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

Amerongen, Y.F. van

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Wild West Frisia

The Role of Domestic and Wild Resource Exploitation
in Bronze Age Subsistence

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“A Link to the Past can only be created by ingenuity, an imaginative mind, and an adventurous heart: requiring the Courage to try new things, the Wisdom to know whether the chosen approach has merit, resulting in the Power to create new insights”
– The Legend of Zelda

Voor Karel en Elisabeth

1. Introduction

Researching the Bronze Age

The European Bronze Age is characterized by the occurrence of multiple changes in comparison to previous periods, mainly related to, as the name suggests, the consistent use of bronze as a new source of workable material. This alloy is obtained either directly from local sources, or through exchange with other areas where it (its components) do (does) not occur locally in the environment. The exchange of metals can include either the raw metal components for local production, or the (semi-) finished metal products for (near-) immediate use. Through these and other finds of non-local materials and products, the Bronze Age can be characterized as a period in which long-distance relations are an important aspect of subsistence.

The introduction of bronze, however, does not appear everywhere at the same time, which means that "the" Bronze Age is different for different areas of Europe. For instance, the north-western European Bronze Age (2300-800 BC) starts relatively late in comparison to other areas of Europe. Besides the occurrence of extensive (metal) trading networks, it is characterized by a form of subsistence in which settlements are sedentary and inhabited year-round, and which is mainly based on agriculture, including both crop and animal husbandry. The Dutch Bronze Age in particular starts around 2000 BC with the Early Bronze Age (2000-1800 BC), followed by the Middle Bronze Age (1800-1100 BC), and the Late Bronze Age (1100-800 BC). This chronology has been established based on both cultural phenomena and 14C dating (cf. ROB 1966; Lanting & Mook 1977). The Dutch Bronze Age ends around 800 BC, when the introduction of a new metal heralds the start of the Iron Age.

The start of the Bronze Age in the Netherlands can be considered a gradual transition from the preceding Late Neolithic period, because the cultures present at the time were only introduced to the use of bronze at a relatively slow pace. These different cultural groups are mainly identified by their pottery styles,

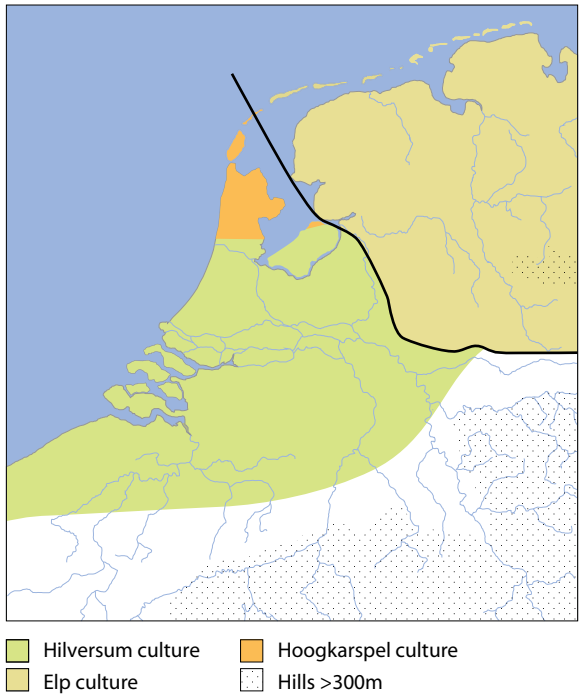


Figure 1.1. The general distribution of the three major cultures present during the Dutch Bronze Age, with the area of West Frisia indicated by the red box (underlying image adapted from: Fokkens 2005, 360-1, figure 16.3).

and include the Elp culture (1800-800 BC), situated in the north-eastern part of the Netherlands, the Hilversum culture (1800-1200 BC), located in the southern and western part, and the Hoogkarspel culture (2000-800 BC), with its seemingly isolated position in the north-west (Fokkens 2005, 360-1, figure 16.3; Figure 1.1).

The occurrence of different cultures is only one of the apparent variations during the Dutch Bronze Age, since there is also a clear difference in soil types throughout large parts of the country. On the one hand, clay forms the major soil type in the coastal areas in the west behind the dunes, and the large river systems in the central part of the country part of the Netherlands (Louwe Kooijmans 1993; Figure 1.2). Combined with a low position in the landscape and a relatively high water table, these

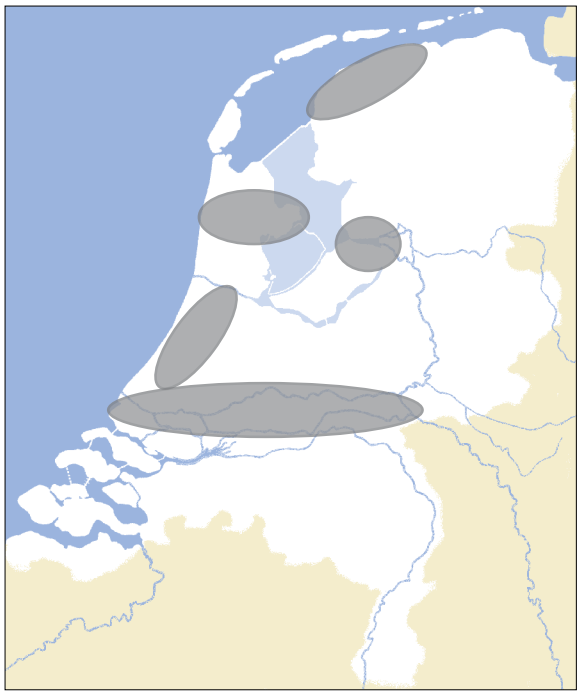


Figure 1.2. Overview of the major clayey wetland areas inhabited in the Dutch Bronze Age (indicated in grey), including the coastal areas in the west behind the dunes, and the large river systems in the central part of the country (after: Louwe Kooijmans 1993, 72, figure 6.1).

clayey areas mostly result in large wetland[1] areas. On the other hand, most areas in the south and the east of the Netherlands are distinctly different, being located on drier, sandy deposits. This type of subsoil results in a relatively higher position in the landscape which means in the Netherlands they are considered to be upland areas. However, in this thesis, the term upland will be substituted by the term well-drained areas, since elevation differences in the Netherlands are negligible in comparison with other countries.

The cultures present in the wetland areas of the Netherlands experience more pronounced changes in their subsistence during Bronze Age than cultures in most of the other areas. Whereas a true mixed farming system, in which crop and animal husbandry are fully integrated, had already been a part of many agricultural societies living on the well-drained soils in the Netherlands since the Neolithic (Bakels 2009), its introduction in the wetland areas occurs for the first time in the Bronze Age (Louwe Kooijmans 1993, 104).

Of the different cultures living in wetland areas, the Hoogkarspel culture in the north-western Netherlands, situated mostly in the present-day area of West Frisia (Figure 1.1), has been a major research focus for many years. This research has been equally focused on excavating and on studying the numerous remains which these excavations have yielded. The large number of excavations which have taken place in West Frisia for instance have led to enormous datasets on settlements and habitation here can be regarded as being very dense and as being organised into permanent settlements with separate houses. The house-plans are clearly recognisable by the distinct configuration of their post-holes and surrounding house ditches (Appendix A1.1). These house ditches, in turn, have been major sources of archaeological, but also many botanical and zoological data. Since the preservation conditions are excellent in this particular area due to the properties of the clayey subsoil and relatively high water table, organic remains are especially well preserved, both in charred and uncharred form. This preservation of remains is distinctly different from areas where the soil is well-drained, since in these areas nearly exclusively charred botanical remains and nearly no bones are preserved. The favourable conditions for these remains in West Frisia therefore results in large datasets of botanical and zoological data. The extensive data available in West Frisia in the form of excavated settlements and both archaeological and organic remains, and in combination with a good chronology covering a large part of the Bronze Age has enabled research on all the different aspects of Bronze Age life in a wetland environment.

