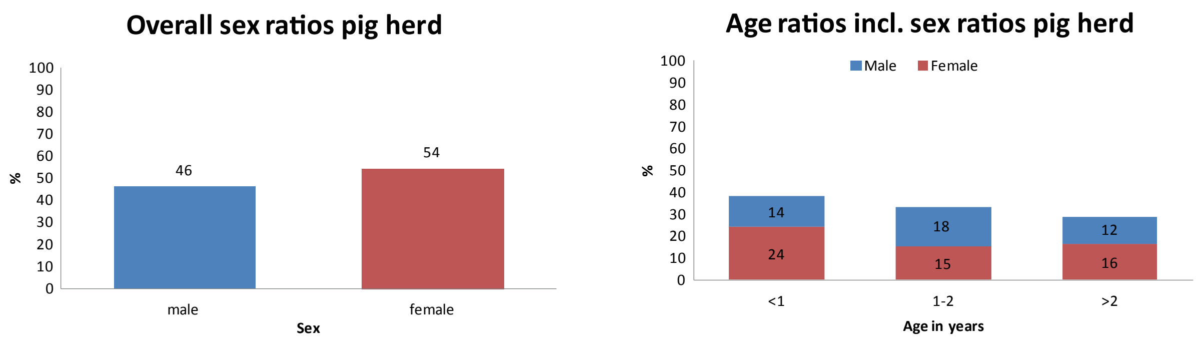


Figure 5.4. Example of the general composition of a small-scale living pig herd in terms of age and sex (after: Karimuribo *et al.* 2011, 3-4). This study forms another one of the very few examples wherein this type of detailed quantative information on small-scale herds in mixed farming communities is taken into consideration.

for a period of time before subsequent slaughter. On average, a pig herd in small-scale mixed farms consists of 3 individuals, of varying sex and age depending on the breeding strategy applied. All three individuals could for example have been female, with a boar being borrowed from neighbours.

5.3.2 (In)breeding

In order to secure the future of the herd, new animals need to be produced on an annual basis. To achieve this, breeding schemes need to be adequate. In this section, factors affecting breeding are further explored, as well as to what extent inbreeding might have affected animal husbandry on small herds. Breeding and birthing seasonality are discussed in section 5.3.6.

Factors affecting breeding: birth rate and mortality

A herd should be composed of a certain amount of animals of different age and sex to ensure a prolific herd in the long term. As mentioned, it is important to create a constant flow of new individuals each year to ensure a healthy population demographic. For domestic animal herds, this entails that farmers should aim for female animals undergoing breeding and birthing every year. Only examples of cattle and sheep are presented here, because adequate information was available for these species.

Birth rates of livestock (*i.e.* the number of young born per female/yr) differ per species and can vary from 0.1-0.7 in cattle (Mukasa-Mugerwa 1989; Negassa & Jabbar 2008, 14), to 0.3-1.4 in sheep due to twin births (McKinnon & Rocha 1985; Negassa & Jabbar 2008, 15). Low birth rates indicate that females do not produce offspring each year.

Once born, young animals are not all destined to make it to adulthood either, due to both controllable and incontrollable factors. High natural mortality rates range from 10 to 60% in calves (Dahl & Hjort 1976, 37-8; Fall 1982; Inamdar 2012) and from 10-30% for lambs (Dahl & Hjort 1976, 95; Fall *et al.* 1982; Wilson, *et al.* 1985a; Wilson *et al.* 1985b; Cribb 1987, 380-1; Bekele 1992; Dwyer 2008, 31; Kennedy 2012), due to disease or other external factors. Additional losses of calves and lambs occur due to deliberate culling (*i.e.* slaughtering), mostly of male individuals. Most male calves and lambs are slaughtered for consumption before they reach one or two years of age (Cribb 1987, 380-1; Munson 2000, 395-7; Schwalbach 2001, 201) since the costs of maintaining them are higher in terms of nutrition demand than are the losses of the animal itself through slaughter and consumption. Young animals which are purposefully kept alive mostly include female calves and lambs, which form the replacement population for older cows and ewes.

Death of adult breeding livestock can also occur, and is always unwanted. Losses can result from natural mortality (around 10% in cattle (Dahl & Hjort, 1976, 39; Muma 2007, 787), and 10-20% in sheep (Dahl & Hjort 1976; Bekele 1992), disease (such as pneumonia or liver fluke infection, Dwyer 2008, 36; Inamdar 2012), or intentional culling due to illness, poor reproductive performance, or old age (Sol 1984, 152). The combination of low birth rate and relatively high mortality rate means that considerable numbers of (young) animals are lost on an annual basis. In order to still possess enough individuals for the next year, farmers in most small-scale communities therefore need to produce more livestock than is annually required (*i.e.* overstocking) to be able to endure all potential losses encountered (Cribb 1987, 384).

Inbreeding

In order to maintain a viable self-sustaining small domestic herd, the risk of inbreeding needs to be assessed since this can pose a threat to healthy animal husbandry practices, especially in smaller populations. Data on this phenomenon can be obtained from several populations, including small populations under the threat of extinction, which in the wild are represented by endangered species, and in domestic environments by certain domestic animal breeds (Nomura *et al.* 2001; Tada *et al.* 2013). Although inbreeding is in itself unrelated to total population size (Weigel 2001, E177), the chance of related individuals mating increases when populations are (kept) small (Lehmkuhl 1984, 168 and references therein).

Inbreeding can cause adverse effects on livestock by reducing the gene pool, allowing defects and reduced fecundity and longevity, as well as impaired growth to occur (Weigel 2001, 178; Sewalem *et al.* 2006). Furthermore, it can have a major impact on long-term animal husbandry practices, since human influence in herd composition may induce situations not normally observed in the wild (Keller *et al.* 1990).

The minimum size of a population no longer at risk of substantial inbreeding is known as the minimum viable population (MVP). The calculation of this MVP is based on the effective population (Ne), which is defined as the portion of breeding males and females within a population, *i.e.* the animals within a population which partake in reproduction. As a general rule in wild animal extinction research, the effective population size is set at 50 individuals (Lehmkuhl 1984, 170). This figure of 50 individuals therefore only involve the breeding population, meaning that the entire population size is larger, including young, non-producing, and old animals. From the previous section is has become clear that total herd sizes in small-scale animal husbandry systems rarely reach over 10-15 individuals. This means that the effective population is even smaller than this number and that the required number of 50 individuals would never be reached.

At first glance, it then appears impossible that small-scale farmers can maintain healthy herds of livestock for a prolonged period of time under these conditions because inbreeding would form a serious problem. However, the Ne of 50 individuals deserves some further investigation.

The Ne of 50 was derived at through calculations based on a limit on inbreeding rate of less than 1% per generation: f=1/2Ne, where f equals the inbreeding rate[7]. When the effective population increases, the inbreeding rate decreases inversely proportional to this value.

This conservative inbreeding limit has been applied specifically for wild animal populations (Franklin 1980), because these possess a higher chance of inbreeding based on their genetic composition than domestic animals (Lehmkuhl 1984, 170). Many deleterious alleles (which would be lethal to an animal) have already been removed from domestic animal populations through a long domestication process, but they still exist in wild populations. Therefore, inbreeding is more lethal in wild populations and inbreeding limits for these types of populations are kept very low.

However, the general rule of 50 individuals to sustain a healthy population should not be applied to domestic animals without consideration of the particular population characteristics in question (Lehmkuhl 1984, 170). When domestic animals are considered, a 2-3% inbreeding limit should be employed, which is also the limit applied by

7. Inbreeding rate is defined as the percentage of inbreeding occurring per generation.

domestic animal breeders (Lehmkuhl 1984, 170). When the effective population is recalculated with these values, the minimum number of individuals within the effective population ranges from 16-25. Although considerably lower than the original 50 individuals, the size of this effective population is still not reached by the limited sized herds of small-scale animal husbandry households, even when several households are combined. This shortage of breeding animals in the effective population would thus imply that inbreeding would form a serious problem for small-scale farmers. Still, before drawing final conclusions on the effects of inbreeding, some additional factors need to be taken into consideration.

Another critical investigation of the article by Lehmkuhl (1984) reveals that the Minimum Viable Population model is based on the assumption that: "the original number of animals will constitute a viable, stable, closed population (...) throughout the planning period" (Lehmkuhl 1984, 168; author's underlining). A closed population is characterized by the inability to reach other populations. However, it can be assumed that actual livestock populations are not closed or isolated, or that at least the possibility exists for interaction between households or settlements. When these domestic animal populations are indeed considered as interacting rather than closed, a new view on the Minimum Viable Population size for domestic herds is possible.

One of the methods applied to the dispersal strategies of interacting populations is the core population method (Lehmkuhl 1984). In this method, populations of animals are assumed to reside in core habitat areas, each with some distance between them (Figure 5.5a). Interestingly, if one or two animals are exchanged each generation, these core populations could be regarded as a single population (Franklin 1980). Furthermore, apparently only one new animal exchanged per generation is already sufficient to reduce the risk of inbreeding (Avery 1978).

When core habitat areas are instead viewed as settlements (Figure 5.5b), it becomes clear that for small-scale farming, the exchange of one or more animals per generation between settlements would be sufficient to ensure a healthy population. The

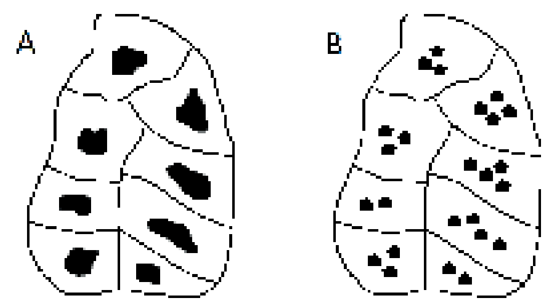


Figure 5.5. Theoretical model for the occurrence of inbreeding in a natural, and a man-made situation; a: The core population method (wild populations) (after: Lehmkuhl 1984, 174, fig 2); b: The settlement population method (domestic animal populations). Here, each core from Figure 5.5a is replaced by a settlement consisting of two to four houses.

limited size of herds in small-scale animal husbandry systems actually seems to require this exchange, since inbreeding would otherwise become a definite risk. Indeed, borrowing breeding males from neighbours was observed as a common practice in many small-scale farming societies (section 5.3.1), alleviating the risk of inbreeding regardless of the initial reason for such exchange.

5.3.3 Use

Domestic animals can be exploited for several uses, including consumption (*e.g.* meat, milk, fat, and blood), traction power, manure, wool, status, company, etc. The different possible uses of domestic animals are discussed per species below.

Cattle

Cattle on small-scale mixed farms are often kept for more than one use, including milk, meat, traction power, manure, hides, etc. (Moorosi *et al.* 2001; Ndebele *et al.* 2007). A single species can be kept for more than one use, and often, in small-scale farming systems, no real specialisation for a specific use occurs. Cattle can already be considered multi-purpose when being principally bred for meat, but milked for human consumption when with calf (Schiere & Kater 2001; Oosthuizen n.d.). Indeed, in several areas of South Africa, 91-96% of the small-scale farmers milk their cows, but none indicate this as the main reason for keeping cattle. The reason is

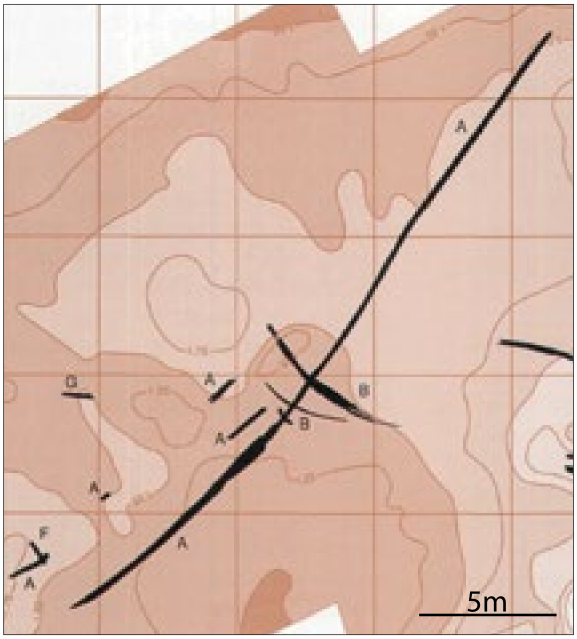


Figure 5.6. Overview of the Bronze Age track ways observed on the island of Texel, the Netherlands (from: Woltering 2006, 110). Trackway A represents a cart trackway that was possibly already in use at the end of the Middle Bronze Age and in the Late Bronze Age (Woltering 2001, 109-114).

meat production (Moorosi *et al.* 2001; Schwalbach *et al.* 2001, 201). Cattle which are intended for meat production can provide enough milk for both calf and human consumption; when milked moderately, no impaired growth of the calf is observed (Oosthuizen n.d.). Conversely, specialized dairy cattle breeds do not yield much meat because most of their energy is directed towards milk production (Royer & Royer 2012, 32). The combined exploitation possibility is probably the reason why small-scale subsistence farmers keep cattle primarily for meat production and additional milk production, rather than as specialised dairy cattle.

Traction power for pulling a plough is another advantage of keeping cattle, and it can be supplied by both oxen and cows (Schiere & Kater 2001, Box 10; Hajnalová & Dreslerová 2010, 175; Bakx 2011, §8.2;). However, cows are less efficient in ploughing (Bakx 2011, §8.2), and can be susceptible to adverse effects of this hard labour during pregnancy (Schiere & Kater 2001, Box 10). Milk production can even

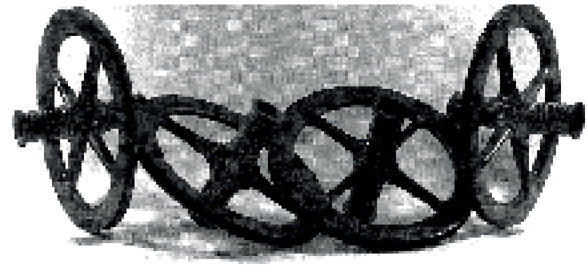


Figure 5.7. Wooden solid wheels and spoked bronze wheels dating to the Bronze Age (from: Uckelmann 2013, 404).

be reduced to two-thirds of normal production (Hajnalová & Dreslerová 2010, 185).

The presence of wooden cart wheels in bogs throughout Europe (Uckelmann 2013, 401-2) as well as from Dutch bogs (van der Waals 1964) dating back as far as the Neolithic, show that cattle could also have been used for transport by pulling carts (Schiere & Kater 2001, Ch 4; Bakx 2011, §8.2). Elaborate track ways have also been observed in several places in Europe dating in general to the Bronze Age (Uckelmann 2013, 401-2), in north-western Europe in particular (Menotti & O'Sullivan 2013 and references therein), and also in the north-eastern Netherlands (Casparie 1987), and off the north-western coast of the Netherlands on the island of Texel (Woltering 2006, 109), which is located relatively close to West Frisia (Figure 5.6). Depictions of (cattle pulling) carts are already known dating to the late Neolithic, not from north-western Europe, but from Germany and Poland (Sherratt 1981, 265; Milisauskas & Kruk 1991). From the Bronze Age, multiple finds of solid wooden wheels and spoked bronze wheels are also known (Figure 5.7). All these finds underline the (importance of) mobility for Bronze Age people and the possible role of cattle therein.

Sheep and goats

Sheep and goats can provide the farmer with meat, milk, hides, and wool. Often these uses are of combined interest, so the breeds kept are often multi-purpose (Cribb 1987, 401). Sheep kept for milk production can also provide wool, and these sheep also have a higher potential for meat production due to higher availability of youngstock in this strategy. Alternatively, a focus on meat production will also

Figure 5.8. Examples of Bronze Age horse gear; a: Middle Bronze Age (1300-1050 BC) horse bridle-bit from Sigmaringen, Badem-Württemberg, Germany (British Museum 2016a); b: Late Bronze Age (1000-750 BC) horse bridle bit from Auvernier, Neuchâtel, Switzerland (British Museum 2016b).

provide farmers with milk and wool, although at different ratios (Cribb 1987, 401). Specialized wool production strategies however, rely on high proportions of adult sheep in the flock, possibly also consisting of wethers (*i.e.* castrated individuals) (Cribb 1987, 401). Such a herd composition is not viable in the long-term, due to an overabundance of old and/or non-reproducing animals and a resulting lack of a regular supply of youngstock. Small-scale farmers cannot afford to possess such herds, because their livelihood depends on an annually reproducing herd. Therefore, in general, specialisation is not assumed for small-scale subsistence farms, and a specialisation towards wool production is deemed even more unlikely.

Pigs
Pigs are mainly kept for providing meat for consumption and fat for consumption and other uses (section 5.4.7.4). Pigs are known for their prolific properties due to short reproduction cycles (section 5.3.6): they are sexually mature at 8 months, have a short gestation period, and sows can raise around 6 piglets to adulthood (Rekwot *et al.* 2003, 36; Lemke & Valle Zarate 2008, 209). Furthermore, pigs are also ideal meat producers, because they can efficiently convert feed to meat, and yield very high amount of meat per carcass (van Loon 1985, 84).

Dogs and horses
Although dogs and horses often do not form a part of the production side of a subsistence farm, they do have several characteristics which make them valuable property. Dogs can be used for a multitude of activities, including hunting, shepherding, and guarding. Horses are mainly used for transport and draught purposes. Evidence of a Bronze Age bridle made of red deer antler uncovered in Denmark

(Nyegaard 1983, 33-5), and several bridles and Middle and Late Bronze Age bronze horse bridle-bits from south-western Germany and Switzerland (British Museum 2016a; 2016b; Figure 5.8a and b) underline the possible use of horses for transport and/or traction during this time.

Influence of use on herd composition

Within a small-scale mixed subsistence farming system, people are focused on maintaining the herds that can provide them with wanted products. Farmers make conscious selections[8] on herds by killing certain animals for a specific use.

Interestingly, the composition of living herds can be quite similar although they are kept for different purposes. Therefore, the specific use of a herd cannot be distinguished solely based on its living structure (Cribb 1985, 81). The specific breeding goal of a farmer can only be deduced from his selections made on the herd population and the subsequent culling (*i.e.* killing of animals) practices performed.

For meat production, the relative proportion of culled animals of various ages is important; it is assumed that the level of milk production can be deduced from the proportion of lactating females and culled young (leaving more milk for human consumption). Certain proportions of adult individuals in the population finally, can be regarded as evidence for wool production (Cribb 1985, 87-8). It is clear that different age ratios of culled animals (*i.e.* the mortality profile) are observed depending on the reason for keeping the herd. However, multiple uses of a herd will inherently result in a mixed mortality profile, since no single use is independent of other possible uses (Cribb 1987, 401). Furthermore, a mortality profile alone should not be used to infer the use of a herd or flock, since static properties reflected in a mortality profile do not reflect the dynamic processes behind its formation (Cribb 1987, 410). When known, the dynamic human behaviour lying behind the formation of a mortality profile can be used to reconstruct what happened to the original population and why, and this should instead be(come) the main focus of zooarchaeologists (Cribb 1985, 81). A new method to gain insight into these dynamic properties is presented in section 5.4.2/Appendix A1.7.

8. As opposed to selections which need to be made regardless of a farmer's choice, *e.g.* when an animal is showing signs of disease or low productivity and has to be culled for those reasons, or when natural death occurs before a decision can be made.

5.3.4 Handling and related locations

Domestic animals need to be handled from time to time to ensure their health and safety. Other reasons for handling animals may include remaining familiar with the animals to avoid feral behaviour or using them for specific purposes, which are discussed below. First, some standard animal handling procedures are discussed before considering the requirements of handling facilities.

Handling

Castration

Any male that is not used for breeding purposes is either castrated or slaughtered (Schiere & Kater 2001, Ch 5, Photo 48; Abebe *et al.* 2013, 330). When castration is being performed on male youngstock, it is best done before 6 months of age in cattle (Lehloenya *et al.* 2007, 223; Hayes 2008, 95-6), and from 2-10 weeks (Hinton 2006, 102) to 4-12 months in sheep (Abebe *et al.* 2013, 330). Pigs are not always castrated (Kagira *et al.* 2010, 868; Karimuribo *et al.* 2011), but when performed, it is usually performed after 4 weeks of age (van Loon 1985, 156; Kagira *et al.* 2010, 868). Castrated individuals will in general be more docile, will fatten more easily, and are safer to handle.

Dehorning/tusking

Dehorning is usually practiced to ensure the safety of cattle and people. Furthermore, dehorning will reduce possible damage to hides. Dehorning should be performed on cattle under 6 months of age (Hayes 2008, 95), and on goats under one week old (Oltenacu 1999). Since dehorning is a painful process, breeding polled (*i.e.* hornless) animals will avoid this practice completely. However, on many farms, such as on small-scale South African farms, cattle are seldom dehorned (Lehloenya *et al.* 2007, 223). Tusks of pigs can be cut back when the animals are around 18-24 months old in order to prevent injuries to both man and animal (van Loon 1985, 168).