Results of the previous research on West Frisia have resulted in a model for subsistence in West Frisia during the Bronze Age, mostly concentrating on the Middle (1800-1100 BC) and Late (1100-800 BC) Bronze Age periods. This current model discusses both landscape, habitation, and subsistence. In the

1. Throughout this thesis, the general term wetland will be applied to different types of wet area according to the definition provided in Appendix A1.1.

model, the Middle Bronze Age West Frisian landscape consisted mainly of low-lying, clayey areas, representing the actual wetlands, alternated with relatively high sandy ridges, which were regarded as the drier areas in this wetland environment. Farmers situated their houses at the edge of these sandy ridges in the landscape, and cultivated arable fields on top (van Regteren Altena 1977, 20), producing emmer wheat (*Triticum dicoccum*) and hulled barley (*Hordeum vulgare var. vulgare*) in equal ratios, and also linseed (*Linum usitatissimum*) (Bloemers *et al.* 1981, 58; Buurman 1996). The landscape outside the settlements was reconstructed in general as nearly treeless, and the lower-lying wetland areas surrounding the sandy ridges formed the grazing areas for livestock (van Regteren Altena 1977, 20). Cattle formed the most dominant livestock species in West Frisia (IJzereef 1981), which is a common observation for the Bronze Age (Bartosiewicz 2013). Around 20 cattle were thought to be kept per household, as well as five to ten sheep and a few pigs (Bloemers *et al.* 1981). Cattle would have been kept inside throughout the winter and would have provided ample manure for fertilizing the arable fields.

During the Late Bronze Age, environmental conditions rapidly worsened. The combination of a rising groundwater table and a change in climate resulting in more rain and subsequent peat growth (van Geel *et al.* 1982, 274; van Geel *et al*. 1997, 45) resulted in shifts in habitation and subsistence strategies. Cattle, which was previously mainly kept for specialised meat production, was bred for milk production instead (IJzereef 1981), and hulled barley was almost exclusively cultivated at the expense of emmer wheat (Buurman 1996). Because of the increasing wetness in the environment, farms in the Late Bronze Age were no longer built at the edge of the sandy ridges, but rather on top of mounds on the sandy ridges, where the arable fields were also still situated (van Regteren Altena, 20). The Late Bronze Age climate led thus to an increasing shortage of suitable land for cultivation and habitation, which ultimately led to the abandonment of this area at the end of the Late Bronze Age (van Geel *et al.* 1996).

The model discussed in the previous paragraph has been the leading model for West Frisia for almost 40 years. Excavations performed in recent years however, have consistently brought forth new data that do not match the main components of the current model. For instance, entire settlements consisting of both Middle and Late Bronze Age houses were found situated in the lower-lying wetland areas (Roessingh & Lohof 2011), which were previously exclusively the domain of grazing livestock. These types of new observations indicate that the current model is no longer able to explain the West Frisian Bronze Age situation based on the entire dataset available for this area, and both the model and the underlying data should be re-evaluated. Apart from the insufficient coverage of the data by the current model, there are still other reasons why West Frisia should be a primary focus for new research. Although many excavations have taken place and much data has been gathered here, the number of publications incorporating this abundance of information has been surprisingly low. Much of the available data lay unpublished, even though the potential it holds for obtaining a better understanding of the Bronze Age wetland communities is great. Cultures inhabiting wetland areas in the Netherlands, Denmark, and north-western Germany are often described as being distinctly different from neighbouring communities on well-drained soils by their settlement dynamics (*e.g.* IJzereef 1988; Bech 1997; Ethelberg 2000), cultivation regimes, and burial traditions (cf. Bakker *et al.*1977; IJzereef 1988; Buurman 1996; Bech 1997; Boas 1997), giving them an entirely unique character. Sadly, comparatively little focus is given to these interesting communities in present-day studies towards the Bronze Age.

It is high time that this lack of focus is remedied using the new data available. West Frisia provides an excellent starting point, a case-study. Since the preservation conditions in West Frisia are, as mentioned, so favourable, all aspects of Bronze Age life can potentially be researched based on the data already available, including landscape, habitation, subsistence, and cultural identity and communication networks. Results from the analyses of the West Frisian data could subsequently be used to compare with other wetland communities. Ultimately, this should lead to a new model for Bronze Age wetland communities along the southern

North Sea coast. An application for a research project with the aims outlined above was granted (Fokkens 2010). The research project, called Farmers of the Coast, was funded by the Netherlands Organization for Scientific Research (NWO). This overarching project consists of four sub-projects, investigating all the aspects related to Bronze Age life: the physical landscape (van Zijverden forthcoming), the cultural landscape and settlement dynamics (Roessingh in prep.), cultural identity and communication networks (Valentijn in prep.), and the subsistence economy.

Towards a new approach

This thesis is concerned with the latter subproject of the Farmers of the Coast project outlined above, and investigates the Bronze Age subsistence economy in wetlands. It aims to reconstruct this economy in its entirety through the integration of all possible aspects, resulting in a model of year-round agricultural life.

In the past, much research has been focused on separate research components, *i.e.* landscape reconstruction, reconstruction of crop husbandry, and animal husbandry. Landscape reconstruction is normally performed by analysing the pollen and botanical macro remains from a site in order to assess the surrounding landscape of a site. The reconstruction of crop husbandry is mainly concerned with the analysis of what cereals were cultivated, what the quality of the soils of the arable fields was, and how harvesting took place. Finally, archaeozoological research towards animal husbandry is usually a means to identify different domestic animals present at a site, the age at which they died, and the use they may have had to people. Although some interaction between these different types of research does happen, often no real integration of results occurs. Without this kind of integration, interpretations are restricted to conclusions that may not be supported, or may even be contradicted by other disciplines. For example, a landscape reconstruction based on on-site botanical remains can give results of an open landscape, but this type of landscape may not be at all reflected by the wild animal species present at the same site. When analysis results are not integrated, the potential to uncover added information from and for the various disciplines is lost. It is therefore key that all the available data on a subject is combined and integrated before the interpretation of the results, especially when dealing with a complex system such as a subsistence economy. Only then will the interconnectedness of the different parts of such a subsistence system become apparent.

During the Bronze Age, as briefly introduced at the beginning of this chapter, people were practicing mixed farming as their main subsistence strategy. Careful consideration of the practice of mixed farming, just like any other form of prehistoric subsistence, reveals that it is a balanced interaction between humans and the environment in which they operate. Landscape is a vital part of life as a farmer because it is in this environment that they grow their crops and breed their livestock, and where they obtain the raw materials for all aspects of their subsistence. Therefore, a reconstruction of the landscape is the first step in understanding the Bronze Age subsistence economy (Chapter 2). Although a separate sub-project already focuses on the physical landscape based on physical geography (van Zijverden forthcoming), this thesis provides additional and unique information on the environment based on organic remains. Many new insights into the local and regional environmental conditions were obtained by introducing new proxies for landscape reconstruction (*i.e.* fish, birds, mammals) and integrating these results with the conventional proxies such as pollen and macrobotanical remains. A further integration of the results from this thesis with the results of Van Zijverden has resulted in an even more clear perspective on the landscape and its dynamics throughout the Bronze Age.

Similar to the landscape,. These individual parts can, in practice, not be separated because each part requires the presence of the other in order for a mixed farm to operate successfully. This interconnectedness of practices means that it is not possible to comprehend the full extent of a subsistence economy without investigating every aspect related to it. Research focused on only one of the aspects of subsistence, such as on only crop husbandry or animal husbandry, as is often the case, will therefore miss the true scope of farming life.

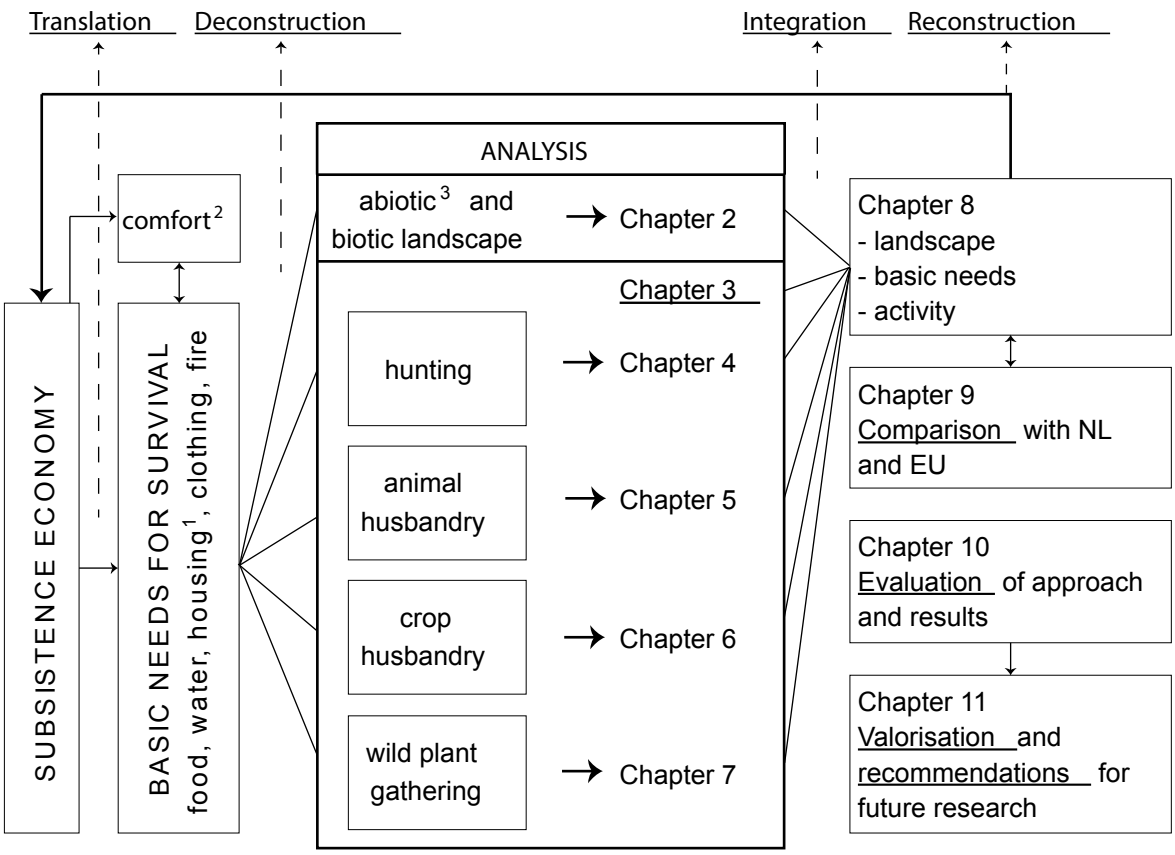


Figure 1.3. Flow chart of the approach of this thesis with regard to the analysis of the subsistence economy. 1: house structures are researched by Wouter Roessingh (Roessingh in prep.), who investigates the cultural landscape; 2: underlying cultural and social phenomena related to subsistence and to living in comfort are researched by Patrick Valentijn (Valentijn in prep.).; 3: the abiotic landscape is mainly researched by Wilko van Zijverden (van Zijverden forthcoming), on a physical geographical basis.

In this thesis, a new approach for investigating the subsistence economy is presented (Figure 1.3), which not only tries to identify (Chapter 3) and analyse (Chapter 4-7) all the aspects related to subsistence, but also integrates them (Chapter 8) in a manner that shows that farming is more than the sum of its parts.

Identifying all the aspects of subsistence is not an easy task, but when subsistence in its purest form is viewed as a form of survival, it means that there are five basic requirements (*i.e.* food, water, housing, fire, clothing) that must be met (Figure 1.3: "basic needs for survival"). These five basic requirements form the survival threshold, but it must be emphasized that Bronze Age people will no doubt have aimed to remain comfortably above that threshold to be able to deal with potential setbacks (Figure 1.3: "comfort"). The aspects related to comfort include many social and cultural phenomena which can occur parallel to or intertwined with subsistence, such as exchange or certain rituals. Although no doubt very important to subsistence, these aspects are not the focus of this thesis, and will be discussed elsewhere (Valentijn in prep.).

Still, the principle of basic requirements is used for translation into Bronze Age practice, to result in the expectation that most activities on a farm will have been focused on satisfying these needs by means of hunting (Chapter 4), animal husbandry (Chapter 5), crop husbandry (Chapter 6), and wild plant gathering (Chapter 7) (Figure 1.3: "Deconstruction").

These four aspects of the economy are considered anew (Figure 1.3: "Analysis"). First, the main components of each subject in the current model for Bronze Age West Frisia are identified. These main components are subsequently compared to the conclusions based on the results of the re-evaluation and re-analysis of the data. When the old main components are proven inadequate after a comparison with the new results, new main components are constructed which form a new model for each researched subject. The re-evaluation and re-analysis of the data are performed in an innovative manner. Instead of listing a summary of the known data for each subsistence strategy and drawing conclusions solely based on these observations, it is first established what may have been present, but may not or no longer be visible. This expectation is based on the integrated input of a variety of disciplines which include ethnography, ecology, biology, archaeology, archaeozoology, biochemistry, statistics, ethnobotany and archaeobotany.

Ethnographical information from around the world on the different aspects of subsistence has proven to be especially helpful in creating an expectation of the basic manner in which people with comparable subsistence economies to that in West Frisia operate, regardless of climate, geographical location, and time period. By creating a clear understanding of the consistent basic elements of each subsistence strategy, the elements that are likely to be present or missing when dealing with an archaeological assemblage become apparent. The differences observed between this constructed expectation and the analysed data of West Frisia can thus be interpreted in a more detailed manner. Although these observed differences may indeed reflect (differences in) past human practice, which is the ultimate research goal in archaeology, in this thesis it is also assessed whether missing elements might be (partly) explained by taphonomical processes, methods applied during field or laboratory work, or by interpretation based on data which has not been corrected for internal biases.

The outcome of the analysis of the main components is integrated (Figure 1.3: "Integration") into three major themes related to Bronze Age daily life (Chapter 8). These themes include the landscape (discussing the relative distribution and impact of plants, animals and humans on the environment in West Frisia), the basic subsistence requirements (discussing the contribution of each of the researched strategies to the overall diet, range of clothing, and shelter options in West Frisia), and activity (discussing how, when, and where the resources for consumption and raw material were obtained in West Frisia). The results thus obtained represent the new model for the West Frisian Bronze Age subsistence economy (Figure 1.3: "Reconstruction"). As mentioned before, West Frisia was chosen as a case-study for Bronze Age farmers active in a wetland environment, for north-western Europe in general. Therefore, to test whether this case-study was aptly chosen, the new model is subsequently compared to other regions of north-western Europe, such as Denmark and Sweden, in order to assess whether the West Frisian situation is unique or whether general trends in subsistence economies can be observed in the Bronze Age (Chapter 9). In this same chapter, a short excursion into the economy practiced by Bronze Age farmers living on the borders of lakes in Switzerland serves to evaluate whether the model has a still wider application.