Branding/marking

Identification of animals can be very important and will prevent any discussion over ownership. Identifying methods include ear tags (Lehloenya *et al.* 2007, 222; Hayes 2008, 103), ear notches (van Loon 1985, 153-5; Hinton 2006, 103; Lehloenya 2007, 222), tattooing (van Loon 1985, 155; Lehloenya *et al.* 2007, 223; Hayes 2008, 103-4), and branding (Schiere & Kater 2001, Ch 5, Photo 47; Lehloenya *et al.* 2007, 222; Hayes 2008, 105). Branding of cattle should occur before 3 months of age, and preferably at locations where hide damage is minimal (Hayes 2008, 105). Marking of sheep occurs around the same time as castration (Hinton 2006, 103).

Slaughter

Slaughter is the ultimate animal handling procedure. An animal is consumed thereafter. Although slaughtering practices can vary widely depending on the group of people performing the action, one of the most basic slaughtering techniques include hitting the animal on the forehead with a blunt object to stun it, after which the throat is slit. Subsequent carcass dressing steps are not discussed.

Handling locations

In small-scale animal husbandry, a few simple structures for animal handling and shelter suffice.

Handling structures allow for restraining the animal and reducing its stress while being handled (Hayes 2008, 39). In general, animals need to be inspected for disease or pregnancy, and handled regularly for castration, dehorning or other procedures mentioned above (Hayes 2008, 40).

Structures related to restraining animals for periods of time can include simple tethering poles, more complicated structures such as an in-house barn, a separate barn further away from the farmstead, or specific separate structures such as corrals and pens. In all these structures, good ventilation is of the utmost importance.

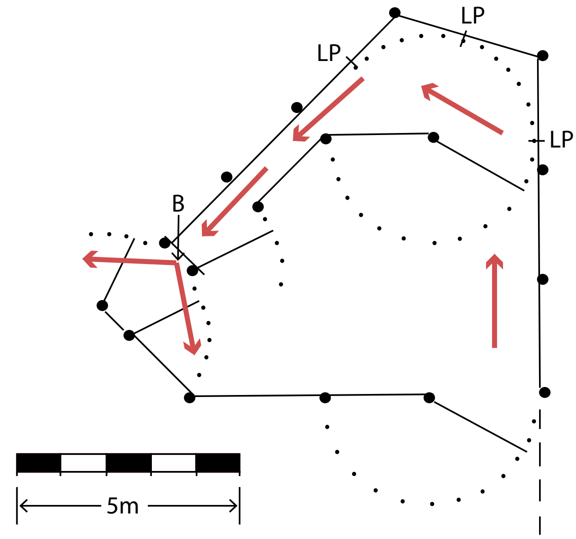


Figure 5.9. Example of a minimal handling system for small cattle herds, in this case 20 animals (adapted from: Hayes 2008, 41). B: head bail; LP: locking point; arrows indicate movement direction of cattle.

Reasons for the construction of specific structures might include protection against the elements, manure collection, disease control, protection against animal or human predators, more efficient labour time because animals are confined, control of animal health and products, and crop protection (Schiere & Kater 2001, Ch 5). Furthermore, each domestic animals species has particular preferences and size requirements for handling structures, which are discussed below.

Cattle

Small cattle (*i.e.* of comparable size to Bronze Age cattle) do not require elaborate or intricate handling systems (Hayes 2008, 39). The minimum requirements for small cattle handling structures are a yard, a race, and a head bail. A yard is defined as a confined area where animals can be kept for handling procedures. A race is a narrow pathway enclosed from the sides by fences. A head bail is the blunt ending of the race, wherein the cattle can be restrained by the head.

The race dimensions for small cattle are around 70 cm wide, and at least 3 meters long (Figure 5.9 from: Hayes 2008, 41; Figure 5.10 from: Bengtsson & Whitaker 1988). Furthermore, cattle specifically

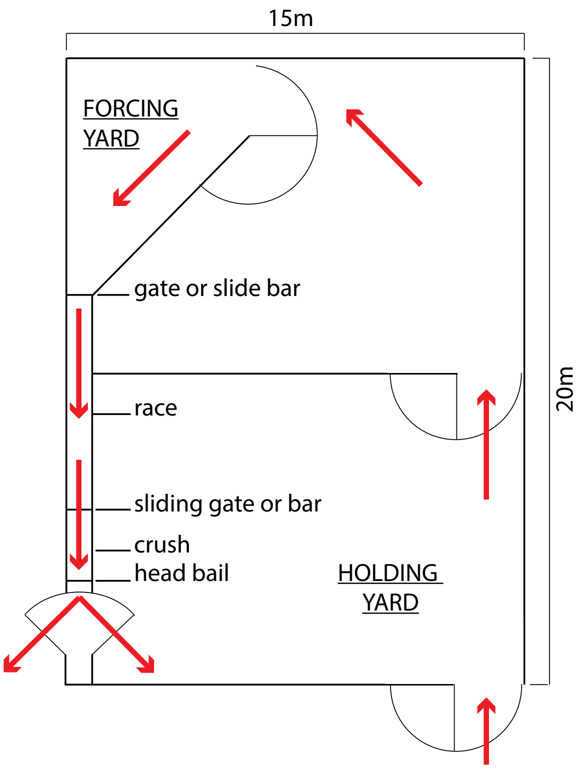


Figure 5.10. Example of a minimal handling system for small cattle herds (adapted from: Bengtsson & Whitaker 1988). Arrows indicate movement direction of cattle.

prefer a curved yard shape to a straight one; the curve creates a feeling of safety by returning to where they came from. Shade, which is also essential for any restricted animal, can be provided by natural cover (*i.e.* trees), or a covered shelter.

Sheep and goats

Sheep are best handled on a small holding paddock, which is composed of a large yard, a race and two drafting pens (Hinton 2006, 37). The drafting race, in which sheep can be handled most easily, is approximately half a metre wide, and 3-4 metres long (Figure 5.11, from: Hinton 2006, 39 fig 7.3).

Additionally, sheep may require some shelter from the worst weather conditions. This however, can be accomplished by very simple structures to protect from wind and rain or by trees. Especially pregnant or birthing mothers require this extra care (Schiere & Kater 2001).

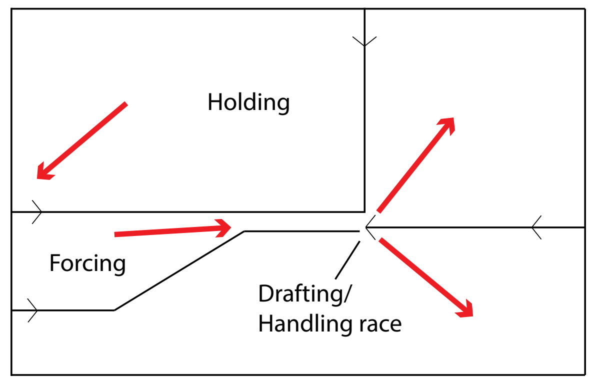


Figure 5.11. Example of a handling structure for small sheep herds (adapted from: Hinton 2006, 39, fig. 7.3). Arrows indicate movement direction of sheep.

Pigs

Pigs can be kept within a delimited area. They do not require special structures to reside in, but they do require an adequate shelter which protects them from the harshest of weather conditions. Pig shelters are preferably oriented on an east-west axis to improve cross-ventilation in most areas and to minimize heat gain in summer (Owsley 2010). Pig shelters additionally need to be sturdy to prevent escape of the animals by butting and rooting.

Handling of pigs can be minimal, since their main purpose is often for slaughter. Therefore, and because piglets are often castrated when very young, no specific handling structures are required.

Dogs and horses

For both dogs and horses, shelter against the harshest weather conditions is needed. Horses also need to be restrained for health inspections, but this aspect is not elaborated upon here.

5.3.5 Nutrition and related locations

Most livestock animals rely on vegetative matter for their nutrition, which can be obtained by grazing or browsing. These foraging activities occur on pasture, which may consist of paddocks (enclosed areas of pasture) or on an extensive basis, in which livestock roams free in the surroundings of the settlement. The use of paddocks, although prone to overgrazing, provides the farmer with the control over which (sub)groups of domestic animal are located at certain locations at specific times. Overgrazing of paddocks can be prevented by rotational grazing systems. During this process, livestock is moved from paddock to paddock allowing grazed fields to recover. Additionally, less suitable paddocks, such as waterlogged paddocks, can be avoided until unwanted circumstances improve (Grazing Livestock Factsheet 2013).

Extensive grazing by free-roaming livestock has the advantage of low risk of overgrazing, but the disadvantage of a reduced amount of control on herds or flocks, which may result in uncontrolled breeding and high (47%) mortality rates (Kapa *et al.* 2001, 7). Both strategies are applied on small-scale farms, but which is most applicable depends on the animal species. An alternative form of nutrition for animals is provided by humans in the form of feed/fodder, which can be supplied either on pasture, or in barns.

Both grazing and feeding strategies are discussed separately, and will include the required grazing area based on feed requirements per animal species.

Grazing

Effects of grazing and pasture management

Grazing puts pressure on pastures because – notably young – plants are being foraged. If a pasture is grazed for a prolonged period of time by too many animals, it can lead to exhaustion of the pasture (Troxel & Simon 2010, 6). This risk can be reduced by farmers in three ways. First, conservative stocking can be applied, reducing the chance of overgrazing (Troxel & Simon 2010, 6). Second, the breeding of smaller individuals allows for a higher stocking rate without increasing a risk of over-grazing (Long *et al.* 1975, 416). Smaller sized cattle kept on pasture for example, are more efficient grazers than larger cattle, because their conversion rate of food to meat is more favourable (Long *et al.* 1975). Third, rotational rather than continuous grazing can be applied, allowing pastures to replenish themselves when livestock is grazing elsewhere (Troxel & Simon 2010, 7; Grazing Livestock Factsheet 2013), and subsequently preventing the infection by parasites which occurs when pastures are used for prolonged periods of time. Besides being beneficial to the pasture, rotational grazing also allows for controlled herd/flock dynamics, especially when groups based on age and sex are kept separate. Additional management of pasture can be attained by burning pastures in early spring, thus rapidly revitalizing the pasture by locking it into the vegetative state. This practice is still performed today in many parts of the world including North-America (Ohlenbusch & Hartnett 2000; Lemus & Gordon 2012), and Europe (Ascoli & Bovio 2013).

Grazing behaviour of livestock

Different animal species have different preferences and requirements for their nutrition. Most grazing herbivores can sufficiently nourish themselves on good quality grassland pasture (The Merck Veterinary Manual 2013; van Wijngaarden-Bakker 1988, 158).

Cattle will seek out grassland pasture even when it is the least abundant habitat type present in the environment (Putman 1986; Baeté & Vandekerkhove 2001, 25: fig 6). Especially cows in lactation require high quality pasture in order to obtain a sufficient milk quality for their calves (The Merck Veterinary Manual 2013). During winter, when pasture is scarce, cattle are known to also consume woody plants (van Wijngaarden-Bakker 1988, 158; Baeté & Vandekerkhove 2001, 23).

Sheep are intermediate feeders placing them in between grazing and browsing strategies. Their split upper lip allows them to graze closer to the ground than cattle, meaning that pasture already grazed by cattle still contains enough nutrition for sheep (van Wijngaarden-Bakker 1988, 159). Sheep also tend to consume woody plants, especially when lush grassland vegetation is scarce (Baeté & Vandekerkhove 2001, 22).

Sheep and cattle can be combined in a mixed grazing system, which means both species are kept on the same plot of land simultaneously or subsequently. This system has several advantages, although sheep usually experience the highest benefits. Major advantages of mixed grazing include reduced competition for food within species, higher weight-gain per animal, and improved control over gastro-intestinal parasites by cross-immunity (Esmall 1991, 36). Other advantages include efficient usage of forage (species-specific toxic plants are removed by the other species), and reduced predation by wild carnivores compared with single-species herds (Esmall 1991, 36).

Goats are browsers and exploit different plants than either cattle or sheep (van Wijngaarden-Bakker 1988; Schiere & Kater 2001, Ch. 2). Goats are known to consume many different kinds of vegetation, which may also include leaves from trees and shrubs.

Because of their specific and deviant nutritional preferences, goats can also be included in a mixed grazing system. However, there are no additional advantages in comparison with a mixed cattle-sheep herd since sheep and goat are very similar in their reaction to parasites and toxic plants.

Pigs can also thrive on pasture, with minimal need for additional feed (van Loon 1978, 116-8; O'Meara 2010, 51-5). They therefore do not require the presence of forests to survive. Horses finally, have comparable grazing characteristics to sheep and cattle (Baeté & Vandekerkhove 2001, 23).

Grazing requirements for livestock

Each domestic animal species has requirements for the size of pasture needed in order to obtain sufficient amounts of food. The size of the pasture depends on the soil conditions, available pasture types and grazing behaviour of the animal. Note that even though pig can also thrive on adequate pasture, it is not included in this section, because no information on this species was available.

Cattle and horse normally require a substantial amount of hectares of grassland pasture per animal (Baeté & Vandekerkhove 2001, 22). It should be noted, however, that cattle and horses in the Bronze Age were smaller than present-day examples and should not be compared in size and requirements to large modern-day equivalents directly. Still, the current Dexter cattle breed is comparable in size to Bronze Age cattle (Appendix A1.5). Ponies can be considered as the modern-day size equivalent of Bronze Age horses (Appendix A1.5). Using this information, the amount of pasture required can be reconstructed more accurately. Two different researches were employed to calculate the requirements. The first is a stocking rate guideline for small-scale farm holdings (van Gool *et al.* 2000). Stocking rate is defined as "the numbers of stock, *e.g.* sheep, cattle, horses (…) that can consistently be kept on a piece of pasture all year round with minor additional feed and without causing environmental degradation" (van Gool *et al.* 2000, 3). The required amount of grassland pasture in the research by Van Gool *et al.* is expressed in Dry Sheep Equivalents (DSE). A sheep has a DSE value of 1.0, and larger animals have higher values. In addition, Van Gool *et al.* relate the soil composition to the stocking rate, and for further calculations, the stocking rate for clayey soils was employed for West Frisia, which is 6 DSE/ha. The values for each livestock species (Dexter cattle, sheep, goat, and pony) were taken from the overview by Van Gool *et al.* (2000, 7: Table 2), and were used as one of the researches for further calculations of required grassland pasture.

The second research used to calculate pasture requirements allows for a differentiation in grassland and woodland pasture (Baeté & Vandekerkhove 2001). In this research, instead of DSE, the value GVE (*i.e.* Grootvee-eenheid) is used, which is related to the requirements of a dairy cow. A dairy cow has a GVE value of 1, and smaller animals have lower values, which were proportionally calculated based on the research by Van Gool *et al.* (Appendix A1.8).

Under management conditions, livestock pasture grazing is maintained at 2/3 grassland pasture and 1/3 woodland pasture (in terms of nutrition, not size), also to accommodate for the different food strategies and preferences of different foraging domestic animal species (Baeté & Vandekerkhove 2001, 21-2). Due to the fact that woodland pasture contains less nutrients than pasture, relatively larger grazing areas are required per animal than of grassland pasture, and less animals can be sustained on woodland pasture: 1 GVE/ha for grassland vs. 0.1 GVE/ha for woodland. Requirements for grassland pasture alone were first calculated based on this research (Appendix A1.8),

Table 5.3. Pasture grazing requirements of domestic animals.

	Grassland pasture on clay in ha (Van Gool, et al. 2000)	Grassland pasture in ha (Baeté & Vandekerkhove 2001)	2/3 Grassland pasture + 1/3 woodland pasture in ha (Baeté & Vandekerkhove 2001)
Dexter cattle	0.7	0.8	3.2
Sheep	0.2	0.2	0.8
Goat	0.3	0.3	1.2
Pony	0.8	1.0	4.0

in order to compare with the values obtained from Van Gool *et al.* (2000). It has become clear from the landscape reconstruction made in Chapter 2 however, that woodland pasture as well as grassland pasture would have been available. Therefore, the abovementioned ratios of both types of pasture and the resulting stocking rates will also be used for further calculations on grassland and woodland pasture requirements for livestock (Appendix A1.8).

The resulting pasture requirements from the three calculations for each animal species are summarized in Table 5.2.

Since the results based on the research of both Van Gool *et al.*, and Baeté & Vandekerkhoven are very similar, it was decided to incorporate only the latter for further calculations of grassland pasture, since these values are more comparable to the other calculations on both grassland and woodland pasture. When the approximate size of the herds in West Frisia are acquired in section 5.4 West Frisian data analysis, the required pasture sizes will be used to calculate the total required amount of pasture for West Frisian households based on column two and three in Table 5.3.

Location of pastures

To create an idea of the average location of pastures with respect to the settlement, modern-day small-scale farming parallels in Eastern Europe were employed.

In Albania, most of the pastures (*i.e.* 73%) are located more than 1 km from the settlement, and more than 30% are located more than 3 km from the settlement. In contrast, only 16 % of the pastures of one settlement are less than 1 km away from the next settlement, and more than 40% are located further away than 3 km (Shundi 2006). This means that the settlements in Albania are quite dispersed and lie at least 2-6 km from each other.

Romanian pastures are located at more than half an hour walk from the village, which would amount to more than 2.5 km, when a walking speed of 5 km/hour is assumed (Hajnalová & Dreslerová 2010, 172).

Feed/fodder requirements of livestock

As stated above, most livestock herbivores can obtain enough nutrition from pasture, shrubs, and trees (van Gool *et al.* and Baeté & Vandekerkhoven), and therefore feeding animals might not have been necessary. Still, (additional) feeding might be carried out depending on factors such as climatic conditions, species, age, and sex of animals. The reasons for feeding and external factors which influence feeding can vary widely, which means that only general possibilities for feeding of livestock are presented here.

Supplementary feeding can be required during harsh winters, heavy snowfall, drought or floods, because livestock will be unable to find enough sustenance on their own (van Wijngaarden-Bakker 1988: 158, 161; Baeté & Vandekerkhove 2001). However, winters in the Bronze Age were most likely not very harsh, since overall, the climate in this period is considered comparable to the present climatic conditions (Zagwijn 1991).

Figure 5.12. Polling of trees for the acquisition of leaf fodder (photos courtesy of C. Bakels).

Another reason for feeding animals, besides environmental conditions, is that some species might be restrained from natural foraging by their particular location within the settlement. Tethered goats or horses or pigs in a pigsty are not able to obtain enough nutrients by themselves. Other groups of animal that might need fodder include the very old, the weaned young, and the weak animals. Animals belonging to either or more than one of these groups need more special attention than healthy adult animals. Finally, the sex of an animal can affect whether fodder or additional feed is given. Lactating females have a very high demand for nutrients to ensure the lactation production is optimal before birthing. Breeding bulls, rams, and especially oxen need more nutrients than other animals in a herd or flock to remain healthy for heavy labour activities such as ploughing and breeding.

Fodder for ruminants and horses may include crop residues (Hajnalová & Dreslerová 2010, 187; Chapter 5: Crop husbandry), hay from maintained hay meadows, or leaf fodder (Rasmussen 1989 and references therein; Figure 5.12). Pigs can additionally be fed a multitude of different nutritional resources including harvest waste, household waste, roots, nuts, milk and milk products, and fish.

5.3.6 Seasonality

Seasonal aspects related to animal husbandry, including breeding and birthing, can vary and differences may depend on factors such as geographical location, climate, and breeding objectives of the farmer. Other activities of animal husbandry which include seasonal aspects include culling, nutrition, and housing.

Breeding and birthing season

In the northern hemisphere, animals have a restricted breeding season. Due to the lower availability of light in some seasons, breeding behaviour is only induced at certain times of the year (van Wijngaarden-Bakker 1988, 161-2). The birthing period of many north-west European farm animals therefore occurs roughly in spring, which also coincides with the most advantageous environmental conditions: pasture will be lush and temperatures favourable. Each animal species however, has specific breeding and birthing cycles, which are summarized in Table 5.4 and are individually discussed below.

Cattle

Cattle breed from May to August (-September; van Wijngaarden-Bakker 1988, 162). Since a cow has a gestation period of 9 months, the resulting calving period lasts from February to May (-June; van Wijngaarden-Bakker 1988, 162; The Merck Veterinary Manual 2013). Cows usually give birth to one calf, and on rare occasions, to twins. Cows often calve for the first time at 2-3 years of age (Dahl & Hjort 1976, 33; Lehloenya *et al.* 2007, 223), with a calving interval of 12-24 months (Lehloenya *et al.* 2007, 223).

Breeding of cattle can occur by various strategies. One option is to allow the bull (if owned) to run with the herd throughout the year. A bull is able to detect cows in heat before the farmer can and will be less aggressive if they form a part of a cow herd than when kept isolated. This type of breeding strategy however, does not readily allow for controlled or selective breeding, and calves can consequently be born during a longer period of time in the spring.

The other type of breeding strategy is the seasonal presence of the bull. In this case, one or more bulls are kept in a separate herd on the settlement, in which they have their own hierarchical system and are therefore less aggressive. These bulls are only allowed to join the adult females during breeding season. Alternatively, the bull of a neighbour is borrowed during breeding season to join the female herd (Rocha *et al.* 1991; Moorosi *et al.* 1999, 5; Schwalbach *et al.* 2001, 201). This seasonal presence of a bull allows for controlled breeding and therefore a concentrated and shorter calving season. This strategy is often applied on mixed farms, since a limited amount of time spent on assisting with calving in spring means that more time is available for other farming activities during this busy period (Halstead 2014). Assistance or at least the presence of the farmer during calving is assumed, since new youngstock is very valuable to sustain the future herd, and therefore subsistence at large.

Sheep

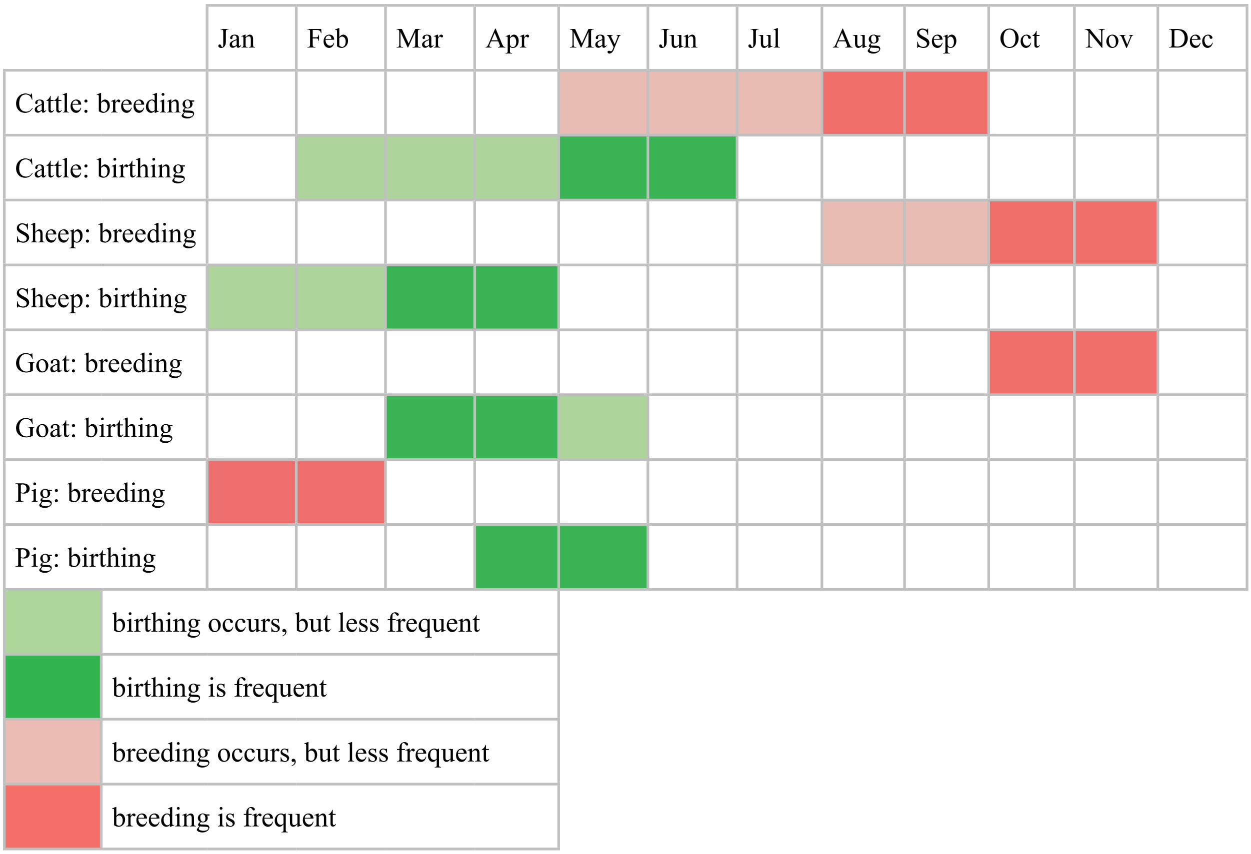
The breeding season of sheep lasts from August to October (-November; van Wijngaarden-Bakker 1988, 162). Ewes have a gestation period of around 5 months, which means the lambing season roughly occurs from January to March (-April; van Wijngaarden-Bakker 1988, 162; de Vos 2012, 7; pers. comm. A. Wichers). Animals giving birth early in the year, when temperatures are low, are often given the opportunity to find shelter with their lambs until conditions improve. Most sheep breeds are likely to give birth to twins, and sheep usually give birth before they reach 18 months, with a lambing interval of 12 months (Lehloenya *et al.* 2007, 224).

Shearing or wool plucking takes place before natural moulting starts, in order to attain the highest amount of wool, usually around April to June (*e.g.* Blockmans 1970, 115), although somewhat earlier in the year is also a possibility.

Goats

Goats are similar to sheep in their breeding behaviour. They breed from roughly October to November,

Table 5.4. Overview of the breeding and birthing seasons of livestock species.



resulting in a kidding season which lasts from about March to May (van Wijngaarden-Bakker 1988, 162). Several breeds of goat are likely to give birth to twins. The age at first kidding of goat is similar to the lambing age of sheep, as is the kidding interval.

Pigs

The breeding season for pigs occurs in winter, from January to February (van Wijngaarden-Bakker 1988, 162). Since the gestation period of pigs is only 3 months, the piglets are born in April or May (van Wijngaarden-Bakker 1988, 162). Sows can give birth to up to 14 piglets, although on average, 6-7 piglets make it to adulthood (Rekwot *et al.* 2003, 36; Lemke & Valle Zarate 2008, 209).

Breeding season for most farm animals occurs from August to February, depending on the species. Birthing season for most farm animals occurs from February to May. It becomes clear from Table 5.4 that domestic animals need to be monitored almost throughout the year, especially when controlled or selective breeding is preferred.

Culling season

Culling of multiple animals often occurs at specific times of the year. Autumn is usually mentioned as the peak slaughter period of animals, culling actually occurred during multiple times per year. The autumn cull peak phenomenon was based on a myth created by the modern economic and social historians (Trow-Smith 1957, 182). In fact, although "it is possible – indeed, probable – that after bad haysels some peasants had to cull their stock (…) none of them would, except as a last resort, destroy the breeding or rearing stock upon which their existence depended" (Trow-Smith 1957, 129). Some weak or old individuals may indeed have been culled in autumn, but culling for this reason can occur throughout the year. Valuable breeding stock would always be kept alive until the next spring, whenever possible (*e.g*. Hodgetts 2006, 128 and references therein).

Instead of a clear peak in culling in autumn, an actual peak of culling individuals would more often occur during spring/early summer. Unwanted males are slaughtered during this time, as well as sick newborn animals, and female animals dying from/during giving birth (*e.g*. Munson 2000, 391). Alternatively, unwanted males could be castrated and fattened and culled when needed, possibly before winter, since the extra effort of feeding surplus male animals throughout the winter is more costly than their high yield as a source of protein after slaughter (Munson 2000, 395).

Finally, old, unproductive or diseased animals would have been culled as well. All the above examples indicate that culling was a regular, if unwanted, practice throughout the year, with a peak usually occurring in spring/early summer rather than autumn.

Nutrition: grazing

Pasture can be grazed throughout the year, although quality and quantity of plants differs per season. Ideally, plants should be continuously kept in their vegetative phase, in which both quantity and quality are high. Good pasture management aims at prolonging this vegetative phase throughout most of the year, before allowing annual plants to set seed. In order to ensure high pasture quality, animals should graze pastures for limited amounts of time, to allow plants to recover, such as in a rotational grazing system (Baeté & Vandekerkhove 2001, 14-5; Hinton 2006, 72).

If and when burning of pasture is practiced, it is very important to burn in the early spring. The worst cold will be over and natural regeneration of the pasture will not yet have occurred (Ohlenbusch & Hartnett 2000; Lemus & Gordon 2012).

Nutrition: feed/fodder

One of the important issues with feed or fodder supply is whether it is needed, especially during winter. As has been stated in the previous section, certain animals might need additional fodder at certain times, and it is clear that in general it is a good strategy to have some fodder available for livestock for unforeseen events. Feed or fodder for unforeseen or harsh times in a year might be obtained from harvesting hay meadows, or, when hay is unavailable, by collecting leaf fodder from trees (Rackham 1980). Both types of harvest occur in (late) summer when plants are still green, but dry enough to facilitate subsequent drying and storage procedures (Halstead 1998, 223).

Housing

Housing of animals depends on many factors. As mentioned in section 5.3.4, structures can be used for reasons such as climate, manure, protection of animals or crops, labour efficiency, and control of animals and products.

In the Netherlands, most livestock can be kept outside throughout the year (van Wijngaarden-Bakker 1988), although specific species and age groups do require shelter in colder periods.

Pregnant animals, such as ewes, are usually kept inside for the winter, in order to protect them against predators during these dark and cold months, as well as to provide lambs with the best growing conditions for the first period of life (Schippers 2006, Ch 11). Other groups that can be kept inside in winter are goats, which are less resistant to cold and wet conditions.

Besides cold periods, livestock may also be kept inside during the night for reasons of protection.

Both vulnerable and valuable animals are at risk of being lost through predation or theft, so keeping them inside enables the farmer to protect the animals better than when left on pastures. Oxen, are, as mentioned, costly animals in terms of nutritional requirements and lack of breeding potential: they do not contribute to the proliferation of the herd, but do require a lot of resources. The investment put into these animals without a return such as producing new stock, makes them a valuable possession to farmers. Horses, being rare in the Bronze Age, may also have been valuable. The additional use of dogs as guard dogs or sheep dogs, will have reduced attacks from man and animal.When kept inside, animal manure is produced at a concentrated location, and may be used as fertilizer.

Another advantage to keeping animals inside is the protection of crops. Domestic animals themselves can form a threat for the settlement, when they forage on growing crops, so securing the animals in a holding pen or corral, well confined paddock, or inside other structures will minimize crop losses.

Controlling animals and their products is another advantage to keeping animals confined. When animals are used for milk or for traction, it can be advantageous to keep them close to the farmstead, removing the need to travel to and from pastures. Dairy cows or goats can be stalled in the night, to allow for morning milking, after which they and their young can graze during the day. Sheep which are to be sheared or plucked can be kept in a confined area in order to improve labour efficiency.

5.3.7 Summary and additional main components

Exploration into consistent animal husbandry practices on small-scale mixed subsistence farms throughout the world has yielded general observations of these economies.

Herd sizes of all livestock species (i.e. cattle, sheep, goat, and pig) were of limited size and never exceeded 15 individuals. Furthermore, herds never seem to consist of many male animals, since they are not required in high numbers to ensure the future of the herd. Female animals prevail, and unwanted males are often slaughtered at birth or castrated to be fattened. Oxen are found not to be an essential part of a small-scale subsistence economy, since their tasks can be fulfilled by other (female) animals available. Keeping oxen is a luxury many small-scale farmers cannot afford due to their high nutrient demands and lack of reproductive value. Many factors affect breeding with small herds. Birth rates can vary strongly and natural mortality of animals is high. Calf and lamb mortality ranging from 10-60% often results in a devastating loss of animals, meaning that more animals need to be reproduced than are needed to account for these potential losses. Another major risk in breeding with small herd is inbreeding. A minimum number of 16-25 breeding animals (excluding young, old and unproductive animals) need to be present in a herd in order for it to remain healthy. The herd sizes observed in small-scale communities do not cover this many animals, so interaction between settlements is necessary to avoid the risk of inbreeding affecting the herds.

Small herds are often exploited for more than one use, since specialisation towards one particular use normally results in an unhealthy herd composition. Such specialised compositions do not ensure the long-term viability of the herd as a self-reproducing unit and therefore endanger the livelihood of small-scale farmers.

Handling animals requires certain structures for restraining them for health and safety reasons. At small-scale farms, the size of such handling structures is limited and minimum requirements include a handling yard, a race, and a head bail. Additional forms of structures related to handling domestic animals include a shelter against the elements, or a holding pen.

Livestock can obtain their nutrients through natural foraging on pasture or by being foddered. Natural grazing can occur on paddocks or on an extensive basis and may, depending on the animal species, include both grassland and woodland pasture. Fodder for animals may be provided in some cases, such as during harsh climatic conditions or to certain vulnerable animal groups or animals restricted from natural foraging.

Animal husbandry experiences peaks in activity, which mainly occur during (early) spring, and (late) autumn, although all livestock requires some form of daily attention. Culling of animals mainly occurs during spring, rather than autumn, due to the culling of unwanted male young, or animals dying after being born or from giving birth. Other reasons for the culling of animals, which occurs throughout the year, include culling diseased, old, or unproductive individuals, as well as fattened (castrated) male animals.

Housing of certain animals may have occurred mostly during cold and dark winter months or on a nightly basis, and may have included valuable and vulnerable animals, such as pregnant females, oxen, horses, and breeding males.

Finally, an additional main component was identified related to the observations made regarding inbreeding. This main component is added to the list of main components of the current model, and is challenged in section 5.5:

(6) Interaction was required between the

settlements in West Frisia in order to ensure a genetically healthy domestic animal population and avoid the effects of inbreeding.

5.4 West Frisian data analysis

In this section, the basic aspects related to animal husbandry practices, as identified in section 5.2 and 5.3, are analysed based on the West Frisian data. First, however, a re-evaluation of the current methods related to the analysis of archaeozoological data is provided. This re-evaluation is needed because during the analysis of the West Frisian data, several aspects of the current methods have been shown to be incorrect. After the identification and discussion of these flawed aspects (section 5.4.1), a new method to analyse both livestock and herd dynamics is introduced: Faustitas (section 5.4.2/Appendix 1.7). With the aid of this improved method, every animal husbandry practice (cf. section 5.3.1-5.3.6) is analysed based on the archaeozoological data for each of the domestic animal species uncovered in West Frisia. The potential impact of methodology and taphonomy is discussed in relation to the interpretation of animal husbandry, so that past human practice and selection on the animal assemblage may be elucidated and assessed (section 5.4.7); other reasons for practicing animal husbandry besides providing a source of food are discussed in section 5.4.7.4.

5.4.1 Interpreting archaeozoological data

For the interpretation of archaeozoological data, several factors related to the researched animals are important to consider since the weight and the size of a researched animal can affect both the frequency with which remains are identified in the field, and the eventual reflection in the data. Age and sex differentiations between animals furthermore, are required to identify culled animal ratios and reconstruct a mortality profile. It is usually assumed that this mortality profile is a mirror image of the original living herd, therefore it is used to assess the composition of the herd and the purpose with which the herd was bred by past people. To make sure that the West Frisian data is analysed correctly, first, the validity of each of the current methods for interpreting the weight, size, age, sex, and size and composition of a herd is elaborated upon below.

5.4.1.1 Weight and size

Weight

To determine the general composition of the different livestock species killed on a settlement based on archaeological bone finds, the ratios of the numbers of bones of the different domestic animal species are normally presented. In cases where high fragmentation of bones is observed, such as in West Frisia, the weight of the bones is normally used in combination with numbers of bones. However, when graphs of weight and number of bones are compared, differences are usually observed.

Differences between these types of graphs are normally not seen as a problem, especially when number and weight data are both available for inter-site comparison: one type can be chosen and applied throughout. However, when not every site provides weight data, for example due to the employment of old research data, the differences between the numbers and weight of bones become important. In West Frisia, the data from the Bovenkarspel Het Valkje site for instance, contained the highest number of bones retrieved in the area, but only the numbers of bones was available from this site. Further investigation into the differences between number and weight data was pursued, to assess whether the numbers of bones could be used for comparison instead, improving the comparability of this important site to the other West Frisian sites.

In effect, the underlying problem of comparing the numbers and weight of bones is that they are not directly comparable. Whereas the main domestic animal species (i.e. cattle, sheep/goat, and pig) have comparable numbers of bones in their body, their weight differs significantly: femurs of cattle will always be heavier than those of pigs or sheep. Since no correction is made for this difference in the weight of the animal species to which the bones belong, heavier animals will inherently become over-represented.

A correction for this bias in the data might simply be achieved by dividing the total weight of bones of a species by the average weight of a skeleton of that species. However, since so many internal and external taphonomical factors could also have differentially influenced the weight of archaeological bone material (section 5.4.7.2), a correction for all these unknown factors is impossible. Therefore, the numbers of bones should always be employed as a comparative unit, not the weight of bones, regardless of the level of fragmentation. The West Frisian data will thus also only include the numbers of bones for further interpretation.

Size

Another important aspect to consider when investigating ratios of domestic animals is the size of the animal species. Cattle bones are much larger than sheep bones. Therefore, cattle bones are more likely to be noticed, and therefore collected, during excavation. At many excavations, bones are collected by hand (*i.e.* with the use of a shovel/trowel). In some cases sieving is employed for certain features, but sieving is rarely performed systematically on an entire site, at least in the Netherlands.

The fact that remains from smaller species such as sheep/goat are always relatively higher in number in systematically sieved sites means that sieving influences the relative ratios of the main domestic animal species present on sites.

In order to investigate the general effect of sieving on ratios of animal species within a bone assemblage, two Dutch sieving experiments were previously performed. The first experiment was performed by Lauwerier (1988) on five refuse pits dating to the early Roman period. In this experiment, bone material from the pits was hand-collected and the remaining soil from the feature was sieved over a 5 mm mesh size. The resulting effectiveness with which the numbers of main domestic animal remains were retrieved by hand was: 63, 24, and 41% for cattle, sheep/goat, and pig, respectively (Lauwerier 1988, 25). These percentages indicate the loss of material of certain species, especially sheep/goat and pig, when only hand-collecting has occurred.

Lauwerier however, provides a word of caution: "(…) data are specific for a particular excavation. Thus the data can only be used for those excavations where the conditions, the excavation technique, the amount of attention paid, the nature of the soil and the size of fragment per species are the same as at the place where the hand-collecting/sieving experiment was carried out." (Lauwerier 1988, 26). His research took place on upland Pleistocene sand deposits, which are not comparable to the clay deposits in West Frisia. Lauwerier's study and the abovementioned percentages are therefore merely an indication for what is missed when sieving is not applied.

For the area of West Frisia, a sieving experiment was attempted by IJzereef (IJzereef 1981, 30-4). Unfortunately, no distinction was made between species within large domestic animal groups (including horse and cattle) and small domestic animal groups (including sheep/goat, dog and pig). Since the raw data from the sieving experiment was also missing, no species-specific losses could be reconstructed. However, in general, it could be concluded that remains from smaller domestic animals are more often missed than large domestic animals when collecting by hand, since numbers of the large domestic animal bones increased by only 11% after sieving, versus an increase of on average 85% (range: 38-132%) of bones of the small domestic animals (IJzereef 1981, 31, table 6A). The retrieval effectiveness of hand-collecting was calculated by dividing the hand-collected material by the total yielded amount after sieving, which resulted in that 90% of the bones of large domestic animals were collected by hand, but on average only 58% of the small domestic animal bones.

Both of the above experiments have shown that it is important for the interpretation of animal husbandry to realise that smaller domestic animals are always under-represented in hand-collected assemblages. Furthermore, in areas with high fragmentation, smaller animal bone fragments may become too small for adequate identification, even when sieving is performed (Orton 2000, 166). This means that high fragmentation of animal bones will increase the under-representation of small domestic animals, regardless of retrieval technique.

Ideally, a new sieving experiment should be performed for West Frisia, but despite multiple attempts, it has not yet been possible to do so.

The under-representation of small domestic animal remains needs to be realised when interpreting animal husbandry practices. Ideally, sieving experiments should be performed on each large-scale excavation in order to calculate the percentages of loss of domestic animal species remains, and these percentages should be used to correct the eventual zooarchaeological dataset for internal biases. In this manner, animal husbandry practices between sites can be compared. When sieving experiments are not available, sites should only be compared when time period, soil properties, and excavation techniques are comparable. Therefore, in West Frisia, in the absence of adequate sieving experiments, only sites with comparable excavation techniques are compared with each other.

5.4.1.2 Sex and age

Sex determination
A herd consists of animals of different sex and age. The determination of the sex of an animal can be achieved via multiple methods, of which only the most often applied are shortly discussed here.

The sex of cattle is usually identified using metric data. The dimensions and shape of the pelvis, metacarpals, and horn-cores can all provide information on the sex of the animal (Armitage & Clutton-Brock 1976; Klein & Cruz-Uribe 1984; Greenfield 2006).