Chapter 10 provides a summary of the results as well as an evaluation of the applied method, followed by recommendations for further studies (Chapter 11) to ensure that research towards Bronze Age wetland communities will continue to advance in the future.

2. Reconstruction of the Landscape

2.1 INTRODUCTION

It is of great importance that the landscape which was present around settlements is established before the reconstruction of subsistence can commence. The environment is essential for all aspects related to subsistence: the stage needs to be set before the actors come into play.

A model for the Bronze Age landscape in West Frisia already exists, but seems largely inconsistent with observations made at recent excavations in the area. In this introduction, a short overview of the inconsistent main components of the current model, which are of relevance to this thesis, will be discussed below, each followed by a number between brackets. These numbers will later be reiterated in the methods section (section 2.2) and will be used for specific approaches towards the research of each of the inconsistencies of the current model. For further specific information on the current palaeo-geographical and habitation models and their re-interpretation, the reader is referred to the other sub-projects (Roessingh in prep; van Zijverden forthcoming).

2.1.1 Previous research

In the current landscape reconstruction model, the Middle Bronze Age West Frisian landscape consisted of mostly wet grassland, with a few higher sandy ridges, and trees were absent from the area. In the Late Bronze Age, the landscape was still treeless, and deteriorating weather conditions and a rising sea level during this time led to an increasingly wet environment consisting of expanding peat growth. These factors ultimately led to the abandonment of West Frisia altogether at the end of the Late Bronze Age.

It is clear that several influences of water on the land were postulated for West Frisia, basically forming the main components of the current model. First of all, it was expected that no marine influence of the North Sea was present in (eastern) West Frisia after ca. 1550 cal BC, because the Bergen inlet (*i.e.* the connection to the sea to the east of West Frisia; Figure 2.1) was assumed to be closed during that time (Roep & van Regteren Altena, 1988, 219) (1). Although further physical geographical research in this area has been performed, no change in the closing time of the inlet has so far been proposed. Recent excavations have, however, revealed indications of marine influence at several Middle Bronze Age sites, which clearly date after the previously proposed closure of the inlet (Lohof & Vaars 2005, 65; Schurmans 2010, 144; Roessingh & Lohof 2011, 319; van Zijverden 2013). Related to this first example of water influence based on the current model, the water around the settlements in both the Middle and Late Bronze Age was characterized as a purely freshwater environment (2). This was established based on the fish bone assemblage (IJzereef 1981, 126), small mammals (Buurman 1996, 149), botanical macro remains and molluscs (Buurman 1996, 149-50), and algae (van Geel *et al.* 1997, 159-161). Recently observed marine influences at several sites again seem to contradict this statement.

The postulated wide-spread occurrence of peat growth in the Late Bronze Age (3) is another major aspect of the current landscape model. This peat growth, supposedly caused by a worsening of the climate in combination with a rising groundwater level during this time, was postulated as the reason why people abandoned West Frisia around 750 BC (van Geel *et al.* 1982, 274; van Geel *et al.* 1997, 45). However, several indications for habitation dating to the Iron Age are present in West Frisia (Woltering 1985, 225; Buurman 1993; van Wijk 2008), indicating that indeed people were still present here after the Bronze Age. In addition, so far, no peat layers dating to the Bronze Age were identified, even at locations where they were expected (Roessingh & Lohof, 2011, 46; Geerts 2012).

A final aspect of the current landscape reconstruction, and possibly the most important, is that the terrestrial

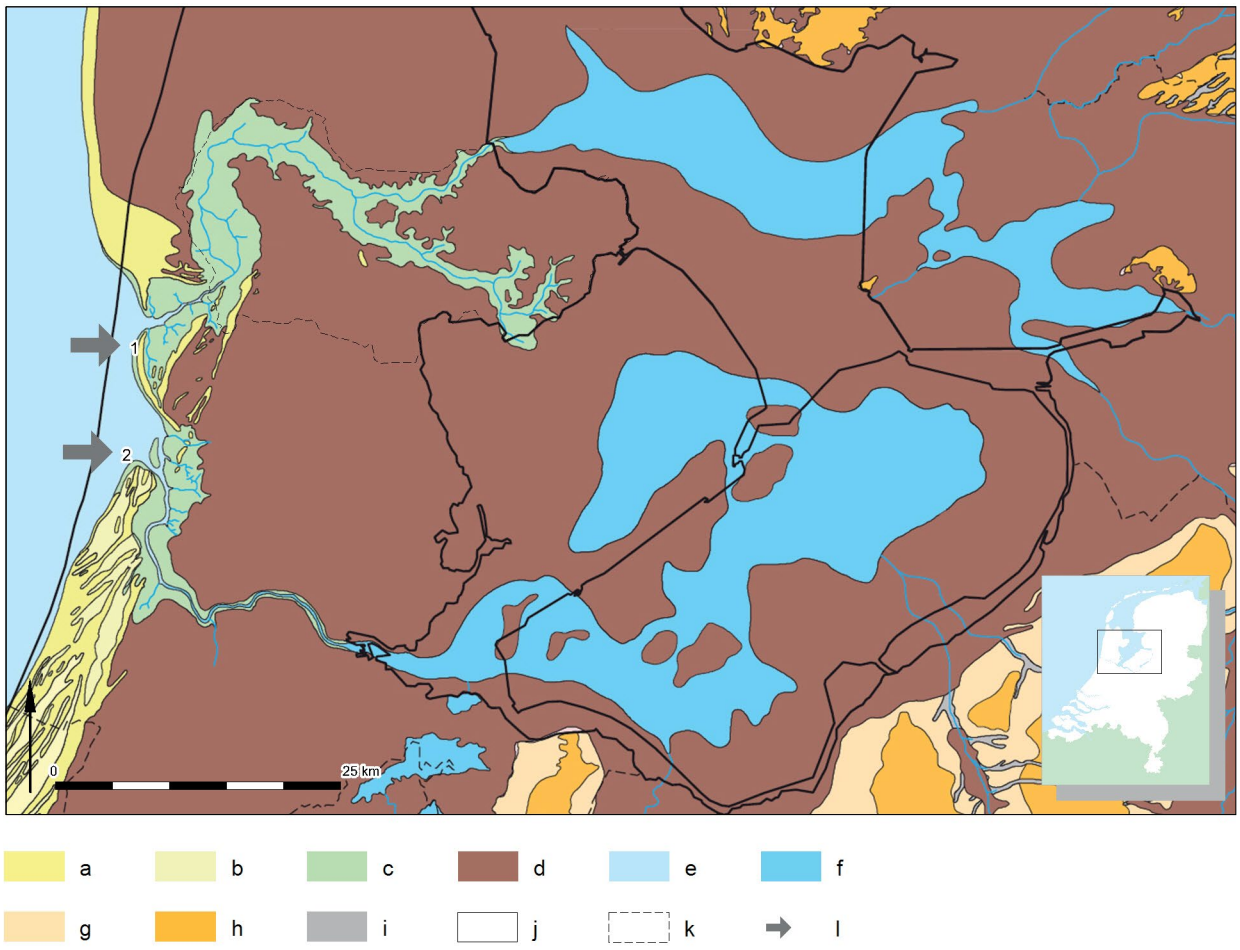


Figure 2.1a. Position of West Frisia and its drainage basins in the Bronze Age according to the current model (from: Vos 2011, 55). a: low dunes; b: beach-plain and dune valleys; c: intertidal areas: sand- and mudflats; d: peat; e: outer water: mainly brackish and marine areas, North Sea, tidal channels and lagoons; f: inner water: mainly freshwater areas, river channels and lakes; g: Pleistocene sand areas above 0 m –NAP; h: ice pushed moraines and drumlins; i: fluvial areas and brook valleys; j: outline of the recent Netherlands; k: outline of the recent area of West Frisia; l: coastal inlet/estuary; 1: Bergen inlet; 2: Oer-IJ estuary.

landscape of West Frisia has been reconstructed as a treeless, open landscape (Bakker & Brandt 1966, 188 and references therein) (4). Pollen analyses based on data from several old excavated sites indicated a general absence of trees, of which Bovenkarspel Het Valkje is the most prominent example (Buurman 1996, 83). New excavations however, have yielded multiple indications for the presence of trees (*e.g.* Kooistra 2010, 134), which undermine previous conclusions.