Metacarpals, being quite solid bones, are often used for sex determination in areas with high levels of bone fragmentation, such as West Frisia. Recently, the effectiveness of determination of sex based on metric cattle metacarpal data was assessed by employing ancient DNA research on the measured metacarpals. This research showed that metacarpal distal width indeed has a high correlation to the sex of the animal (Svensson *et al.* 2008; Davis *et al.* 2012). Although not directly comparable to the West Frisian situation due to environmental, temporal, and animal breed-specific aspects, these results remain very promising. Therefore, metacarpal width is used in the sex determination of the West Frisian slaughtered herds. Additional aDNA research was attempted on the metacarpals of Bovenkarspel Het Valkje to assess the metric sex determination accuracy for West Frisian cattle as well, but sadly, the aDNA in these bones was too degraded for analysis.

Sex determination of sheep is often achieved by assessing the dimensions and shape of the pelvis or horn-cores (Boessneck *et al.* 1964; Greenfield 2006). In areas of high fragmentation, usually only horn-cores are available for determination, and indeed this was the only sex data for sheep from West Frisia as well.

The sex of pigs is often determined by the shape of the canine teeth.

Age determination
The age of animals can be determined by two methods. The first involves analysing the age of the animal based on tooth eruption and wear (Silver 1969; Habermehl 1975; Grant 1982), which involves many stages from birth to death. It is therefore a precise method which allows for a differentiation in many narrow age groups. The second method involves the analysis of post-cranial bones (Silver 1969; Habermehl 1975). The fusion of the epiphysis in these bones occurs at different times in an animal's body and differs per animal species. The identification of a fused, fusing, or unfused epiphysis of a bone can lead to a relative age determination in groups broader than identification based on dental material. Dental age determination is therefore more often applied than post-cranial bone material, even though post-cranial bones usually form the largest part of bone assemblage in the Netherlands. In order to also accommodate more and better analyses of post-cranial bone material, which was most often uncovered in West Frisia, a new method was developed to calculate the ratios of ages of slaughtered animals (*i.e.* mortality profile; section 5.4.2/Appendix A1.7).

5.4.1.3 Small-scale animal husbandry: herd size and composition

It is important to reconstruct the size of the living herd in order to compare it with expectations, and to reconstruct herd logistics (*e.g.* pasture size). However, since living herds can be very similar in composition for different types of use, living herds are not important aspects of animal husbandry when reconstructing the use or purpose of a herd or flock (Cribb 1985, 81). Rather, the details of the animals removed by people from those herds can provide information on the purpose of the original herd more accurately (Cribb

1987, 394, 409). Therefore, the reconstruction of the living herd should always start with the analysis of the culled herd.

Herd size

The main method used for the reconstruction of the size of herds, is the minimum number of individuals (*i.e.* MNI) method. This method uses the most frequent skeletal element of an assemblage to establish the minimum number of animals represented in that assemblage. The MNI can be further refined by dividing skeletal elements into bones from the left or right side of the body, as well as by considering the epiphyseal fusion stage of the bones, in order to assess whether bones derive from one or more individuals (*e.g.* Chaplin 1971, 69-75). Still, the reconstructed MNI only informs about the number of animals that died, not the number of animals originally present in the living herd.

Information on the mortality of animals based on the MNI method can be interesting when investigating numbers of animals slaughtered and possible amounts of meat consumed. It cannot, however, provide information on the original size of the herd; the amount of slaughtered animals is only dependent on the living herd size to a certain extent. For example, if according to the MNI method and subsequent calculations on average two animals were killed annually (*e.g.* a total of 400 MNI from a site that was inhabited for around 200 years), it is impossible to reconstruct whether the original living herd consisted of 10, 100 or 1000 animals. Still, the calculated MNI can provide rough indirect estimations of relative herd size. For example, when 20 individuals were killed annually, a herd size of 10 would be impossible. So, the MNI method can provide a very rough estimate of minimal living herd size, but only in an indirect manner.

Herd composition

The composition of the herd is dependent on the sex and age ratios of the animals in it. Both types of information can only be obtained archaeologically in an indirect manner, via the age and sex ratios of culled animals (*i.e.* mortality profiles). Mortality profiles in general can fall into two broad categories: catastrophic or attritional (Klein 1982, 58; Figure 5.13). Catastrophic mortality profiles contain all the animals originally present in the population and can therefore be the result of *en masse* death of populations either through catastrophic events, or human-induced slaughter by practicing certain types of non-selective hunting (Levine 2005, 14). In addition, animal husbandry focused on meat production will also resemble this type of mortality profile, since mainly animals in the prime of their life are slaughtered (Levine 2005, 12), as well as large numbers of young stock (Figure 5.13a). The catastrophic mortality profile can therefore be regarded as a direct reflection of the original living herd. Attritional mortality profiles on the other hand, consist of a non-catastrophic selection of dead animals from the original population, and can be the result of natural mortality or animal husbandry practices in which meat production is not the main focus (Greenspan 1998, 974; Levine 2005, 12; Figure 5.13b). Attritional profiles therefore do not reflect the original composition of a herd, but merely a selection from it.

So, depending on the use of livestock by past people, mortality profiles will or will not accurately reflect past original living herd compositions. Therefore, another method is required to assess the composition of the original living herd, which is also incorporated in the new method presented in this chapter (section 5.4.2/Appendix A1.7).

West Frisian livestock

Now that the different aspects of archaeozoological analysis have been discussed and criticized, the general ratios between the different livestock species (*i.e.* cattle, sheep/goat, and pig) in West Frisia can be considered and interpreted. The specific size and composition of herds is assessed in the sections on each respective animal species (section 5.4.3-5.4.5).

The ratios of the three main livestock species are shown in Figure 5.14 for each site in West Frisia in both the Middle and Late Bronze Age. In this figure, the numbers of remains were used, and a distinction was made between sites where sieving was applied versus sites where material was mostly hand-collected. Subsoil was expected to have been similar for all sites. Since no clear sieving experiment was available for West Frisia, it was unknown what the species-specific losses of bone material were.

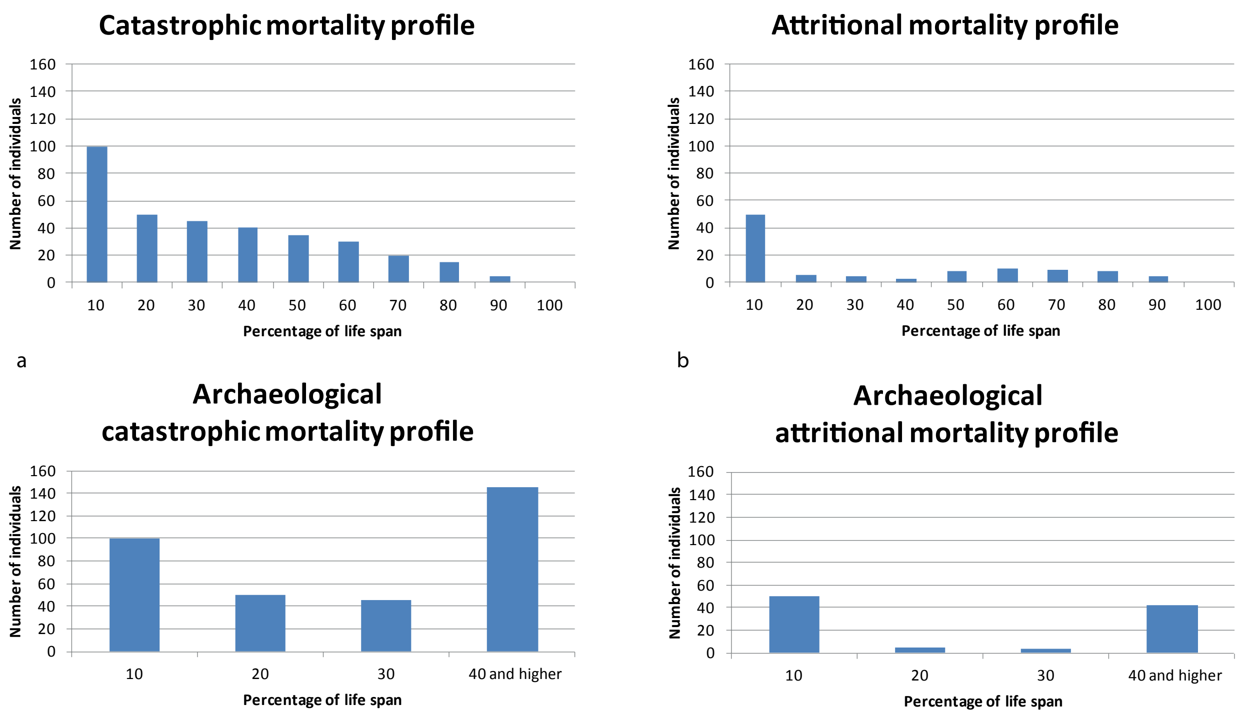


Figure 5.13. Comparison of the two different types of mortality profiles; a: catastrophic mortality profile, representative of the original living herd; b: non-catastrophic or attritional mortality profile, representative of selections of animals from a herd when meat production is not the main focus (adapted from: Steele 2003, Figure 1). Bones from mammals however, do not provide age information after they are fused, so the oldest identifiable age is around four years of age (excluding vertebrae). Archaeological mortality profiles based on post-cranial bones thus amalgamate individuals from four years and older which results in a high peak of mortality in this category. When it is assumed that an animal lives to be 10 years old, the amalgamated peaks at 40 % of the life span and older of both catastrophic and attritional mortality can be expected to resemble those in the lower figures.

However, an under-representation of sheep/goat, and to a lesser degree pig, was expected for all sites, but was expected to be most severe at non-sieved sites.

Figure 5.14 shows that in general the ratios of livestock from many sites appear similar within each category of excavation technique (*i.e.* hand collecting or sieving) and within each time frame. Remains of cattle dominate, followed by remains of sheep/goat, and pig. Exceptions to this trend are observed at the sites Schagen, Hoogwoud, and Zwaagdijk-Oost, which show a relatively higher number of sheep/goat bones in comparison to the other sites. Schagen furthermore yielded more remains of pig.

The underrepresentation of pigs, but especially sheep/goats, was expected at all sites, but even so, cattle remain by far the most frequent species in almost all bone assemblages. Whether this dominance in number of bones can also be translated into a dominance within the subsistence economy is hard to assess. Different uses or mobility of domestic animal species can result in different reflections in the archaeological record. Furthermore, the quantity of remains of an animal species should not be directly linked to importance, since a lower amount of animals with more or different uses or even rare animals can be considered equally important (cf. Chapter 4) depending on the original reasons of past people.

The reason for the higher amount of sheep in Hoogwoud and Schagen is often linked to the fact that environmental conditions here are considered to be more favourable to sheep: the saltwater environments around these sites would prevent the occurrence of liver fluke (*Fasciola hepatica*),

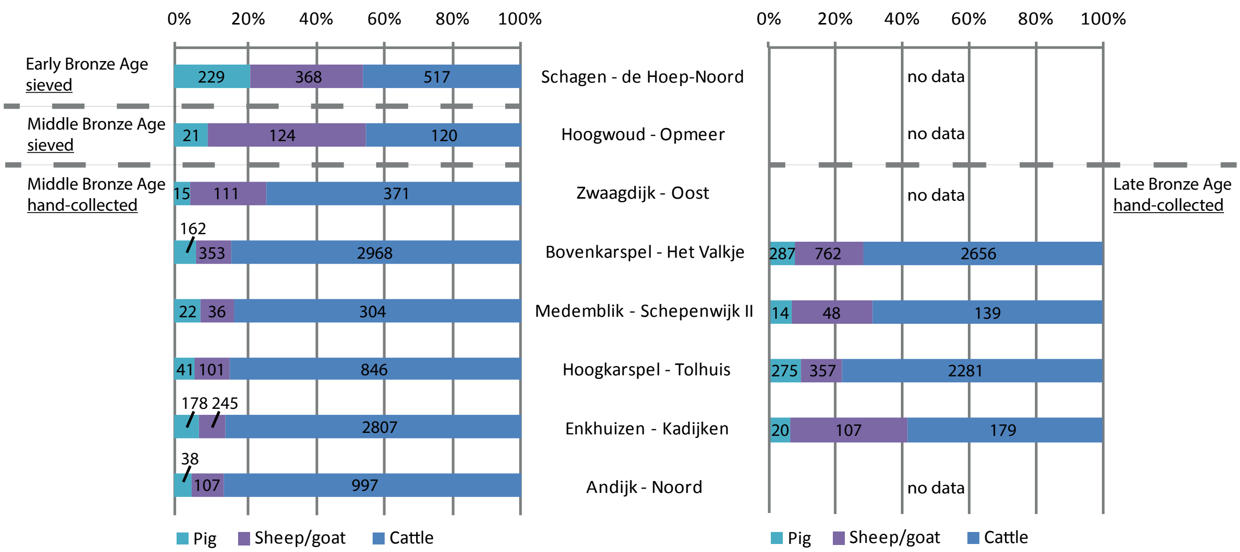


Figure 5.14. Overview of the ratios of numbers of bones from different livestock species present at each site in West Frisia, including cattle, sheep/goat, and pig. Both the Middle and Late Bronze Age material is presented. At the sites Schagen and Hoogwoud, sieving was performed systematically during excavation, whereas bones at the other sites were hand-collected.

which causes lethal infections in sheep (Zeiler *et al.* 2007, 21). However, two aspects are not taken into consideration in this statement. First, at both Hoogwoud and Schagen excavations, sieving was applied. The higher number of sheep/goat here can therefore very well be an artefact of methodology (cf. section 5.4.1.1). Second, it seems that it is not realised that the diagrams in Figure 5.14 represent the ratios of a selection of animals that were culled, not the original living herds (see previous section). Cumulative remains of selected culled animals from several centuries cannot be directly related to the size of the original herd population, and whether many or few sheep were originally present in it. The high number of sheep/goat remains may be a reflection of killing more individuals of these species, regardless of herd size; it might just be the case that people in Hoogwoud and Schagen enjoyed sheep or goat meat over other species in comparison with the eastern sites, environmental conditions were less favourable for sheep survival in some other respect, or that indeed other reasons existed here for killing sheep/goat relatively more often than cattle.

Other arguments against the idea that more individuals at certain sites would reflect favourable environmental conditions come from Middle Bronze Age Zwaagdijk-Oost, as well as on the Late Bronze Age sites in West Frisia. The numbers of culled sheep seem to increase at these sites, but this phenomenon can definitely not be linked to improved or more appropriate environmental conditions: the landscape reconstruction from Chapter 2 has shown that the eastern part of West Frisia in the Late Bronze Age was deteriorating into a large, wet, freshwater environment, where sheep would actually be more prone to liver fluke infection than in the preceding period. The higher number of dead sheep in this period is therefore not representative of better living conditions. Furthermore, these high numbers of dead sheep should not directly be related to an increased importance for subsistence, because they may very well derive from culling due to the results of disease or other adverse effects on the herd, rather than killing solely for consumption.

5.4.2 A new method for the reconstruction of past livestock and herd characteristics

This section forms a short introduction for the newly developed programme Faustitas, which enables an improved construction and interpretation of mortality profiles in order to elucidate past herd use and dynamics. An explanation of the development as well as the manner in which the programme works is briefly discussed here, since Faustitas was used for the analysis of the West Frisian data in the following sections. The actual article discussing the method and its application, however, is located within the Appendix (Appendix A1.7). Its location was chosen on purpose, as it is believed that if an elaborate article discussing mostly methodological issues were placed within this chapter it would distract from the actual analysis of the West Frisian data and the flow of results section in general.

From section 5.4.1 it is clear that a re-evaluation and improvement is required of the current zooarchaeological methods widely employed to construct and interpret mortality profiles based on post-cranial bone data. These current methods (cf. Chaplin (1971) and Payne (1973)) are identified as being inadequate in their methodology and assumptions, and therefore their ability to accurately interpret past human practices related to (domestic) animals (Appendix 1.7).

The new programme consists of a new method which creates a mathematically correct mortality profile (*i.e.* slaughter pattern) by correcting for internal biases inherently present in raw post-cranial bone data, as well as for the external effects of taphonomical processes on the bone assemblage. Additionally, a simulation option is provided which allows the user to evaluate past herd characteristics such as exploitation potential for different uses, long-term viability, birth rate and mortality rates of different age groups, and composition of the original live herd.

The newly constructed mortality profile and subsequent simulation of the data in this chapter results in the reconstruction of a healthy growing herd, with relatively low birth rates, and with the potential to be exploited for multiple purposes (see following sections).

Faustitas is a considerable methodological advance in the zooarchaeological research field, with ample potential to be extended and improved in the future to ensure that this progress is continued, allowing for more accurate and elaborate interpretation of past human-animal interactions.

5.4.3 Cattle

Cattle remains were most frequently uncovered, so most information was obtained for this domestic animal species. The appearance and characteristics of Bronze Age cattle are further elaborated upon in Appendix A1.5.

Herd size and composition

Herd size

As stated in section 5.4.1.3, original living herd size cannot be directly reconstructed based on zooarchaeological material. It can however, be indirectly estimated based on the MNI present at a site. Since cattle remains were uncovered at high quantities at Bovenkarspel Het Valkje, a MNI culled/year was calculated for this site. Since ratios of cattle remains are least affected by hand-collecting, and the effects on other livestock species remains unknown, only the MNI for cattle is directly useable in this research. The calculated value was only based on the most frequently present skeletal element, since further differentiation was not possible. Based on the data from Bovenkarspel, where most remains were uncovered, the resulting value was 1.0 MNI/year (713 MNI/700 years). This low amount of cattle being culled per year is in concurrence with culling practices imposed on a small herd. Since this indication matches the size expectation for cattle herds in small-scale mixed subsistence farming communities, the average value of 5-8 cattle per household (cf. section 5.3.1) is used from now on for further calculations.

Age differentiation

The age of West Frisian herds was first investigated based on dental information (cf. Hambleton 1999) with an additional ravaging correction for taphonomy based on the work by Munson (2000, 401; Faustitas article). Sadly, only Bovenkarspel yielded considerable amounts of age data which could be used to investigate ages based on teeth. The results are summarized in Figure 5.15.

The ravaging correction applied resulted in high

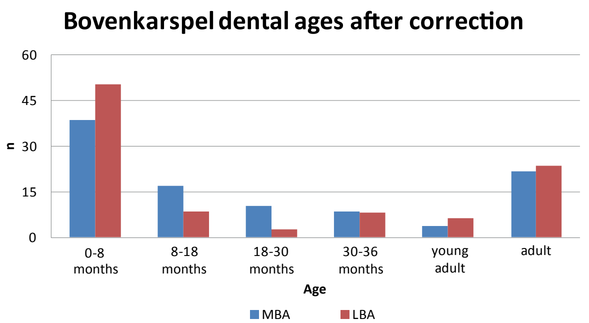


Figure 5.15. Corrected age data of Bovenkarspel cattle based on dental remains for both the Middle and Late Bronze Age. Original data before correction is for the MBA: n=212, and for the LBA: n=146.

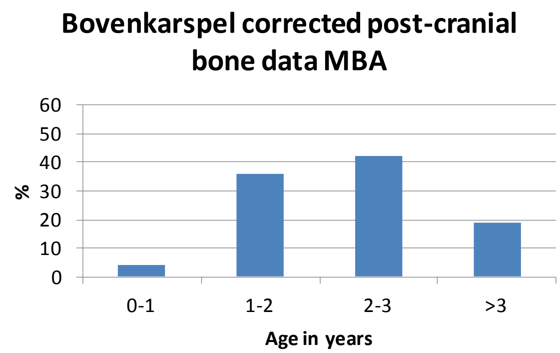


Figure 5.16. Middle Bronze Age mortality profile of cattle from Bovenkarspel based on post-cranial bones. Original data before correction is: n=619.

levels of dead young animals in the Middle Bronze Age. These high levels of dead young followed by adult animals are actually normal in an animal husbandry situation, where most animals often die or are culled at a young age (younger than 12-15 months (Cribb 1985; Cribb 1987; Munson 2000, 395-6). Animals are also culled at an adult age, for reasons including disease or unproductivity (cf. section 5.3.2). In the Late Bronze Age, a shift seems to occur, towards even more young animals being culled, as well as a higher number of older animals (young adult and adult).

The mortality profile based on cattle ages was also reconstructed based on post-cranial data with a ravaging correction (cf. Munson 2000) with the aid of Faustitas for the sites Bovenkarspel and Enkhuizen, since only these sites yielded sufficient numbers of bones (*i.e.* > 100; cf. Hambleton 1999, 39). The bone remains were divided into the Middle and Late Bronze Age, but only Bovenkarspel yielded enough data to reconstruct the Late Bronze Age mortality profile. The results can be observed in Figure 5.16-Figure 5.18.

Clearly, in the Middle Bronze Age, most animals were selected for slaughter between the ages of two and three, and young animals are almost absent. In the Late Bronze Age, especially younger animals were selected, possibly signifying a different animal husbandry practice during this time, which is discussed further in the section on use below. However, differences may also be due to different taphonomical processes between both time periods, which is further discussed in section 5.4.7.2.