Besides affecting the West Frisian landscape, the supposed deteriorating weather conditions in the Late Bronze Age have also resulted in several statements concerning the habitation in West Frisia. The (increasing) wetness would have urged people to inhabit only the higher areas in the landscape after the closure of the Bergen inlet, and this changing climate allegedly also affected the subsistence strategies practiced. The accurateness of this major statement will be further investigated in Chapters 4-7.

2.1.2 The sites and the proxies

The landscape model presented here is a collaborative effort between drs. W.K. van Zijverden (another

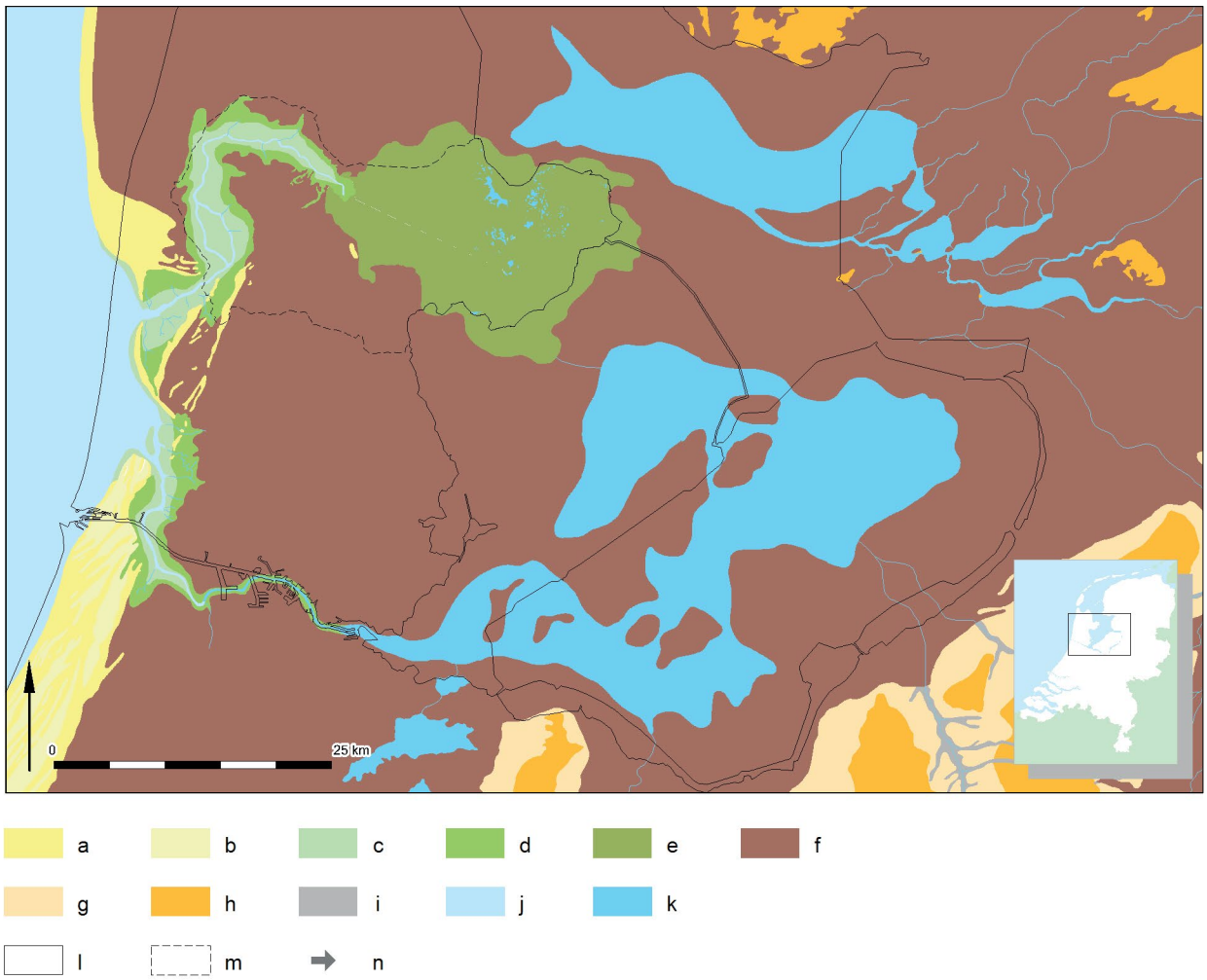


Figure 2.1b. Position of West Frisia and its drainage basins in the Bronze Age according to Van Zijverden (forthcoming). a: low dunes; b: beach-plain and dune valleys; c: intertidal areas: sand- and mudflats; d: fluvial flood plain and marine salt marsh areas; e: former mudflats (now freshwater environment); f: peat; g: Pleistocene sand areas above 0 m –NAP; h: ice pushed moraines and drumlins; i: fluvial areas and brook valleys; j: outer water: mainly brackish and marine areas, North Sea, tidal channels and lagoons; k: inner water: mainly freshwater areas, river channels and lakes; l: outline of the recent Netherlands; m: outline of the recent area of West Frisia; n: location of an excavated site; o: coastal inlet/estuary; 1: Bergen inlet; 2: Oer-IJ estuary.

member of the Farmers of the Coast project) and the author. Therefore, several ideas from and references to Van Zijverden's palaeo-geographical work will be used in this chapter, as well as the new maps created for the Bronze Age (*e.g.* Figure 2.1b). Whereas drs. Van Zijverden focuses mainly on the physical landscape from a geographical point of view, the research in this chapter is concerned with the added information potential for landscape reconstruction based on organic remains.

The data from both the old and new excavations was researched in order to re-evaluate the current landscape reconstruction model (cf. Figure 2.1a). As was introduced in Chapter 1, the new approach here was to first establish an expectation of what could be found in the West Frisian environment based on a combination of proxies (section 2.2). This approach ensured that the reconstruction of the landscape was not only made by merely summarizing what was found, but also by taking into consideration what

Table 2.1. Information on the sites of West Frisia used for the reconstruction of the landscape.