A comparison between the ages based on dental and post-cranial bones from Bovenkarspel reveals that although few young animals appear to be present in the Middle Bronze Age based on mortality profiles of post-cranial bones, teeth do reveal a high presence of youngstock. This lack of youngstock in the post-cranial bone assemblage therefore signifies that the taphonomical effects on post-cranial bones were probably high, which was already clear from the ravaging ratio of 8.7:1 (Appendix A1.7). In the Late Bronze Age, both age determination types show an increase in animals younger than 12 months.

Mortality profiles, however, are not necessarily comparable to the original living herd composition (cf. section 5.4.1.3). Since the West Frisian living herd composition is required for comparison with the expected values based on ethnographic parallels, the mortality profiles from Figure 5.16-Figure 5.18 were translated into the original living herds with the aid of Faustitas (section 5.4.2/Appendix A1.7). These results are summarized in Figure 5.19-Figure 5.21.

It is clear that in the Middle Bronze Age, age compositions of herds from both Bovenkarspel and Enkhuizen are very comparable to herds on small-scale mixed subsistence farms, with a high percentage of adults (nearly 60%), and around 25% youngstock. In the Late Bronze Age however, the number of adult animals far exceeds expectations, whereas

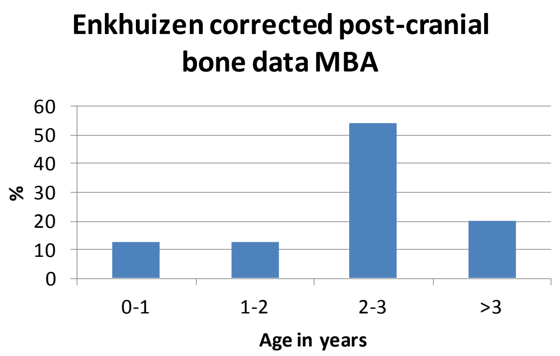


Figure 5.17. Middle Bronze Age mortality profile of cattle from Enkhuizen based on post-cranial bones. Original data before correction is: n=479.

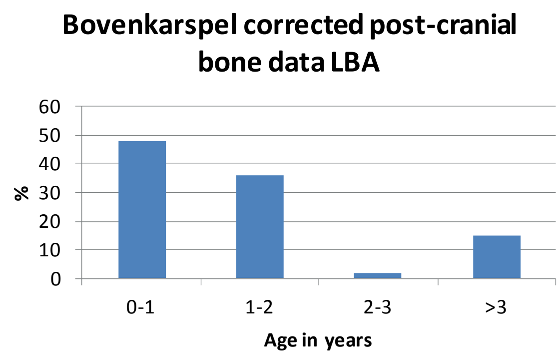


Figure 5.18. Late Bronze Age mortality profile of cattle from Bovenkarspel based on post-cranial bones. Original data before correction is: n=288.

the number of immature animals is far fewer than expected. This difference in age composition in the Late Bronze Age might signify a difference in animal husbandry practices, which is further explored below in the section on use.

Sex differentiation

The sex of cattle herds was reconstructed based on the metacarpal bones from Bovenkarspel, where most bone remains were found. The cattle metacarpals show a clean differentiation into two groups (Figure 5.22) of which the left group is normally interpreted as being females, and the right as being males. A further differentiation of the data into the Middle and Late Bronze Age reveals similar groups, but no change in the overall size of cattle (Figure 5.23).

The 41 metacarpal bones together indicate a sex ratio within the dead herd of 66% females and 34% males, which differ from the expected ratios based on ethnographic parallels (section 5.3.1; Figure 5.2).

However, it should be assessed whether this set of metacarpal bones is representative of the original living herd, since, in farming communities where meat is not the main production purpose of the herd, mortality profiles are not considered representative of the living herd (cf. section 5.4.1.3). From the use of cattle herds reconstructed with the aid of Faustitas in the section on use below, it has become clear that cattle herds had equal potential for meat and milk production: no specialisation towards

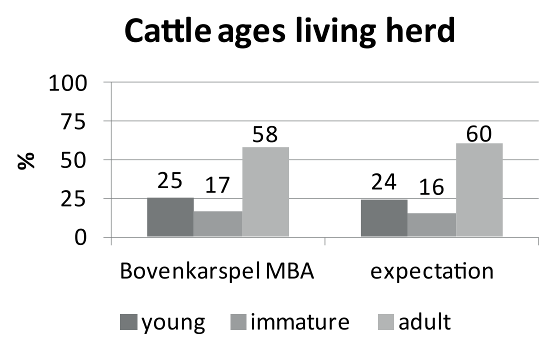


Figure 5.19. Living cattle herd composition comparison between reconstructed Middle Bronze Age data from Bovenkarspel (left) and ethnographic parallels (right). Young: 0-1 year; immature: 1-2 years; adult: > 2 years.

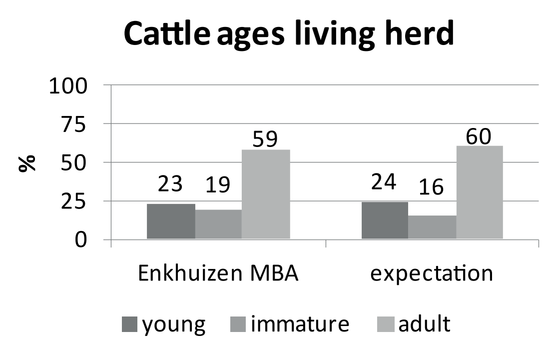


Figure 5.20. Living cattle herd composition comparison between reconstructed Middle Bronze Age data from Enkhuizen (left) and ethnographic parallels (right). Young: 0-1 year; immature: 1-2 years; adult: > 2 years.

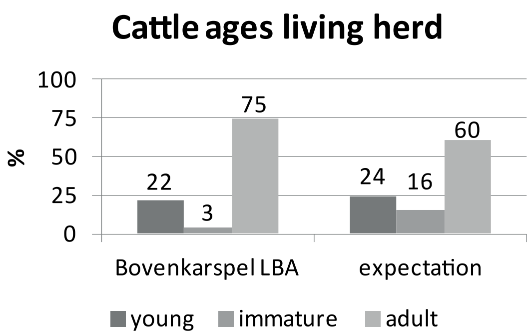


Figure 5.21. Living cattle herd composition comparison between reconstructed Late Bronze Age data from Bovenkarspel (left) and ethnographic parallels (right). Young: 0-1 year; immature: 1-2 years; adult: > 2 years.

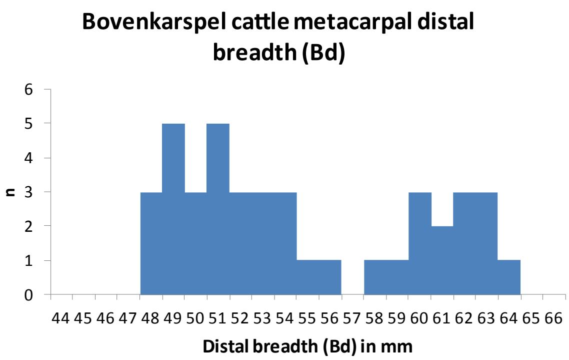


Figure 5.22. Metacarpal widths of cattle from Bovenkarspel from the entire Bronze Age. A clear difference in size groups can be observed ranging from 48-56 cm and 58-64 cm, which are interpreted as evidence for female and male cattle, respectively.

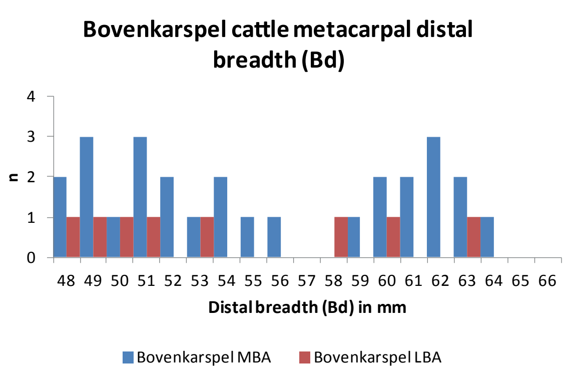


Figure 5.23. Metacarpal widths of cattle from Bovenkarspel divided into metacarpals from the Middle (blue bars) and Late Bronze Age (red bars). Divisions of widths within each time period presumably reflect the differentiation in female (small) and male (large) animals. No clear size difference of cattle between the two periods can be observed.

meat production was observed. Therefore, it can be assumed that the mortality profiles of West Frisian cattle are indeed not representative of the original living herd. The observed sex ratios for West Frisian cattle seen in Figure 5.24 should therefore be interpreted as selections made on the population rather than a reflection of the composition of the original population (Figure 5.25). The reconstruction of original ratios within living herds in West Frisia, which was possible for age composition (cf. Figure 5.19-Figure 5.21), could not be reconstructed for sex composition. Thus it cannot be assessed to which extent the expected sex ratios based on ethnography match with the West Frisian data. Still, since the original age ratios approach those observed in the small-scale herds of the ethnographic parallels very closely, it is assumed that sex ratios may also have been comparable.

Therefore, because the original sex composition of the living herd could not be accurately reconstructed, and due to the similarity of other herd characteristics to the ethnographic parallels, the sex ratios of those parallels are used for the further interpretation of animal husbandry. The presence of oxen, finally, could not be established and it is therefore not assumed that these were necessarily kept in West Frisia.

(In)breeding

Inbreeding

Inbreeding is hard to establish directly from the archaeological record. Still, several indirect indications for inbreeding could be investigated based on the cattle data of West Frisia.

A first indirect indication related to inbreeding derives from cattle skulls, which can provide information on genetic defects. Cranial perforations are often observed in skulls of both domestic (*i.e.* pig and cattle) and wild animals (*i.e.* aurochs, European bison). Since both domestic and wild animal skulls contain these perforations, Fabis *et al.* state that such a defect must be genetic rather than human-induced (*i.e.* from pulling a yoke) (Fabis *et al.* 2011, 349). The occurrence of cranial perforations is considered a recessive genetic defect, and so only becomes expressed in homozygous recessive individuals. Homozygous recessive individuals in turn, regularly

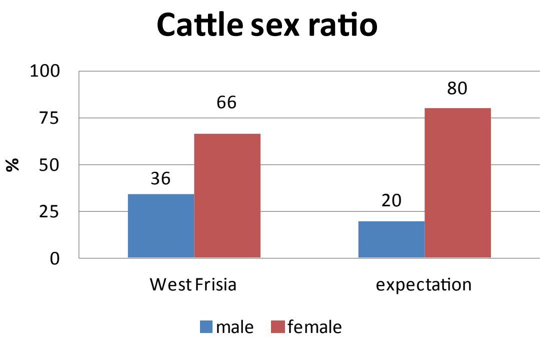


Figure 5.24. Cattle herd sex composition comparison between reconstructed West Frisian data (left) and expected values based on ethnographic parallels (right).

occur when inbreeding takes place. Therefore, not many wild animals show this characteristic under normal circumstances, but domestic animals will indeed have a higher chance of expression.

In Enkhuizen Kadijken, 8 out of 16 of the uncovered cattle skulls possessed these types of cranial perforations (Zeiler & Brinkhuizen 2011, 199), which indicates a relatively frequent occurrence of homozygous recessive individuals, and therefore inbreeding. Similar observations on the other West Frisian sites were hampered by the high fragmentation of bones.

A second indirect indication related to (the possible avoidance of) inbreeding was obtained from isotopic evidence. The strontium isotopes from tooth enamel of molars from 29 mandibles of cattle were analysed in order to investigate whether these animals were born locally or derived from locations outside West Frisia (Brusgaard 2014). From these isotopic analyses, two of the 29 mandibles provided a non-local signal, and it has therefore become clear that two cattle were imported both in the Middle and Late Bronze Age at an age of at least 2.5 years (Brusgaard 2014). These animals could have derived from Pleistocene upland locations which also contained moraine deposits. The origins of these two cattle could lie in the Dutch provinces of Drenthe or Noord-Brabant, which are at least 60 kilometres away from West Frisia, or as far away as Germany or southern Scandinavia (Brusgaard 2014). The import of animals indicates that Bronze Age West Frisian people were willing

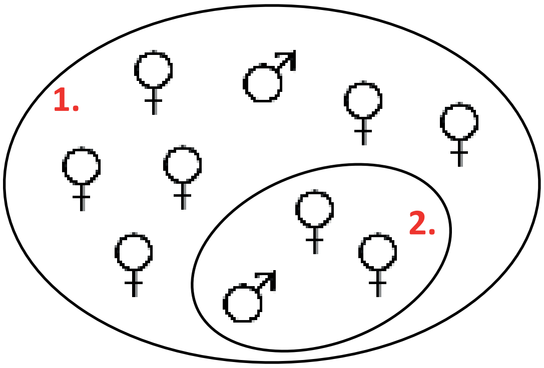


Figure 5.25. Representation of the reflection of an entire population (catastrophic mortality, number 1) versus a selection from that population (attritional mortality, number 2). The first type of mortality would approach the sex ratios observed in the living herds of ethnographic parallels, whereas the second type would reflect the sex ratios of the animals of herds in Bronze Age West Frisia selected from the entire herd for slaughter (cf. Figure 5.24).

to make a substantial effort to obtain new animals. Sadly, subsequent aDNA analysis on the sampled mandibles did not yield any usable results on the sex of the animals.

The import of male animals would have given stronger indications that people were avoiding inbreeding, assuming they were aware of its effects. Still, whether this import of animals was performed consciously for the avoidance of inbreeding is not clear, but by importing fresh blood into the population, people were simultaneously reducing the possible inbreeding effects regardless of initial intent.

The above evidence seems to indicate that inbreeding may indeed have formed a major problem in the animal husbandry practices of West Frisian farmers, at least for cattle. It was expected that inbreeding could theoretically be avoided in West Frisian through adequate exchange of cattle on an annual basis between settlements (section 5.3.2). However, the occurrence of indications for inbreeding seems nevertheless to indicate that animal husbandry was not practiced to a degree at which farmers exchanged (male) cattle on a regular basis. Alternatively, exchange of cattle within West Frisia may have occurred, but may have been ineffective if populations

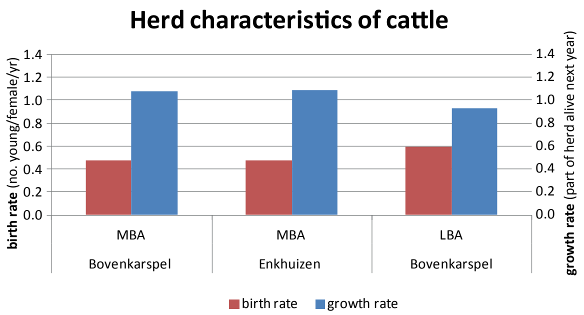


Figure 5.26. Cattle birth and growth rate data from Bovenkarspel and Enkhuizen. Birth rate indicates the number of young born per female per year and growth rate indicates the annual growth of the herd. Growth rate values higher than one indicate an increase of the herd, whereas a value lower than one indicates a decrease.

were already too genetically homogenous: a population with a limited gene pool will still be affected by the occurrence of inbreeding regardless of exchange, since exchange within such a population does not introduce fresh blood.

Breeding

Herd characteristics, including birth rate and growth rate, were obtained from the analysis of post-cranial bones of cattle from the Middle Bronze Age from Enkhuizen and Bovenkarspel, and of the Late Bronze Age from Bovenkarspel, which was only possible through the simulation of Faustitas (Figure 5.26). Growth rate is defined as the annual percentage of added new animals to the herd; birth rate is defined as the average number of young produced per female per year. When growth rate values are higher than one, the herd will grow in size each year, and vice versa. Birth rate values are usually lower than one, since not every female in a herd produces off-spring each year, except for when a female produces twins.

The growth rate of the Middle Bronze Age herds can be considered healthy: 1.08 or 8% per year on average (cf. Cribb 1987, 403). The simulation on the Late Bronze Age data however, only yielded results with an annual growth rate of 0.93, indicating a decreasing herd size. A decreasing herd is always an unwanted and unhealthy herd, since it will not be viable in the long-term when conditions remain as they are. Therefore, it seems that farmers practicing animal husbandry in the Late Bronze Age, at least at Bovenkarspel, were experiencing difficulties.

The birth rate of the Middle Bronze Age sites is also normal compared with the expectations based on ethnographic parallels, at around 0.48. In the Late Bronze Age, the birth rate increases. On its own, this observation would indicate an increasingly productive herd. However, combined with the decrease in growth rate observed as well as the increased mortality of young animals for this period (Figure 5.15, Figure 5.18), it seems as if people were desperately attempting to obtain more youngstock, but to no avail.

Thus, the Middle Bronze Age cattle herds seem to reflect healthy herds which are comparable in birth and growth rate to small-scale mixed subsistence farming communities today. In the Late Bronze Age, for whatever reason, animal husbandry seems to be experiencing problems. Still, it was only possible to investigate the LBA situation based on one site, so further research is needed to confirm this picture for other regions of West Frisia.

Breeds

Although in general West Frisian cattle can be characterised as small horned cattle (IJzereef 1981; Appendix A1.5), there are indications that some differences in size and appearance of cattle existed. Both the analysis of West Frisian cattle metacarpals (Figure 5.22) and of horn-cores (Aal 2016) have indicated that variations in body size and the size and shapes horns of cattle existed. In Enkhuizen Haling, even a naturally hornless cattle skull was uncovered (van der Jagt 2014, 59), which is a very rare find for this area of north-western Europe during this time (Bartosiewicz 2013, 332). This variation in cattle size and appearance is observed throughout the Bronze Age (Bartosiewicz 2013, 332), and should therefore not only be interpreted as a possible variation in the sex of the cattle researched, but also a possible variation in breed, especially since cattle were also being imported to West Frisia from other locations within the Netherlands.

Use

The potential of using West Frisian cattle herds for different purposes (*i.e.* meat and milk) was investigated using Faustitas, for both the Middle Bronze Age and Late Bronze Age data (Figure 5.27). The potential of a herd for a specific use is not related to the amount of actual product produced, but rather to the ability of the herd to produce these products based on its composition of animals of different age and sex (cf. Cribb 1985, 87).

Again, only Bovenkarspel (MBA and LBA) and Enkhuizen (MBA) yielded enough data (>100 age-determined bones) to perform the analysis.

Middle Bronze Age

As is clear from Figure 5.27, the potential of Middle Bronze Age herds for meat and milk production is low. Furthermore, no clear specialisation for a particular use can be discerned, since values of both uses are very similar. Therefore, the Middle Bronze Age herds can be considered to consist of multi-purpose cattle.

Late Bronze Age

The data for the Late Bronze Age is limited, but the production potential for both meat and milk has increased in relation to the Middle Bronze Age. This higher production potential is most likely due to the increased birth rate (Figure 5.26), and appears to signify that people were attempting to increase the production of the herd. However, the growth rate of the Late Bronze Age herd (Figure 5.26) was too low to sustain a viable self-reproducing herd on the long term. Therefore, the increased production strategy applied by LBA farmers would eventually not lead to a healthy herd. The potential for both meat and milk production however, remains similar in the Late Bronze Age, indicating that still no clear specialisation was occurring.

Other archaeological indications for use of cattle

The potential purpose of the cattle kept on the researched sites was as expected: multi-purpose. The use of cattle in providing meat is further emphasized by the presence of slaughter marks on many cattle bones at every site in West Frisia.

The use of cattle for milk however, was harder to identify based on archaeological evidence. Even though cattle herds had the potential for milk

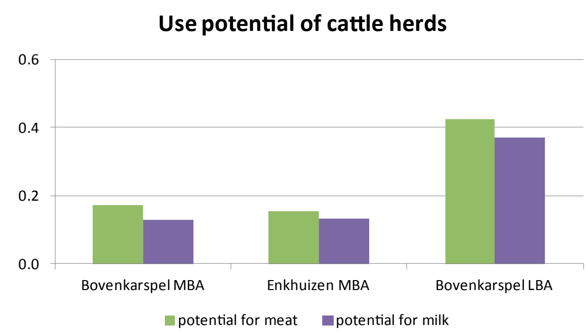


Figure 5.27. Potential of West Frisian cattle herds for meat or milk production. Use potential is a relative value to evaluate the production potential of a herd for different uses (cf. Cribb 1985). The higher the value, the higher the potential.

production (Figure 5.27), evidence for its use by people still needs to be assessed, which includes the processing, consumption, and digestibility of milk by Bronze Age people.

Recent DNA research has shown that adult Bronze Age people in north-western Europe were indeed already capable of digesting milk (Curry 2013). Other research, based on Bronze Age tooth calculus, has provided indications that in the more northern latitudes of Europe, adult Bronze Age people were actually consuming milk from cattle and sometimes sheep (Warinner *et al.* 2014, Suppl. Table 1 and 2). Finally, the occurrence of possible ceramic cheese strainers indicate that people were processing milk into cheese or perhaps also yoghurt since the Middle Neolithic times (Barker 1985, 145). Therefore, in general it can be assumed that north-western European Bronze Age people used milk.

In West Frisia, remains of possible cheese strainers were also uncovered (Figure 5.28), indicating the potential to process milk into other products here as well.

Furthermore, residue analysis on ceramics from Enkhuizen Kadijken has shown the presence of ruminant milk fat in pots (Roessingh & Lohof 2011, 184), providing another indication for the use of milk in West Frisia.

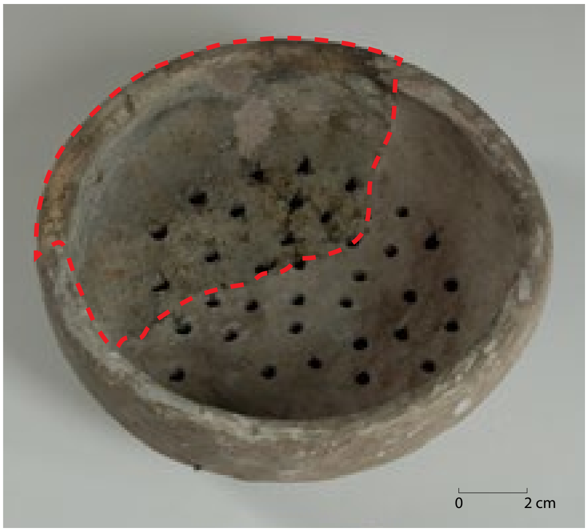


Figure 5.28. Possible ceramic cheese strainer found at Zwaagdijk-Oost. Red dashed outline indicates the original find, the remaining part is reconstructed.

The other archaeological indications for use of cattle therefore confirm the reconstruction of potential uses of the herd based on Faustitas. The Bronze Age West Frisian cattle herds seem to have been exploited for both meat and milk.

Handling and related locations

No definitive indications for handling or related locations have been identified in West Frisia. However, several indications for the movement of cattle across the settlement were found, as well as possibilities for how animals may have been kept inside.

Hoof prints

The presence of possible cattle track ways has previously been proposed based on certain features found in West Frisia (Gerritsen *et al.* 2014, 31; Figure 5.29a). However, these types of track ways cannot have been caused by cattle for several reasons. First of all, the pits forming the "track ways" are too parallel to belong to cattle, since a cattle's gait creates a more or less zigzag pattern (Telezhenko 2009, 1748, fig. 1; Figure 5.29b). Secondly, the depth of the "tracks" at more than 20 cm below the excavated surface is too great. At all sites in West Frisia, on average 30 cm of the top soil is missing, so only the deepest features remain. Since cattle only sink in mud to about knee-height, which for Bronze Age cattle is around 30-35 cm (IJzereef 1981, 65, fig. 25), this means that cattle tracks could only appear up to 5 cm deep. Most identifiable separate cattle prints uncovered during excavations are indeed of this depth. Therefore, the 50 cm deep tracks indicated by Gerritsen (*i.e.* 20 cm of the feature plus added 30 cm missing) deep could never reflect a cow's movement, let alone an actual track way. Lastly, these "track ways" have never been shown to consist of individual cattle tracks in either feature or cross-sections.

Settlement analysis of the sites Enkhuizen Haling and a part of Enkhuizen Kadijken have, however, provided information on the movement and possible locations of livestock. At Enkhuizen Haling, individual cattle prints were observed in several instances (Figure 5.29), sometimes forming a path or track way. Although generally not discernible, some cattle prints still show the direction of movement of the cattle (Figure 5.30). Two of these track ways lead directly to and from the short end of a building structure, implying that this structure may have housed cattle (Figure 5.31).

Barn

The differentiation between the living area and the part of the house which houses animals is often possible on the basis of a barn with stable partitions, which can, for example, be observed in the Bronze Age houses in parts of north-eastern the Netherlands and Denmark (Arnoldussen 2008). Since these partitions should be able to withstand considerable force from animals, the foundation should be deep and would therefore have been visible in West Frisia as well. However, at West Frisian sites, no barn part of the house could be identified based on clear stable partitions. Roessingh (2014, 74) has indicated that if the presence of a barn is to be presumed in West Frisian houses, it should be located in the eastern part of the house. This theory is based on certain differences in the layout of the house plan and house ditches of some houses at Bovenkarspel.

To investigate what other possibilities for barns may have existed, examples of a different barn layout is presented here from Danish houses dating to the Iron Age. Here, five burnt farms were uncovered in different areas of northern Jutland (Kveiborg 2009a-f). These farms were preserved under exceptional

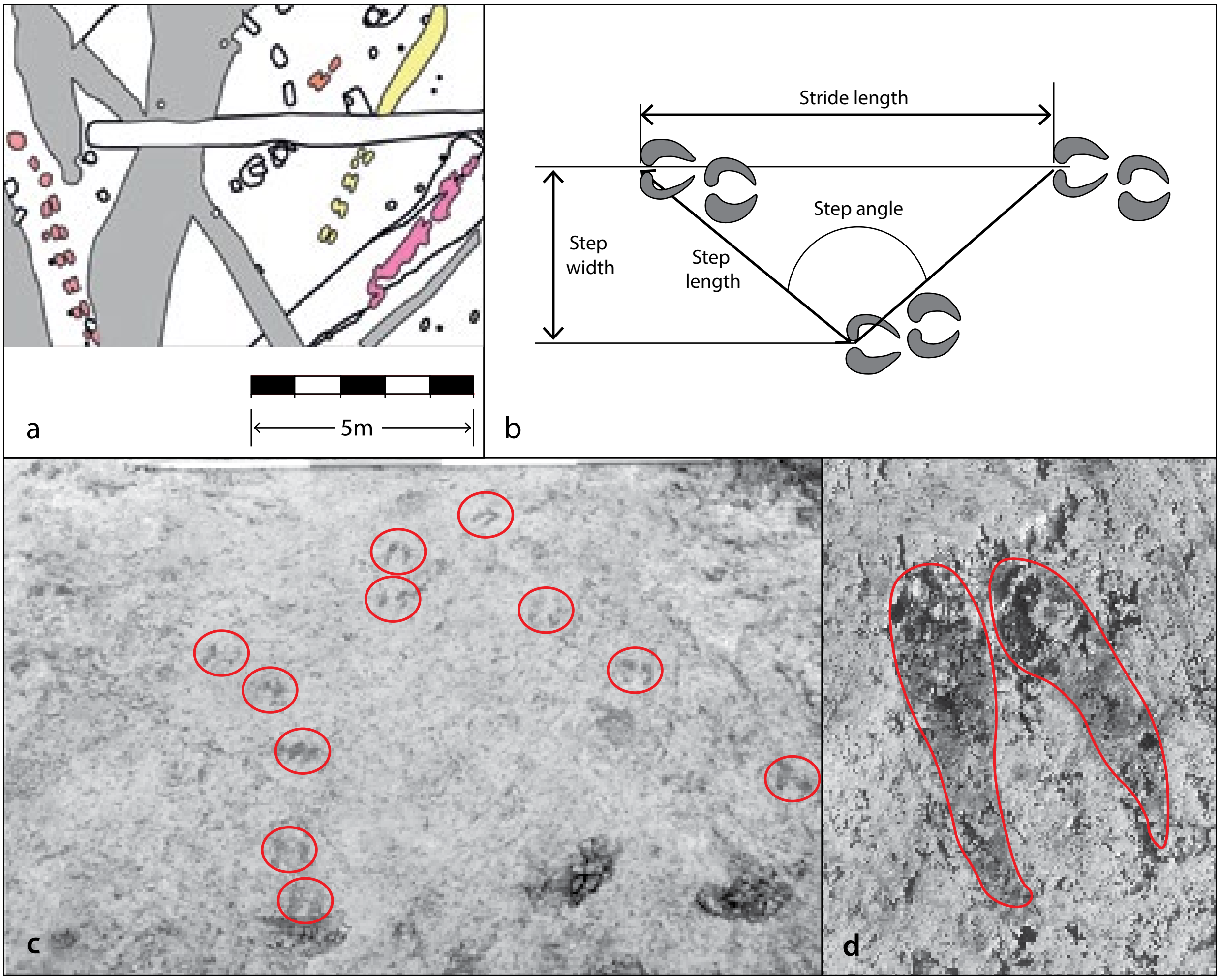
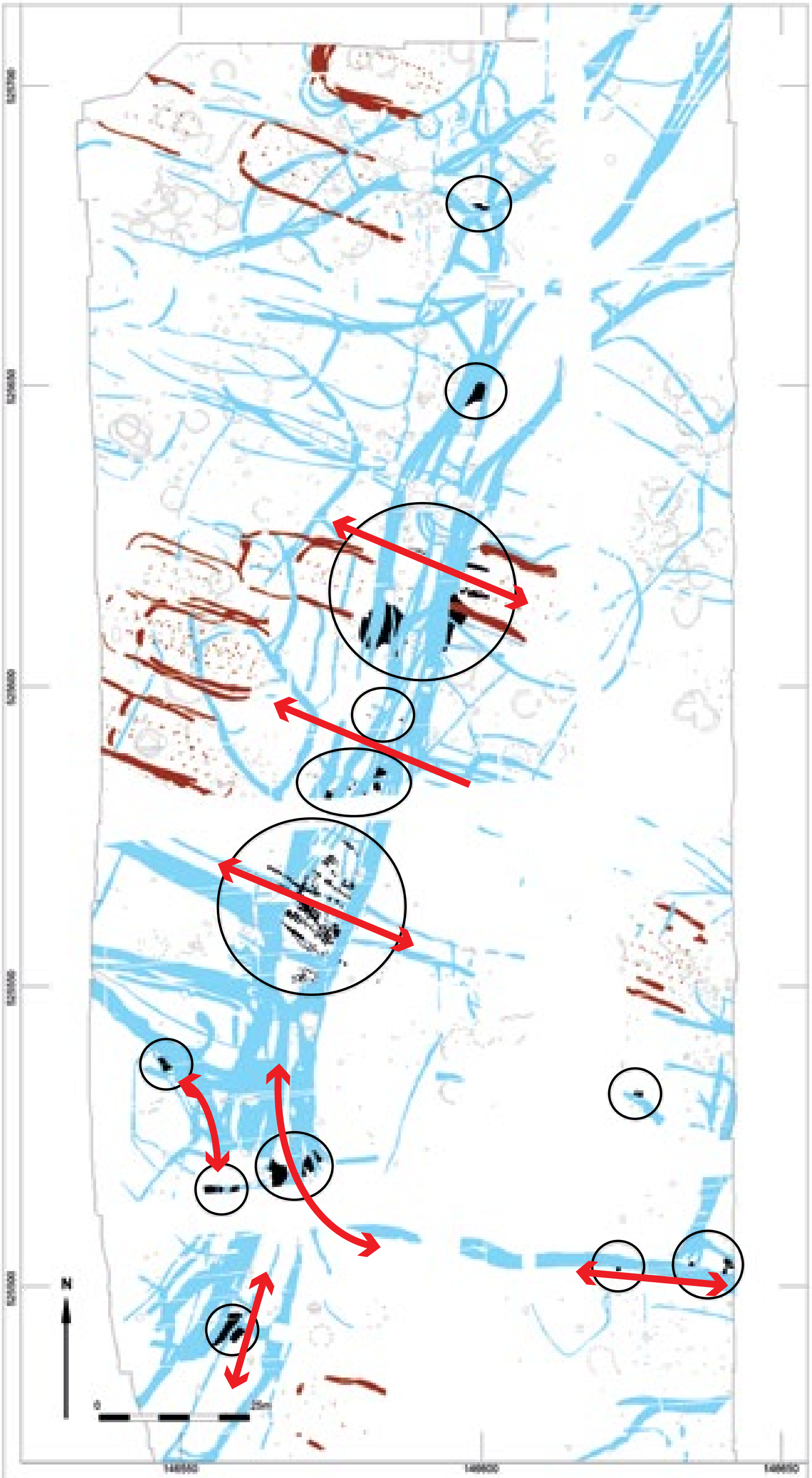


Figure 5.29. Examples of possible and actual track ways of cattle. a. Example of a postulated track way of cattle hoof prints in Medemblik Schepenwijk II; b. Zigzag pattern of an actual cattle gait (after: Telezhenko 2009); c. Overview of a track way of cattle hoof prints (red circles) preserved in the soil at Hoogkarspel; d. close-up of a cattle hoof print (red outline) preserved in the soil at Hoogkarspel.

circumstances, and still contained the remains of the domestic animals that were present in the house during time the farms burnt down. One of the best preserved examples is a burnt farm dating to the Danish pre-Roman Iron Age (600 BC-100 AD), found at Nørre Tranders, near Aalborg (Kveiborg 2009a). On this farm, animals that died during the fire were more or less still situated in their original positions in the barn and their age and sex could often still be established. From this information from the report on Nørre Tranders, the layout of the barn could be reconstructed (Figure 5.32).

No evidence was found for separating structures for the animals in the house plans of any of the burnt farms, even though many different animal species were kept together (Kveiborg 2009a-f). Clearly, the presence of stable divisions in house plans is not a requirement for the presence of a barn. A different separating structure was however, discovered near the sheep in the Nørre Tranders farm. Remains of wicker made from willow twigs was discovered, which might have formed a separate holding pen for sheep within the barn (Kveiborg 2009a, 26). Cattle and horses may have been restrained in another manner, evidence of which was uncovered


N

at the burnt farms of Siggård, Brøndlund and Ginderup (Kveiborg 2009b; 2009d; 2009e). Here, stakes, binding rope and a rope head halter (Figure 5.33, Figure 5.34) were uncovered (Kjaer 1930, fig 9; Christensen *et al.* 2007: fig. 11; Kveiborg 2009b; 2009d, 14; Kveiborg 2009e), and some rope near the skull of cattle (Kveiborg 2009b, 9-10, fig 5), indicating that animals were restrained with rope (cf. Figure 5.35) by tying them to a pole, facing the wall (Kveiborg 2009d, 14). Although Brøndlund and Ginderup date to the early Roman Iron Age (100-200 AD), the finds from Siggård, from the Danish Pre-Roman Iron Age, show that this kind of restraining procedure was already applied in prehistory.

This example shows that a barn section of a house cannot necessarily be identified by features within a house plan. The mixed-species aspect of this barn, as well as from the other burnt houses furthermore signifies that barn space should not be directly translated into numbers of cattle kept (cf. Waterbolk 1974; IJzereef 1981). Clearly, only a part of the herds is kept inside, of which valuable and vulnerable animals seem to form the majority.

Although the Danish examples do not date to the Bronze Age, they do indicate that a barn is not necessarily recognisable through features, and that multiple animal species can be kept inside together, which mostly consist of vulnerable and valuable animals.
Therefore, these aspects of animal husbandry are assumed as options for the West Frisian situation as well.

Nutrition and related locations

Grazing requirements for cattle

The calculation of cattle herd grazing requirements was based on the average herd size of households based on ethnographic parallels (*i.e.* 5-8 cattle), since no original herd size could be reconstructed based on the archaeozoological data. For this calculation, Table 5.3 was employed for two grazing scenarios: cattle grazed on grassland pasture only, or on 2/3 grassland and 1/3 woodland pasture (in terms of nutrition, not size)

On the left: Figure 5.30. Overview of the locations of cattle hoof prints at Enkhuizen Haling and Kadijken. Light blue fill: ditches; dark brown fill: house context; black fill: cattle hoof prints; black outline: concentration of cattle prints; red arrows: general directions of movement across the settlement based on the orientation of the prints.

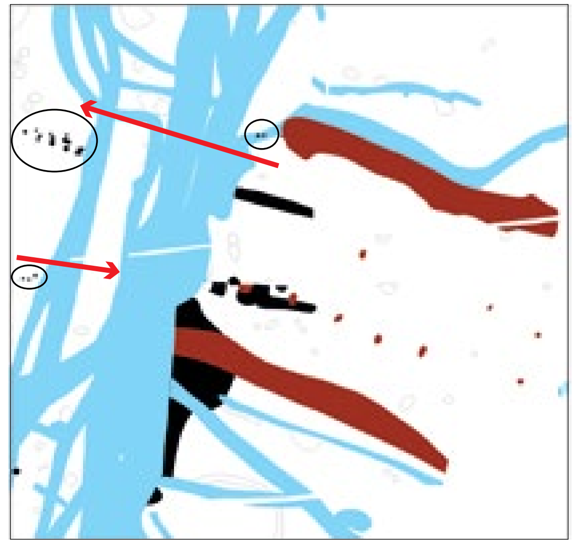


Figure 5.31. Detail of the excavated site of Enkhuizen Haling. Blue fill: ditches; dark brown fill: house context; black fill: cattle hoof prints; black circle: clear cattle prints with a direction; red arrows: general directions of movement across the settlement based on the orientation of the prints.

(Appendix A1.8). Grazing on grassland pasture only results in 4.0-6.4 ha of grassland required per household. Grazing on both grassland and woodland pasture results in 16.0-25.6 (!) ha of pasture, consisting of 2.8-4.5 ha of grassland pasture and 13.2-21.1 ha of woodland pasture required per household (Appendix A1.8). It is clear that the latter demands for pasture requirements are very high for one household, let alone a settlement. Therefore, it is assumed that cattle either grazed solely on grassland pasture or, that if woodland pasture was grazed, it formed a very small contribution to their diet.

Location of pastures

No direct indications for the location of pastures with respect to the settlements were identified. However, the vegetation reconstruction (Chapter 2, section 2.3.3) does indicate that people were probably maintaining an open landscape through grazing practices on the driest parts of the surroundings of the settlement. The use of paddocks may have complemented these practices, although it is unknown how the different animal species were divided between the different grazing areas.

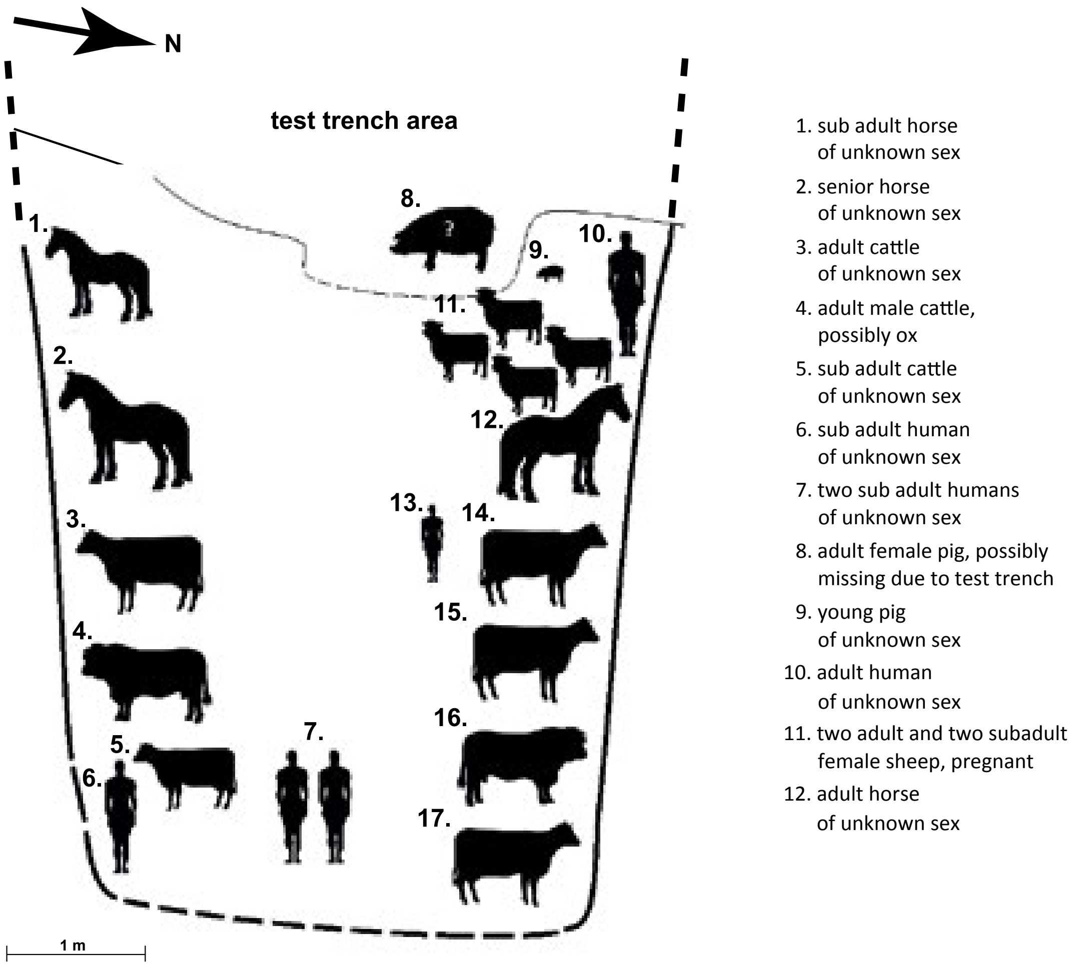


Figure 5.32. Reconstructed barn lay-out of the burnt farm at Nørre Tranders, Jutland, Denmark (after: Kveiborg 2009a). No evidence for separating structures for the animals were found, nor any restraining poles. Near the sheep, wicker made from willow twigs was discovered, which might have formed a separate holding pen within the stable. Many of the animals are pregnant or with young, so it is supposed that the house burnt down in late winter/early spring. The western part of the house is missing due to previous excavations.