Site location	Toponym	Excavated	Date	Dating method	Sieving mesh size	Reference(s)
Andijk		1954	Subboreal	continuous *Fagus* curve	n/a	unpublished old StiBoKa data (off-site pollen)
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	0.25-4.0 mm	Buurman *et al*. 1995; van Geel *et al.* 2012 (on-site pollen) Buurman unpublished (botanical macro remains) IJzereef 1981 (fish, birds, and mammals)
Enkhuizen	Kadijken	2007-2009	1500-800 cal BC	14C-dating and pottery typology	0.25-4.0 mm	Bos & Bouman 2011, 271-74 (on-site pollen) Moolhuizen & Bos 2011, 259-69 (botanical macro remains) Zeiler & Brinkhuizen 2011, 191-216 (fish, birds, and mammals)
Grootebroek		1949	1500-1100 BC	pottery typology	n/a	van Giffen 1954 (on-site pollen)
Hoogkarspel	Klokkeweel	1976	Subboreal	14C-dating and continuous *Fagus* curve	n/a	Pals *et al.* 1980 (off-site pollen)
Hoogkarspel	Tolhuis DEF	1964-1969	1500-800 cal BC	14C-dating and pottery typology	unknown	Smits 1978 (mammals) Suwijn 1981 (mammals)
Hoogkarspel	Watertoren	1973-1978	1500-800 cal BC	14C-dating	0.25-1.0 mm (mammals unknown)	Bakels 1974 (on-site pollen) Pals 1977 (botanical macro remains Clason 1967 (mammals)
Hoogwoud		1991-1992	Subboreal	14C-dating and continuous *Fagus* curve	n/a	Havinga & van den Berg van Saparoea 1992 (off-site pollen)
Hoogwoud	Opmeer	2004	1300-1100 BC	pottery typology	0.25-4.0 mm	van Haaster 2005, 50-4 (botanical macro remains) Beerenhout 2005, 43-50 (fish) van Dijk 2005, 36-43 (birds and mammals)
Medemblik		1954	Subboreal	continuous *Fagus* curve	n/a	unpublished old StiBoKa data (off-site pollen)

Site location	Toponym	Excavated	Date	Dating method	Sieving mesh size	Reference(s)
Medemblik	Schepen-wijk II	2007	1450-800 cal BC	14C-dating and pottery typology	0.25-4.0 mm	Kooistra 2010, 125-42 (on-site pollen and botanical macro remains) Beerenhout 2010, 105-20 (fish) Groot 2010, 83-104 (birds and mammals)
Opmeer		1964	Subboreal	continuous *Fagus* curve	n/a	unpublished old StiBoKa data (off-site pollen)
Schagen	de Hoep-Noord	2003-2004	2200-1600 cal BC	14C-dating	1.0, 2.0, 5.0 mm	Zeiler *et al*. 2007 (fish, birds, and mammals)
Twisk		1980	1300-1100 BC	14C-dating	0.25-1.0 mm	Buurman 1996, 37-68 (botanical macro remains)
Warmen-huizen		2004	1000 cal BC	14C dating	n/a	Bakels 2005, 36-8 (off-site pollen)
Westwoud	1988	1988	1400-800 cal BC	AMS-dating	0.25-1.0 mm	Buurman 1996 (botanical macro remains, fish, small mammals)
Zuid-Scharwoude		1967	Subboreal	continuous *Fagus* curve	n/a	unpublished old StiBoKa data (off-site pollen)
Zwaagdijk	1961	1961	1500-1100 cal BC	14C-dating and pottery typology	unknown	Clason 1964 (mammals)
Zwaagdijk	Oost	2003	1500-1100 cal BC	14C-dating	unknown	de Roller 2003, 189-202 (botanical macro remains) Halici & Buitenhuis 2003, 155-88 (mammals)

was missing from an assemblage and why. After the expectation was established, the West Frisian data was compared to it, and the results of the analysis of again several proxies (section 2.3 and 2.4) was combined into a new landscape model for the Bronze Age in West Frisia (section 2.5).

The usual proxies used for this type of research are pollen and macro-botanical remains. However, in this chapter, this usual set of proxies is supplemented with the proxy of animals (*i.e.* fish, birds, and mammals). By combining both botanical and zoological remains, a more complete image of the past environment is obtained, with the incorporation of the most frequently researched (and available) proxies for landscape reconstruction. Clearly, this set of environmental indicators is far from complete, but future research may incorporate other proxies when enough data becomes available.

The researched sites are summarized in Table 2.1, including the references to the various reports on the different proxies. Sites mentioned in this table include the complete site names. For readability reasons, these names will be abbreviated in the text by only referring to the locality (*e.g.* Bovenkarspel Het Valkje becomes Bovenkarspel). When multiple site names exist for the same locality, however,

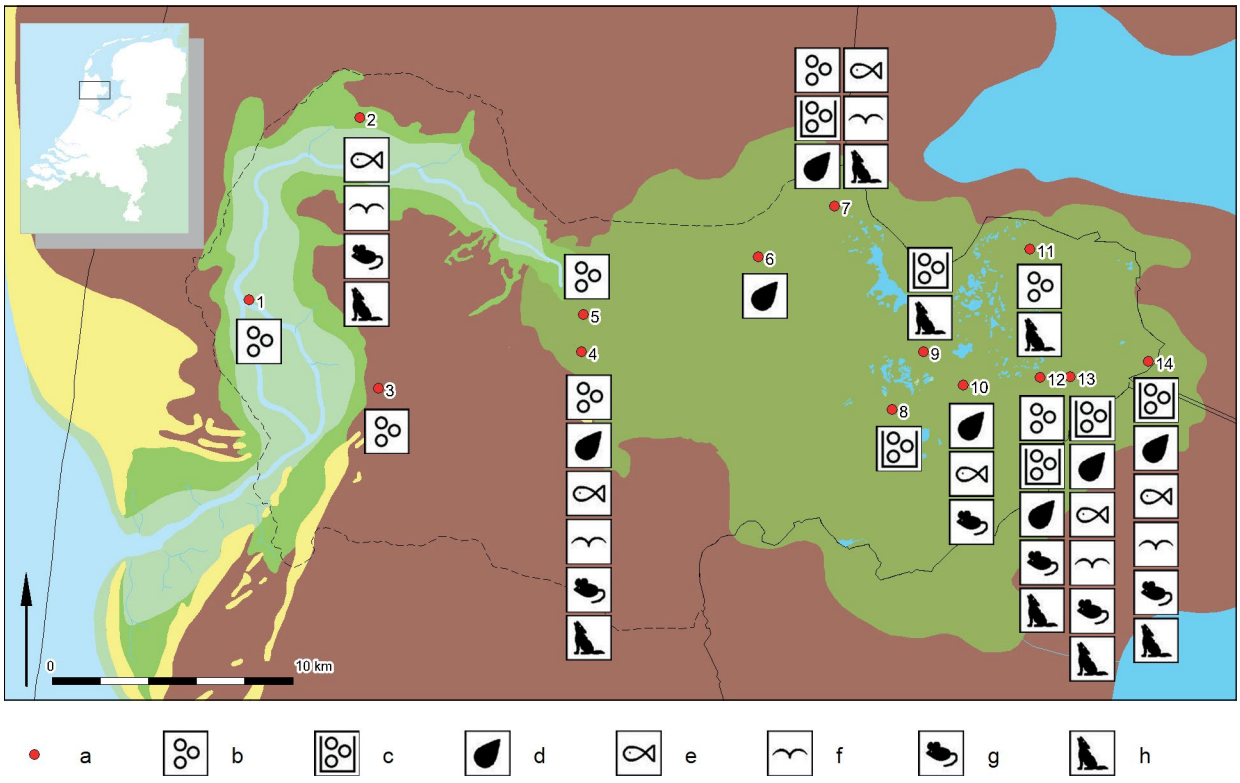


Figure 2.2. The different environmental proxies available at the West Frisian sites. For the legend of the underlying map, see Figure 2.1b. a: location of an excavated site; b: off-site pollen; c: on-site pollen; d: botanical macro remains; e: fish remains; f: bird remains; g: small mammal remains; h: large mammal remains; 1: Warmenhuizen; 2: Schagen; 3: Zuid-Scharwoude; 4: Opmeer; 5: Hoogwoud; 6: Twisk; 7: Medemblik; 8: Grootebroek; 9: Zwaagdijk; 10: Westwoud; 11: Andijk; 12: Hoogkarspel; 13: Bovenkarspel; 14: Enkhuizen.

the entire site name will be indicated instead. The different proxies present at each site are shown in Figure 2.2.

2.1.3 Main current model components

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

(1) The seacoast to the west of West Frisia is closed around 1550 BC therefore making an influx of marine water impossible after this time.

(2) A purely freshwater environment existed around the settlements in eastern West Frisia throughout the Bronze Age.