Fodder

No clear indications for fodder were uncovered in West Frisia. However, few finds of charred straw and small twigs by Buurman (1996) indicate that cereal straw (most likely barley, see Chapter 6, section 6.3.3), hay from meadows, or leaf fodder could have been collected for the animals kept inside during winter. In addition, the possible presence of extensively managed pasture or meadow has also been indicated by the presence of particular cultivated landscape-related bird species in West Frisia, which prefer these types of grassland for nesting (Chapter 2, section 2.4.5.3).

Seasonality

No definitive indications for seasonal animal husbandry practices were found in West Frisia. However, the restriction in day-light at the latitude at which West Frisia is located will have caused cattle to breed in autumn and give birth in spring. Therefore, the seasonality information from Table 5.4 is also assumed for West Frisian cattle. The Danish examples of burnt farms furthermore, are used as an indication that only some animals were kept inside in winter (Kveiborg 2009a, 26; Kveiborg 2009d, 15) and that these animals

Figure 5.33. Binding rope (within red circle) uncovered at Siggård, Jutland, Denmark (adapted from: Kveiborg 2009b, Figure 5).

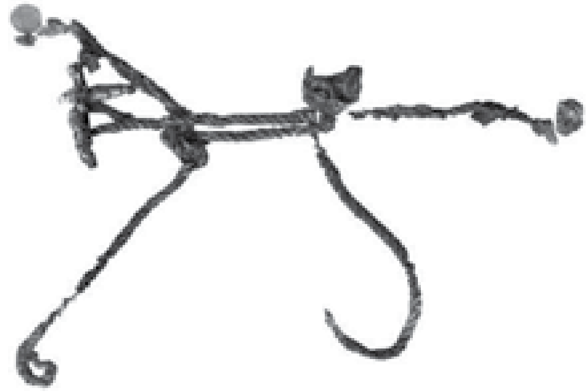


Figure 5.34. Halter made from rope for restraining cattle, uncovered at Ginderup, Jutland, Denmark, scale 1:7. © Den Store Danske and Nationalmuseet.

were mostly the valuable and vulnerable individuals. The rest of the herd will have remained outside during this time of year.

5.4.4 Sheep and goat

Sheep remains are uncovered less often than cattle remains, so only relevant sections for which information was obtained are discussed for these domestic animal species. Due to the great similarities in bones, sheep and goat cannot usually be distinguished based on bone remains in the archaeological record. Therefore, they are in some instances combined for analysis as sheep/goat.

Herd size and composition

Herd size

The MNI of sheep/goat was calculated to assess the rough size of the herd based on the data of Bovenkarspel. The resulting MNI value was 0.2 sheep being culled each year. Such low numbers of sheep culled could indeed be a reflection of practice, but it must be kept in mind that sieving was not performed systematically at Bovenkarspel, which means sheep will have been under-represented at this site. Therefore, the actual number of animals culled each year will have been higher. Nevertheless, this low number of sheep again indicate a small herd size. Due to similar reasons as for cattle, the expected herd size per household based on ethnographic parallels for sheep/goat (5-15 sheep/goat) is employed for further calculations. Since goat is only identified with certainty at low frequencies, it is assumed that goats comprised 25% of the sheep/goat herd.

Figure 5.35. Modern example of cattle restrained in a rope halter (Anscitech 2016).

Age differentiation

The age ratios of sheep/goat were investigated by employing the age data obtained from dental information (cf. Hambleton 1999). To assess whether ravaging had had an effect on the assemblage, the ravaging ratio was calculated (Munson 2000; section 5.4.2/Appendix A1.8). However, the resulting value lay outside the ravaging range, so no ravaging correction was applied

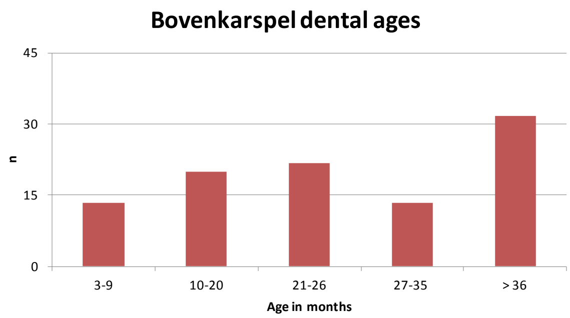


Figure 5.36. Age data of Bovenkarspel sheep/goat based on dental remains from the entire Bronze Age; n=60.

to the dental data. Again, only Bovenkarspel yielded considerable amounts of data for interpretation (Figure 5.36). For sheep/goat, the Middle and Late Bronze Age mandibles used for age determination by IJzereef were not distinguishable based on the old data. Therefore, an overview for the entire Bronze Age is provided.

Based on Figure 5.36, most sheep/goats appear to have died between 1-2 years or after reaching more than 36 months of age. Furthermore, percentages of all age categories fall within the expected mortality ranges for sheep/goat in small-scale mixed subsistence communities. Young animals are often culled before 12-24 months of age (cf. section 5.4.3; Cribb 1985; Cribb 1987; Munson 2000, 395-6), and older animals are usually culled for reasons of poor productivity, disease, or old age (cf. section 5.3.2).

The sheep/goat age mortality profile could also be reconstructed for both the Middle and Late Bronze Age of Bovenkarspel with the aid of Faustitas, the results of which are shown in Figure 5.37 and Figure 5.38. Note that in sheep/goat post-cranial bone data, only a differentiation in ages from zero to older than two years can be distinguished..

In the Middle Bronze Age, in general, the mortality is relatively equally distributed between age groups, but most animals appear to be culled between 1 and 2 years. In the Late Bronze Age, this age group increases, signifying higher mortality of immature animals at the expense of youngstock.

When dental and post-cranial data are compared, it is clear that animals between 12 and 24 months of age were culled most. In the post-cranial data however, the higher number of deceased older animals observed in the dental data was not confirmed.

Similar to cattle, it was unknown whether mortality profiles were representative of the original living herd, which could greatly influence subsequent interpretation. Therefore, the mortality profiles of Figure 5.37 and Figure 5.38 were translated into living herds with Faustitas (Figure 5.39, Figure 5.40). From Figure 5.39 and Figure 5.40 it can be deduced that for both the Middle and Late Bronze Age, living herd compositions for sheep/goat are very similar. Furthermore, the West Frisian herds, hardly differ from the expected values based on the ethnographic parallels. It seems, based on these age examples, that animal husbandry practices regarding sheep and goat remained constant between the Middle and Late Bronze Age periods in West Frisia.

Sex differentiation

Sheep/goat sex determination was performed based on 25 horn-cores from Bovenkarspel (IJzereef 1981, 95), the results of which are summarized in Figure 5.41 (left). The resulting male proportion of the herd was 36,0%, which far exceeded the expected 10,8% based on ethnographic parallels (Figure 5.41 (right)). In the section on use below, it was established that sheep/goat mortality profiles are, similar to cattle, not representative of the original living herd, since uses of sheep in West Frisia are not principally meat-oriented (*i.e.* attritional mortality profiles). Therefore, the results from Figure 5.40 are not representative of the original herd, but rather of people's selections from the original herd (cf. section 5.4.1.3; Figure 5.25). Indeed, it is very possible that relatively more males were selected to be removed from the herd, which is a common animal husbandry practice, rather than that the original herd consisted of a high proportion of males.

Therefore, for further interpretation, the ratios observed in the ethnographic parallels are employed. The presence of wethers could not be established.

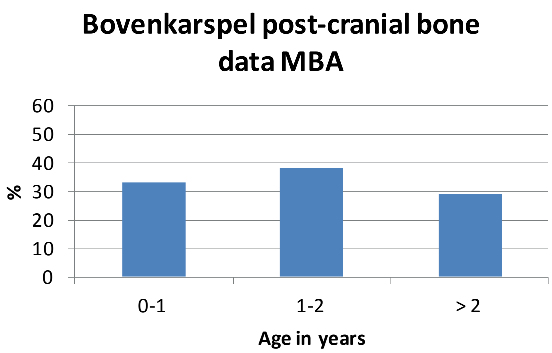


Figure 5.37. Middle Bronze Age mortality profile of sheep/goat from Bovenkarspel; n=108

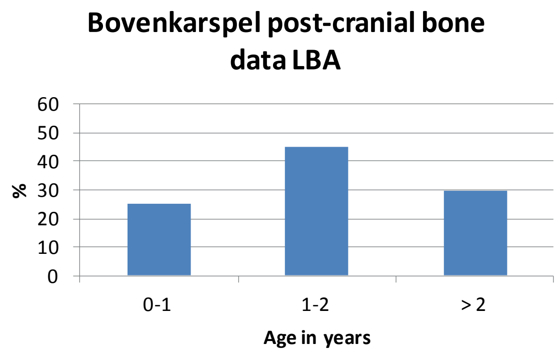


Figure 5.38. Late Bronze Age mortality profile of sheep/goat from Bovenkarspel; n=112.

(In)breeding

Inbreeding

Inbreeding indications could not be established based on external characteristics of bone material, but strontium isotopes have revealed information which could be related to inbreeding in an indirect manner. Six mandibles of sheep/goat were analysed in order to establish whether they were local or imported. One Late Bronze Age sheep/goat sample contained a non-local signal (Brusgaard 2014), which belonged to a sheep or goat of more than 2-3 years. Again, although animals may not have been imported specifically for inbreeding, the action in itself will have resulted in a more genetically diverse gene pool and therefore a lowering of the chance of the occurrence of inbreeding.

Breeding

Birth and growth rate of sheep/goat herd were established with the simulation of both the Middle and Late Bronze Age data from Bovenkarspel by Faustitas (Figure 5.42).

For both periods, sheep/goat herds seems to experience a relatively high annual growth rate of 1.16-1.17, or 16-17%. The birth rate was equally high at 1.13, which may be linked to the occurrence of twin births of animals. Clearly, Bronze Age people were able to sustain healthy sheep/goat herds throughout the Bronze Age regardless of environmental changes. The high growth and birth rate observed (*i.e.* overstocking) will have allowed Bronze Age farmers to overcome annual losses, due to for example liver fluke disease (Appendix A1.6), without severe impact on the long-term viability of the herd.

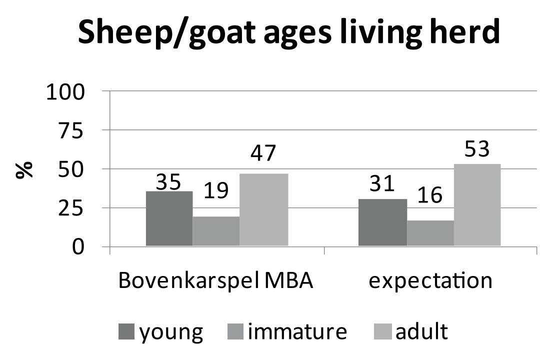


Figure 5.39. Middle Bronze Age living sheep/goat herd composition comparison between reconstructed West Frisian data (left) and ethnographic parallels (right). Young: 0-1 year; immature: 1-2 years; adult: > 2 years.

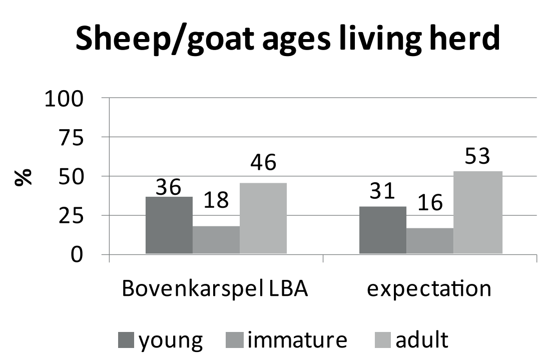


Figure 5.40. Late Bronze Age living sheep/goat herd composition comparison between reconstructed West Frisian data (left) and ethnographic parallels (right). Young: 0-1 year; immature: 1-2 years; adult: > 2 years.

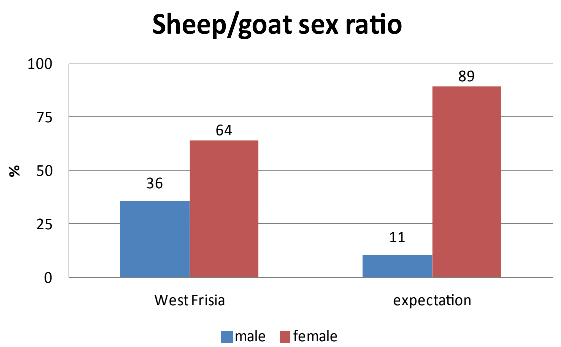


Figure 5.41. Sheep/goat herd sex composition comparison between reconstructed West Frisian data (left) and expected values based on ethnographic parallels (right).

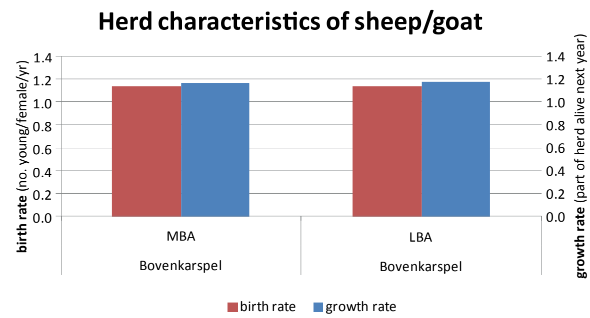


Figure 5.42. Birth and growth rate data of sheep/goat from Bovenkarspel for the Middle and Late Bronze Age. Birth rate indicates the number of young born per female per year and growth rate indicates the annual growth of the herd. Growth rate values higher than one indicate an increase of the herd, whereas a value lower than one indicates a decrease.

Breeds

Sheep can be characterised as small, horned sheep (Appendix A1.5). However, variation in horns exist, which may be interpreted as either sex differences or perhaps also difference in breeds. Especially the import of sheep/goat from other areas of the Netherlands during this time will have resulted in a local mixed flock of varying body types as well as horn size and shape.

Use

West Frisian sheep/goat herds were analysed for their potential for meat, milk, and wool production using Faustitas. Both Middle and Late Bronze Age Bovenkarspel data was employed for this purpose (Figure 5.43).

Both Bronze Age periods show that the potential of sheep/goat herds for different uses is relatively high, but that no clear specialisation towards a specific use is apparent. Wool production in particular has the lowest potential for these herds, signifying the importance of healthy herds to West Frisian people, rather than a lean towards a certain use not related to consumption resulting in an unhealthy herd composition. Mirroring the results for cattle, sheep/goats seem to have been kept for more than one purpose, which could all have been exploited on a moderate basis.

Other archaeological indication for use of sheep/goat
The general indications for using sheep/goat meat and milk are comparable to those for cattle (section 5.4.3). Sheep however, can also be exploited for wool, which is further elaborated upon in section 5.4.7.4.

Handling and related locations

Handling of sheep or goats or locations related to such practices were not observed in West Frisia. However, the Danish burnt Bronze Age farms do seem to indicate that pregnant sheep may have been kept inside a separate structure in the barn section of the house during winter months (Figure 5.32), so this is assumed for West Frisia as well.

Nutrition and related locations

Grazing requirements for sheep/goat

Sheep and goat grazing requirements were calculated with the use of Table 5.3 based on the average herd size of sheep/goats assumed on the ethnographic parallels (*i.e* 5-15 sheep/goat). An additional assumption was made that goats comprised 25% of the herd, since goats are less often identified in West Frisian bone assemblages than sheep. Sheep are assumed to graze on grass only. Due to the browsing nature of goats, it is assumed they require woodland pasture in their diet, so the assumed 2/3 grassland, 1/3 woodland ratio (in terms of nutrition, not size) was employed.

Based on this input, households would require either 0.8-2.3 ha of grassland for sheep, and 1.5-4.5 ha of combined grassland and woodland pasture for goats (Appendix A1.8).

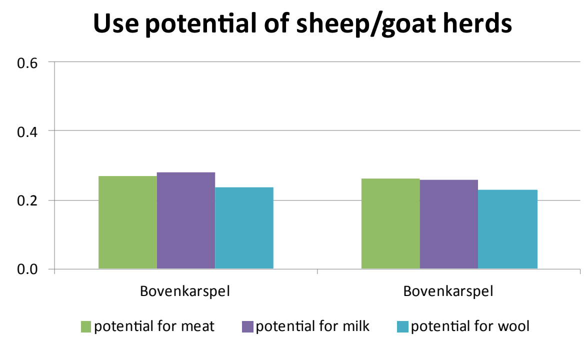


Figure 5.43. Potential of West Frisian sheep/goat flocks for meat, milk, and wool production. Use potential is a relative value to evaluate the production potential of a herd for different uses (cf. Cribb 1985). The higher the value, the higher the potential.

Location of pastures

Similar arguments for the presence of pastures in the surroundings of the settlement exist for sheep/ goat as for cattle.

Fodder

No definitive indications for the use of fodder were observed. Again, as for cattle, both straw, hay and leaf fodder could have been collected for animals kept inside during winter.

Seasonality

Information on the seasonality of sheep and goats behaviour is employed from Table 5.4. Overview of the breeding and birthing seasons of livestock species. Furthermore, similar to cattle, vulnerable individuals of sheep/goat will most likely have been kept inside during winter months to protect them from weather conditions and predators.

5.4.5 Pig, dog, and horse

Limited information was available for pig, dog, and horse in the West Frisian bone data. Therefore, only a limited number of subjects is discussed in this section.

Herd size and composition

The number of pig bones was too low to allow for a discussion on herd size, so the average number of pigs kept in small-scale farming communities in West Frisia is assumed to be three pigs.

The data on age differentiation based on post-cranial pig bones was also too limited, but a total amount of 31 canines allowed for a differentiation in sex (Figure 5.44 (left)), which was compared to the expected sex ratios (Figure 5.44 (right)).

Interestingly, since it is assumed that pigs are principally kept for meat purposes, the mortality profile should in this case actually resemble the composition of the living herd, so values can be compared to the expectation. Pig herds in West Frisia appear to have consisted of around 32% males based on canine data, which is less than the expected average value shown in Figure 5.44. However, the number of males in a pig herd can vary widely (section 5.3.1), so these values could still reflect small-scale animal husbandry pig herds. West Frisian pig herds would thus have been small and consisted of relatively many males.

(In)breeding

Breeding of pigs may have occurred through inter-mixing with wild boar populations, considering the close resemblance of most of the domestic pig bones with their wild counterparts (IJzereef 1981, 81; Appendix A1.5). This constant supply of new genes from wild populations would have ensured a greatly reduced risk of inbreeding, which would normally be very high when such low numbers of pig are kept on a settlement. Baeté and Vandekerkhove similarly indicated the occurrence of such practices in the Middle Ages, whereby female domesticated pigs in heat were tied to a tree, in the hope of being impregnated by male wild boars. Male domestic pigs however, were kept at the settlement, preventing the interbreeding with wild female boars (Baeté & Vandekerkhove 2001, 9). An example of such a pig husbandry practice was also witnessed by the author in the Danube delta in Romania, where "domestic piglets", which roamed freely outside settlements with domestic females, (partly) possessed the characteristic stripe pattern of wild boar piglets (Appendix A1.5).

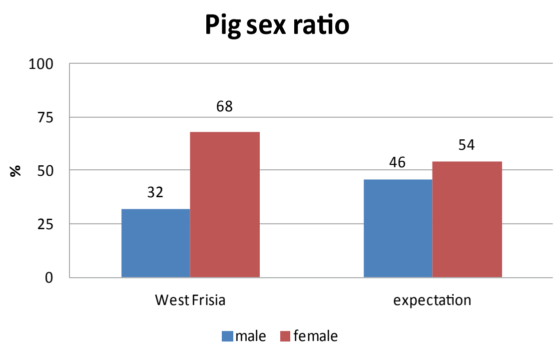


Figure 5.44. Pig herd sex composition comparison between reconstructed West Frisian data (left) and expected values based on ethnographic parallels (right).

Breeds

Dogs at Bovenkarspel and Andijk appear to have been of varying size (withers height of 48-65 cm; IJzereef 1981, 107; Mensch and IJzereef 1975), indicating a possible variation in breed or function. Horse remains were uncovered in such low amounts that a discussion on the existence of different breeds was not possible.

Use

Pig, dog, and horse bones have all been shown to contain slaughter marks (*e.g.* Groot 2010a: 96, 101), indicating that all domestic animals were consumed by Bronze Age people. Other uses for these animals are discussed in section 5.4.7.4.

Handling and related locations

No clear indications for handling of pig, dog or horse have been established at the West Frisian sites, and neither have locations related to handling.

Nutrition and related locations

Grazing requirements for horse

Food for dogs and pigs is assumed to have either been supplied on the settlement by people, or obtained by the animals themselves whilst roaming the surroundings of the settlement.