(3) Wide-spread peat growth occurred in the Late Bronze Age, resulting in the abandonment of West Frisia.

(4) The terrestrial landscape of Bronze Age West Frisia is characterized by treeless, open areas.

2.2 METHODS

Proxies which are used to challenge the above main components include: pollen, botanical macro remains, animals (*i.e.* fish, birds, and mammals), and physical geography (van Zijverden forthcoming). The manner in which each of the different proxies are used in the reconstruction of the landscape will be discussed in more detail below. It was assumed that the climate in the Bronze Age was largely similar to the present (cf. Zagwijn 1991) and that biotic communities remained largely the same. However, when clear indications for differing situations between the past and present occurred, these were taken into account during further analysis.

For both macrobotanical plant remains and animal remains, it was assumed that they were brought by people to the site at which they were uncovered. It is also assumed that they derived from the immediate surroundings of the settlement, since the action radius of the Bronze Age farmers is assumed to be limited (Chapter 3, section 3.3.5). These remains should therefore represent the immediate surroundings of the sites at which they were found. Qualitatively, individual plant and animal proxies are considered to be good indicators for the habitats (see section 2.2.3) present around the settlements, and when multiple proxies overlap in the habitat types represented by the plants and animals, a more firm image of the environment can be obtained. When one of the proxies differs from the image provided by the other proxies for a certain habitat type, however, it is considered an outlier. For such cases, different explanations for these observed differences are discussed (cf. sections 2.3.5 and 2.4.5).

2.2.1 Pollen

For pollen research, both on-site and off-site pollen samples were re-analysed. Off-site pollen reports were collected at the TNO (Netherlands Organisation for Applied Scientific Research) in Utrecht, the Netherlands, which housed old StiBoKa data. StiBoKa, short for Stichting Bodem Kartering, was concerned with performing soil surveys during the second half of the twentieth century before large scale re-allotments destroyed most of the topsoil in West Frisia. Consulted pollen reports were only selected if they included a peat layer, and only samples that fell well within the limits of this layer were analysed further. In addition, the sampled peat layer needed to date to the sub-boreal time period, which includes the Dutch Bronze Age. This date was established by checking whether a continuous*Fagus* curve was present, which signifies the sub-boreal time period (van Gijssel & van der Valk 2005, 61). In some cases, additional radiocarbon dates were available. Subsequently, the raw data of these samples was reinterpreted. First, species present in the peat layer were assigned to specific groups, each signifying a unique ecotype (*i.e.* general types of growth locations of plant communities). These groups are summarized in Table 2.2.

Table 2.2. Ecotypes used for the analysis of botanical remains for the reconstruction of the landscape.

A	upland trees and shrubs
B	wetland trees and shrubs
C	upland herbs
D	salt marsh
E	wetland herbs
F	oligotrophic peat
H	ecologically indeterminate
J	moist to wet disturbed open grounds, low humus

In this manner, environmental indicators could be separated for trees versus an open landscape, wet versus dry conditions, saline versus non-saline conditions, and raised peat formation. The ecologically indeterminate group (H) included taxa which could not be identified to the species level, as well as species belonging to the *Cyperaceae* family, since these plants can grow in many different ecotypes. Subsequently, a pollen sum was created of the groups which signified regional vegetation (*i.e.* vegetation not present amongst the local eutrophic peat vegetation), including group A, C, D and F. Non-local vegetation growing under dry, saline, and/or oligotrophic peat, potentially present in the pollen record, could then be identified. Because dryland vegetation was separated from vegetation from wetlands in the applied method, there was no interference of local wet trees and shrubs, therefore allowing for an accurate assessment of the presence of upland trees in West Frisia.

The on-site pollen was analysed in exactly the same manner. On-site pollen included both settlement and burial mound contexts. Although burial mounds are by no means necessarily located within a settlement, they are included under this category because they are

part of the human activity realm, whereas (extensive) peat layers are natural phenomena occurring at off-site locations, or at least in the absence of human activity.

2.2.2 Botanical macro remains

Botanical macro remains for the reconstruction of the environment were analysed from every available settlement. In this analysis, macro remains from all preservation states and contexts were grouped to create an overview of the existing eco groups (*i.e.* specific types of growth locations of plant communities). With this overview, and using the same ecotype groups as for pollen in Table 2.2, it was possible to assess the salinity of the water present around the sites, as well as the presence of peat, and trees.

2.2.3 Animals: fish, birds, mammals

The animals presented here are not always included in integrated environmental research. Especially mammals have received little attention for this purpose, even though their potential indicative value for the reconstruction of the environment is high. Animals can provide such indications for the surroundings only when it is assumed that they were caught relatively close to the settlement. For West Frisia, it is indeed assumed that people hunted relatively near-by, because they were full-time farmers (cf. Chapter 3).

The manner in which animal remains are used for landscape reconstruction can be summarized under the term the "habitat approach". In this research, animal remains are not analysed quantitatively, because of the varying sampling strategies and mesh sizes applied (Table 2.1). Rather, the species itself is used as an indicator for the direct environment around the site where it was found, irrespective of the number of bones found of each species. Additionally, a list of possible habitats, as well as the possible animal species they could support was composed for West Frisia (Appendix A1.1 and A1.2). The expected species were then compared with the observed species at the West Frisian sites in order to reach conclusions about the environment.

Fish are used as indicators for the water type present around the sites, as well as water salinity. The main assumption made here is that fish in the Bronze Age lived in the same habitats and associations as today and exhibited the same behaviour. It is assumed that these elements have remained relatively the same for long periods of time, and therefore, fish are used in this research as representative indicators of the environment.

Table 2.3. Salinity groups based on grams of salt/kg of water (expressed in parts per thousand, or ppt).

	Salinity (ppt)
Fresh water	< 0.5
Brackish water	0.5 - 30
Slightly brackish water	0.5 - 10
Medium brackish water	11 - 15
(Very brackish water)	(16 - 30)
Salt water	31 - 50

NB. Since no species were found in West Frisia that prefer a salinity between 16-30 ppt, this group is placed between brackets, and will not be used in further analyses.

The habitat preferences of the fish species found, as well as their maximum salinity tolerances were assessed (Vissengids 2016, Marine Fish Map 2016, Copp *et al.* 2009). This information was grouped into five types of aquatic habitat: stagnant to slow-flowing water, (fresh) open water, fast-flowing water (river), connection to the sea, and open sea. Finally, some fish species have no specific preference for their habitat, and these are placed into a separate group, named "non-specific". When fish have more than one water type habitat preference, they are placed in every preferred habitat. Conversely, the maximum salinity that a fish can tolerate depends on the type of fish, but will always be represented by one preferred value (*i.e.* the maximum tolerance value). Salinity tolerance can be divided into salinity groups based on the amount of grams of salt dissolved in 1 kg of water (*i.e.* parts per thousand, or ppt). The groups that are used in this research are summarized in Table 2.3.

Freshwater fish cannot survive under high salinity conditions, but will usually tolerate low levels of salt in the water (0-15 ppt), although often only for a limited time (Vissengids 2016). Saltwater fish can tolerate saline conditions of more than 30 ppt. Migratory fish are capable of living in all salinity groups, because they travel back and forth between fresh water and the open sea. Therefore, their maximum salinity tolerance is >30, although these fish can also be found in fresh water. Because in this research no species with a preference for highly brackish water were found, this category will not be used further.

The different water type preferences as well as maximum salinity tolerances were grouped for each site and plotted in pie diagrams. These site-related diagrams were subsequently placed on a map of West Frisia to investigate regional trends in salinity and water type, and to assess the influence of salt and freshwater in western and eastern West Frisia in the Middle and Late Bronze Age. Within the pie diagrams, *N denotes* the number of species found per site.