Horses may have grazed on pasture, of which the requirements were calculated in a similar manner as for cattle and sheep/goat. Due to horses being very scarce in West Frisia, it was assumed that a household possessed one horse at most. One horse would require on average 1.0 ha of grassland pasture (Appendix A1.8).

Location of pastures

Similar arguments to those for cattle for the presence of pastures in the surroundings of the settlement exist for pigs and horse.

Fodder

No indications for the use of fodder were identified for pig, dog, or horse. Still, pigs may have been fed a variety of food available on the settlement, and may even have included fish (van Loon 1978, 127-8).

Seasonality

Seasonality information for pig behaviour was copied from Table 5.4 for West Frisia. Dog and horse will not be discussed further.

5.4.6 Summary

The analysis of the domestic animal species of West Frisia (with Faustitas) has provided several indications for how animal husbandry might have been organised in the Bronze Age.

The size of the herds was limited, with age and sex ratios within the herds concurrent with what is expected from small-scale mixed subsistence farms. The number of animals in one household would have been 5-8 cattle, 5-15 sheep/goat (25% goat), 3 pigs, and 1 horse.

Inbreeding was theoretically not expected to have been a problem in West Frisian societies, based on the assumption that exchange of (male) animals would occur on a regular basis. Indications of inbreeding on many cattle skulls has however shown that inbreeding was occurring, probably due to the lack of regular exchange of animals.

Cattle birth and growth rates in the Middle Bronze Age reflect a healthy herd. In the Late Bronze Age, animal husbandry practices related to cattle might have changed, since herds begin to show unhealthy characteristics such as unbalanced birth and growth rates. Sheep/goats do show very healthy birth and growth rates throughout the Middle and Late Bronze Age. Both values are so high, that they may be interpreted as overstocking, which is usually practiced by farmers to anticipate potential losses due to for example disease or predation.

Throughout the Bronze Age, no specialisation of herds was identified, and the probable exploitation of both meat and milk could be based on other archaeological indications besides bone material.

Handling locations of animals in general could not be identified, due to the absence of recognisable barn structures or other handling-related structures. However, burnt farms in Denmark revealed a possible housing system for animals which is not reflected in a house plan. Multiple species of animals may have been housed within the same barn, by tying animals to the wall or making separate wattle-work partitions. Additionally, these burnt barns have provided insight into the composition of the animals kept inside as well as seasonality; vulnerable and valuable animals would have been kept inside, at least during winter months.

Grazing requirements of domestic animals were calculated for grassland and a combination of grassland and woodland pasture. The total amount of hectares required per household based on all animal species would have varied from 6.1-10.8 ha of grassland pasture, or, alternatively, 7.3-14.2 ha of pasture (consisting of 6.0-10.5 ha grassland and 1.3-3.7 ha woodland), which thus includes the required woodland pasture for goat.

5.4.7 Discussion

In this section, methodological and taphonomical effects already shortly discussed in other sections are summarized and discussed. Subsequently, the possible selection criteria people may have had for consumption are treated, followed by an overview of other reasons for keeping domestic animals besides for direct consumption purposes.

5.4.7.1 Methodology

The interpretation of past uses of animals and animal husbandry practices is mainly dependent on ratios between animal species as well as age and sex ratios of herds. In section 5.4.1.1 and 5.4.1.2, problems have been identified regarding the analysis of ratios of domestic animal species at a site. First of all, only the numbers of bones should be used for inter-site comparisons. Secondly, a sieving experiment should be employed to assess the loss of animal species when only hand-collecting is performed during excavation.

Methodological aspects of archaeozoological and zooarchaeological research related to the age ratios of herds have been discussed at length in the article on Faustitas (section 5.4.2/Appendix A1.7). In this article, it was made apparent that current methods usually applied in zooarchaeology, those of Chaplin (1971) and Payne (1973), are not valid to interpret past herds and herd use based on their flawed assumptions, application, and subsequent interpretation of bone material.

The representativeness of mortality profiles in general needs to be assessed before subsequent interpretation of the living herd commences, because it is dependent on the use of the domestic animal herd. When animals are not primarily kept for meat production, the resulting mortality profile will not reflect the living population. This living population should be simulated in order to assess living herd composition as well as other herd characteristics (section 5.4.1.3).

Section 5.4.1 and section 5.4.2 in general have shown the inadequacy of zooarchaeological methods, which should, and sometimes already are in this thesis, improved for the interpretation of past animal husbandry practices.

5.4.7.2 Taphonomy

Taphonomical processes have had an effect on West Frisian bone assemblages, even though general preservation conditions are excellent. These effects need to be taken into consideration before interpretation of bone material is undertaken. Most

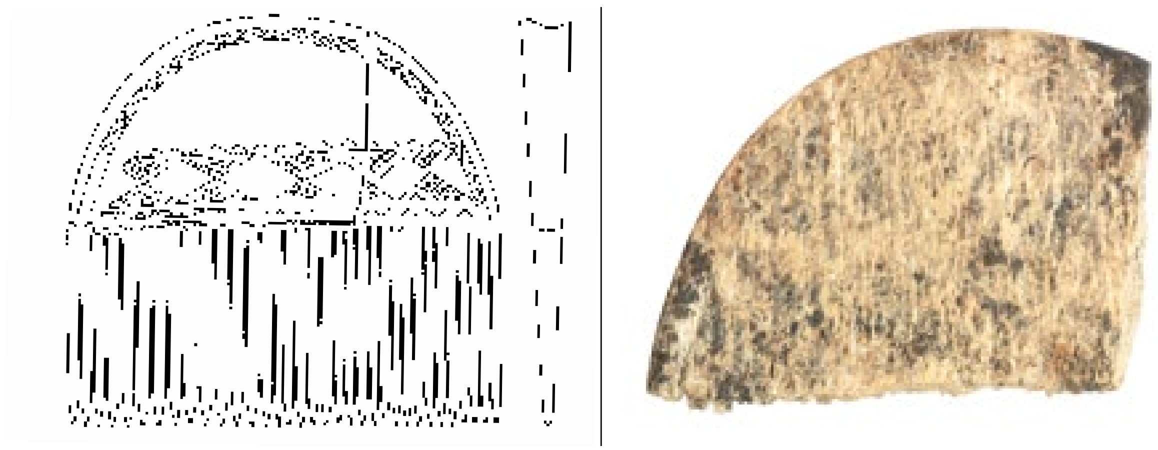


Figure 5.45. Bone comb uncovered at Bovenkarspel. a. drawing of the comb: the top left part of the comb is what is actually found, the rest is a reconstruction (from: IJzereef 1981, 139, fig. 86); b. photo of the comb (courtesy of: Archeologisch Depot Noord-Holland).

taphonomical effects have been discussed in the article on Faustitas (section 5.4.2/Appendix A1.7), and relate to the fact that young animals are almost always under-represented in faunal assemblages (Munson 2000). Although Faustitas does incorporate a correction for taphonomical processes related to ravaging, it must be kept in mind that other taphonomical processes cannot be so easily identified or corrected for. Therefore, some biases may always still be present in the data and caution is advised when interpreting datasets.

Changes observed between time periods should therefore also be cautiously interpreted, since results may have been derived from post-depositional processes rather than conscious past practices by Bronze Age people.

5.4.7.3 Possible selection criteria for consumption

All the domestic animals show signs of slaughter and therefore consumption. Clearly no taboos existed on the consumption of any of these animals.

5.4.7.4 Other reasons for animal husbandry

It is assumed that pig had no further purpose besides consumption. Therefore, it is not discussed in this section.

Cattle

A main reason for keeping cattle besides for consumption is traction. A pair of cattle of varying composition can be used to pull the plough on arable fields or carts for transport.

Possible indications for cattle being kept for this purpose were identified at three West Frisian sites, and derived from pathological deformations of metatarsal bone and pelvis, which are the result of heavy labour (*i.e.* arthritis; IJzereef 1981, 76; Groot 2010a, 98; Zeiler & Brinkhuizen 2011, 199).

Another important aspect of keeping cattle can be to use dung as manure to fertilize arable fields. Manuring has indeed been established for West Frisian soils (Chapter 6; Appendix A1.11), and cattle dung may very well have been applied to arable fields in combination with other types of fertilizer.

Animal manure, or dung, has also been postulated as a possible source of fuel for West Frisia (*e.g.* Buurman 1996, 143-5; Roessingh & Lohof 2011). Buurman has indicated several examples of people living in temperate regions who produced dung cakes, such as in the Orkneys, Scotland, Denmark, Northern England, Ireland, Iceland, and northern Germany (Buurman 1996, 143-5). They would dry dung using sunlight in summer, spreading it out in thin layers out on the grass. In northern Germany, in the terp area, people dried their dung on the southern side of the terp, without the use of fire. However, in contrast to the regions mentioned by Buurman, in West Frisia ample trees were available for firewood in West Frisia (Chapter 2), so fuel sources were not scarce. Under these circumstances, as far as the author knows, people do not normally resort to the effort of making dung cakes.

However, in several instances, burnt dung was found in West Frisia, and analysis has shown that it had been heated to around 1000-1400°C (van Kappel & Exaltus 2011). Since this is a very high temperature, it was postulated that the burnt dung uncovered in West Frisia was the result of lightning (Thy *et al.* 1995). However, the frequency with which burnt dung is uncovered, makes such an explanation very unlikely (pers. comm. H. Huisman).

In the Late Bronze Age, many of these pieces of burnt dung were also uncovered. If fewer trees were present in the surroundings in this period, the need for dung fuel may have increased, but charred wood remains from this period indicate that wood could still have been used for fuel (Chapter 2, section 2.3.2). It appears that wood fuel and dung fuel were used concurrently in both periods.

Keeping cattle for hides is also a possibility, and the finds of cattle hides in Bronze Age Danish burials (Hvass 2000) signifies the potential importance of this material for people during this time.

Finally, many tools made from cattle bone have been uncovered at all West Frisian sites, indicating that even after/besides consumption, cattle remains were used to aid subsistence. Objects include shovel heads, hammers, chisels, grinding tools, etc. (IJzereef 1981, Chapter 5). One example of bone working could even be related to personal grooming, since a bone comb with elaborate decoration was uncovered at Bovenkarspel (Figure 5.45; IJzereef 1981, 139).

Other reasons for keeping cattle, such as for prestige, status, or ritual/religious reasons, although not denied, are not further discussed here.

Sheep/goat

Sheep can provide wool, and although they were not kept especially for this purpose in West Frisia (section 5.4.4), seasonal exploitation of plucking wool from sheep could have provided the wool required to produce garments. An example of a woollen garment dating to the Bronze age was uncovered on a bog body in the Emmer-Erfscheiden bog in Drenthe, the Netherlands (Vons-Comis 1990). The additional finds of Bronze Age balls of yarn in this same bog indicate that people were indeed manufacturing woollen garments during this time in the Netherlands. No textiles have been discovered so far in West Frisia. However, the existence of required techniques, raw material, and finished garments in areas where West Frisian sheep were also most likely imported from, indicates that wool may very well have been used for textile production in West Frisia as well.

In addition, sheep dung can be an excellent fertilizer, which may also have been used in West Frisia. Finally, sheep bone has in many instances been formed into tools such as awls, needles, and chisels, which have been identified at many West Frisian sites (*e.g.* IJzereef 1981, Chapter 5), again indicating that providing meat is not an animal's final use.

Dog

Dogs may have been kept for multiple reasons. In chapter 4, it was already postulated that dogs may have been kept as hunting dogs. Alternatively, dogs may have been kept as shepherding dogs, guard dogs, companions, etc. The size difference of dogs observed at both Bovenkarspel and Andijk seems to suggest that different dogs may have been kept for different functions (section 5.4.5), possibly encompassing all the uses discussed here.

Horse

Horses may have been kept for riding or traction purposes. Although the horse collar was not invented until much later in history, the presence of Bronze Age red deer antler bridles in Denmark and several bridles and Middle and Late Bronze Age bronze horse bridle-bits from south-western Germany and Switzerland, as indicated in section 5.3.3 (Figure 5.8) seems to suggest that using horses for transport or traction may very well already have been possible during this time (Nyegaard 1983, 33-5). Again, other reasons for keeping horses, such as for prestige, status, or ritual/religious reasons, although not denied, are not further discussed here.

5.5 RECONSTRUCTION OF ANIMAL HUSBANDRY

In this chapter, the current view on animal husbandry in the West Frisian Bronze Age was challenged by re-analyzing and re-interpreting the old and new available archaeozoological data. The contribution of the different proxies used to achieve this as well as the general approach in this chapter are outlined below. Subsequently, the results from the analysis of the West Frisian data are compared to the main components of the current model to assess whether it is still a valid model to describe the West Frisian Bronze Age situation (section 5.5.2). Finally, components of the current model which do not comply with the new results are re-formulated and combined into a new model for animal husbandry in West Frisia (section 5.5.3).

5.5.1 Contributions of proxies and approach to the reconstruction of animal husbandry

Ethnographical information has formed a valuable source for the identification of different animal husbandry practices which remain consistent within small-scale mixed subsistence farming communities regardless of geography, time period, or climate. Furthermore, the discipline of biology has provided information on the genetics of inbreeding and the minimum size of herds required to sustain a healthy herd that is viable on the long-term. The creation of an expectation of the effects of inbreeding and the chance of it occurring in West Frisia has allowed for a detailed understanding of breeding practices in the Bronze Age. Birthing, breeding, and grazing behaviour of domestic animals has additionally allowed for the analysis of seasonality of main animal husbandry practices, as well as grazing requirements. Through these analyses more insight was gained into how, when and where animal husbandry practices were taking place.

Biochemical studies, including aDNA and teeth calculus analyses, have provided evidence for the consumption of milk in the Bronze Age, and isotopic analyses on strontium and nitrogen isotopes have indicated the import of animals and use of manure, respectively. The results of these studies therefore show the ability to digest ruminant milk and the use of animals for milk and manure production. The import of animals suggests long-distance relations with areas to the east of West Frisia. Archaeological finds, such as ceramics, a horse bridle, and woollen artefacts, are extra indications for the uses of animals for milk consumption, traction, and textile production, respectively.
Statistics finally, has provided a means to develop a new and improved method to analyse the multi-faceted aspects of herd composition and use.

The intention of this chapter was to show the complexity of animal husbandry by analysing all of its components in detail and combining these details into a larger image. Especially the critical assessment of analytical methods usually applied in zooarchaeology has concluded that these methods are not valid for the accurate interpretation of bone data. The re-analysis of the West Frisian data with the new method, Faustitas, has yielded information on the potential of the herd for different types of production (*i.e.* use), long-term viability of the herd, as well as the age ratios which existed in the original living herds in West Frisia. It was also concluded that some information regarding past herds cannot be directly deduced from archaeozoological data including herd size and ratios between the different species present at a settlement. Overall, this chapter has provided new insights into both animal husbandry analysis as well as past human practice.

5.5.2 Assessing previous main components

The new results produced in this chapter regarding the role and praxis of animal husbandry in Bronze Age West Frisia are compared in this section to the main components of the current model. When current and new views are incompatible, the main components of the current model are re-formulated to match the new results.

Main component 1 was formulated as follows:

(1) Cattle was the dominant domestic animal species in West Frisia and was most important for subsistence.

Based on the available data, it could not be ascertained that cattle were the dominant livestock species in West Frisia, although it is likely. The lack of adequate insight into the effects of taphonomical and methodological processes on the bone assemblage as well as of past selection procedures on different animal species, means that a firm conclusion on dominance cannot and should not be made. The importance of cattle for subsistence was established and based on the potential exploitation of meat, milk, traction power, and manure. However, it should be kept in mind that relative importance to subsistence is not necessarily the result of a higher quantity of remains.

The current main component and the new results are not compatible and main component 1 is therefore newly formulated:

(N1) Cattle remains have, of all the animal species, most frequently been uncovered in West Frisia and their role within Bronze Age subsistence was most likely manifold.

Main component 2 was formulated as follows:

(2) Animal husbandry in the West Frisian Bronze Age was characterized by specialisation towards specific uses of cattle:
(2a) In the Middle Bronze Age, animal husbandry was specialized towards meat production and draught power.
(2b) In the Late Bronze Age, animal husbandry shifted towards milk production.

Based on the analysis of uses of cattle by Faustitas, it could be established that most likely no specialisation of a particular use of cattle was occurring in either the Middle or the Late Bronze Age. Cattle herds (but also sheep/goat) were kept for multiple purposes, and herds show an almost equal potential for meat and milk production. These new results do not match main components 2, 2a, and 2b, so a new main component 2 is formulated as follows:

(N2) Animal husbandry in the West Frisian Bronze Age was characterized by an exploitation of livestock for both meat and milk, both in the Middle and Late Bronze Age.

Main component 3 was formulated as follows:

(3) Milk was consumed by people in West Frisia during the Bronze Age.

Based on the analysis of cattle and sheep/goat, herd/flock usage as well as the results from biochemical studies on aDNA, dental calculus, and ceramics, the use of milk in West Frisia could indeed be established, and its consumption assumed. Therefore, main component 3 does not require reformulation.

Main component 4 was formulated as follows:

(4) Herd size can be related to the (reconstructed) size of a barn of a house.

Based on the analysis of a Danish example of a barn, which was not visible from the house plan, it has become apparent that barns may contain multiple species of animals that do not include all animals from their respective entire herds. Due to its incompatibility with this new insight, main component 4 is therefore reformulated:

(N4) Herd size cannot be directly related to the (reconstructed) size of a barn, since stable partitions are not obligatory elements of a barn, and not all the members of herd are kept inside.

Main component 5 was formulated as follows:

(5) Bronze Age households in West Frisia possessed 10-30 cattle, consisting of 50% cows in the case of 10 cattle, and 30% cows in the case of 30 cattle.

Based on a comparison with ethnographic parallels of small-scale mixed subsistence farms, households only possessed around 5-8 cattle, of which around 80% consists of female animals regardless of herd size. These figures were also assumed for the West Frisian situation.

Therefore, main component 5 is reformulated as follows:

(N5) Bronze Age households in West Frisia possessed 5-8 cattle, with 80% cows, regardless of herd size.

Main component 6 was formulated as follows:

(6) Interaction was required between the settlements in West Frisia in order to ensure a genetically healthy domestic animal population by avoiding the effects of inbreeding.

Direct and indirect indications for inbreeding were identified in West Frisia, indicating that interaction between settlements was not sufficient enough to avoid inbreeding altogether, or that the genetic composition of the herds in West Frisia was too homogeneous for exchange between settlements to have any effect. Again, the current main component and the new results are not compatible and main component 6 is therefore newly formulated:

(N6) Inbreeding occurred in Bronze Age West Frisia, indicating an insufficient regular exchange of livestock between settlements, or severely restricted genetic variation within the West Frisian livestock population.

Clearly, most of the main components of the current model are inaccurate in describing the role and praxis of animal husbandry in West Frisia. The new main components outlined above are therefore combined and integrated into the new model for animal husbandry.

5.5.3 New model for animal husbandry

Animal husbandry probably formed the main food strategy, after crop husbandry, in the small-scale subsistence farming communities which are assumed for the West Frisian Bronze Age. Herds of livestock were small (*i.e.* fewer than 10 individuals per domestic animal species), and consisted mainly of female animals. Male animals were either castrated and fattened, or, in much smaller numbers, kept as breeding stock. Around 25% of the cattle and sheep/goat herds consisted of animals younger than one year, 15% of animals one-two years old, and 60% of adult animals. Since animal husbandry formed a major part of subsistence, animal herds were bred with the aim of maintaining a long-term, self-reproducing healthy herd, although inbreeding probably also occurred on a regular basis. The import of new animals into West Frisia from other areas of the Netherlands however, will have inherently reduced inbreeding risks, as well as created varied herds of species in which possibly more than one breed of animal was kept. The different roles of animal husbandry in Bronze Age subsistence has become clear from the multiple reasons domestic animals were kept during this time: the meat and milk from livestock provided food for the settlement, wool from sheep was the raw material to create garments, and manure from livestock in general and the traction power of cattle more specifically (and perhaps horse) aided both crop husbandry and transport.

Animal husbandry needed careful organization of related activities throughout the year, including the breeding and birthing of animals, but also their location and nutrition. Breeding occurred during summer and autumn months, and the subsequent birthing season occurred in spring. Most livestock was kept on pasture all year round, although some animals, from multiple species, were most likely kept inside during winter months in order to protect them from harsh weather conditions and predation. Animals kept inside did not comprise entire herds, but most likely only the most vulnerable and valuable animals, such as pregnant or old animals, or rare animals such as horse. Grazing requirements of livestock varied depending on the animal species and herd size, but overall, around 7-14 ha of pasture was required per household to sustain herds, consisting of only 1-4 ha of woodland to accommodate for the nutrition requirements of goat.

Overall, animal husbandry formed an integral part of Bronze Age subsistence, both because of the multitude of activities related to its practice, as well as the many different yields obtained from livestock in the form of food, raw material, and labour.