Birds can provide a general indication of the habitat types present in the environment. Furthermore, they can confirm the presence of certain landscapes already indicated by other animals and/or botanical remains. The associations and habitats in which birds lived in the past are assumed to be similar to the present situation, as well as their behaviour.

It is also assumed that bird migratory routes in the past were similar to the routes at present. Although fluctuations do occur, the main migratory routes have remained relatively the same for the past 5000 years (Alerstam 1993, 226). Therefore, information on bird migration will be used in this research, combined with an open mind towards slight deviations from these patterns, especially regarding breeding grounds.

The same general methodology that was applied to fish was used for birds. Of every bird species found, information was gathered on their preference for certain habitats (Europese Vogelgids Online 2012; Nederlands Soortenregister 2015; Soortenbank Nederland n.d). However, since birds mainly provide information on the terrestrial landscape, and only indicate the general presence of fresh or saline water in the environment, the following habitat types were used: grassland, shrub land, trees, (freshwater) wetlands, and seacoast.

When the identification of a bird did not reach beyond the genus or family level, only preferences common to the entire genus or family, if present, were identified and included in the analysis. If these general preferences could not be applied to all the expected species within the genus or family, these birds were excluded. When a certain genus only had two possible expected species and more than two bones were found, preferences of both these species were included. Furthermore, since migratory birds may in fact prefer different habitats depending on their location, only the habitat types preferred by each species whilst present in these regions (*i.e.* mainland north-western Europe) were used. This information was obtained based on present-day migration patterns (Alerstam 1993). Widgeon (*Anas penelope*) for example, prefers grassland in the summer, when it is present in Scandinavia. In winter, however, when it is present in mainland north-western Europe, it prefers wetlands, and this habitat preference is thus used in this research. The habitat types preferred by the birds found on each site were again grouped and plotted in pie diagrams on a map of West Frisia in order to identify local and regional trends. The N denoted in each of the pie diagrams represents the number of species found on each site.

Mammals can be very good indicators of the environment. When small mammals (*i.e.* mice, voles, moles, etc.) are found at a site, they provide a local image of the direct environment surrounding a settlement. Large mammals can provide a more regional image, which can depend on migratory behaviour, as well as the size of the home range (*i.e.* the area in which the animal lives and travels). The size of the home range can furthermore give an idea of the distance of a certain habitat from the settlement.[2] The same general methodology that was applied to fish and birds was used for mammals. Of every

2. A home range analysis of mammals was performed in combination with the available botanical evidence in order to further assess the availability and extent of forest in the Bronze Age in West Frisia (Cronau 2016; Chapter 8, sections 8.2.2 and 8.2.3).

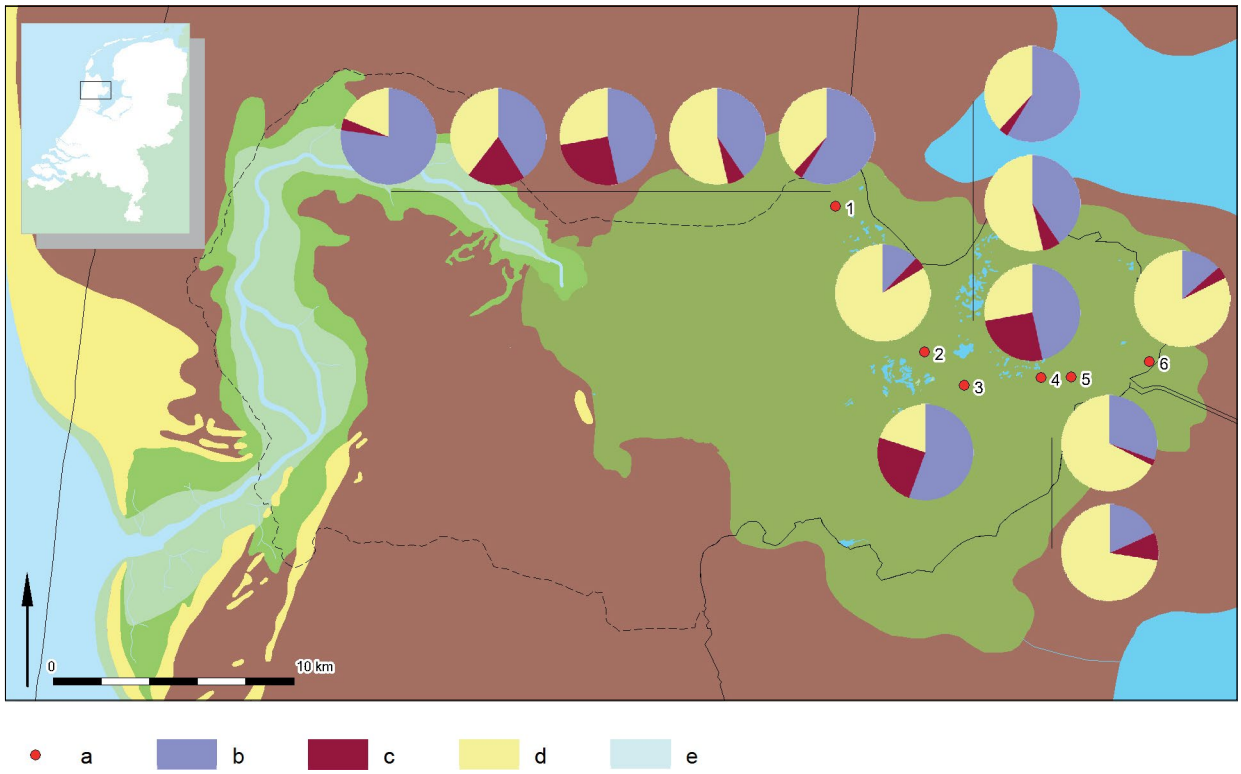


Figure 2.3. Indications for the regional landscape of West Frisia based on on-site pollen data. For the legend of the underlying map, see Figure 2.1b. a: location of an excavated site; b: upland trees and shrubs; c: oligotrophic peat; d: upland herbs; e: salt marsh; 1: Medemblik (deep pit, ard marks and settlement ditches); 2: Zwaagdijk (ditch); 3: Grootebroek (burial mounds); 4: Hoogkarspel (burial mound); 5: Bovenkarspel (deep pit and ditch); 6: Enkhuizen (ditch).

mammal species found, information was gathered on the preference for certain habitats (Twisk *et al.* 2010). These habitat preferences are based on present-day situations and it is assumed that these would have been comparable to preferences of animals in the Bronze Age. For small mammals in particular, it is assumed that they derived from the immediate environment within or around the settlement. However, in some instances, exceptions to this assumption could exist (section 2.4.5).

The types of habitat used here are the same as for birds: grassland, shrub land, trees, wetlands, and the seacoast. For mammals, the most characteristic habitat(s) for each animal was/were used for the construction of the pie diagrams; multiple preferences again resulted in inclusion in multiple habitat type groups. In cases where the identification of a mammal did not reach beyond the genus or family level, it was not possible to find common habitat preferences. Therefore, these were left out of this analysis. When there was uncertainty about the precise identification of a species, usually only two possible species were indicated by the identifying specialist. In such cases, if more than two bones were found, both of these species' preferences were included. The habitat types preferred by the mammals found were grouped for each site and pie diagrams were plotted separately for small and large mammals on a map of West Frisia in order to see local and regional trends.

In general, it must be kept in mind that in all animal groups, the habitat preferences shown in the pie diagrams do not necessarily reflect the actual ratios of habitats present in the surroundings. People actively selected certain animals from their surroundings, for reasons of abundance, personal preference, availability, etc., meaning that some species, and therefore habitat types, may have become over- or under-represented compared to the originally present

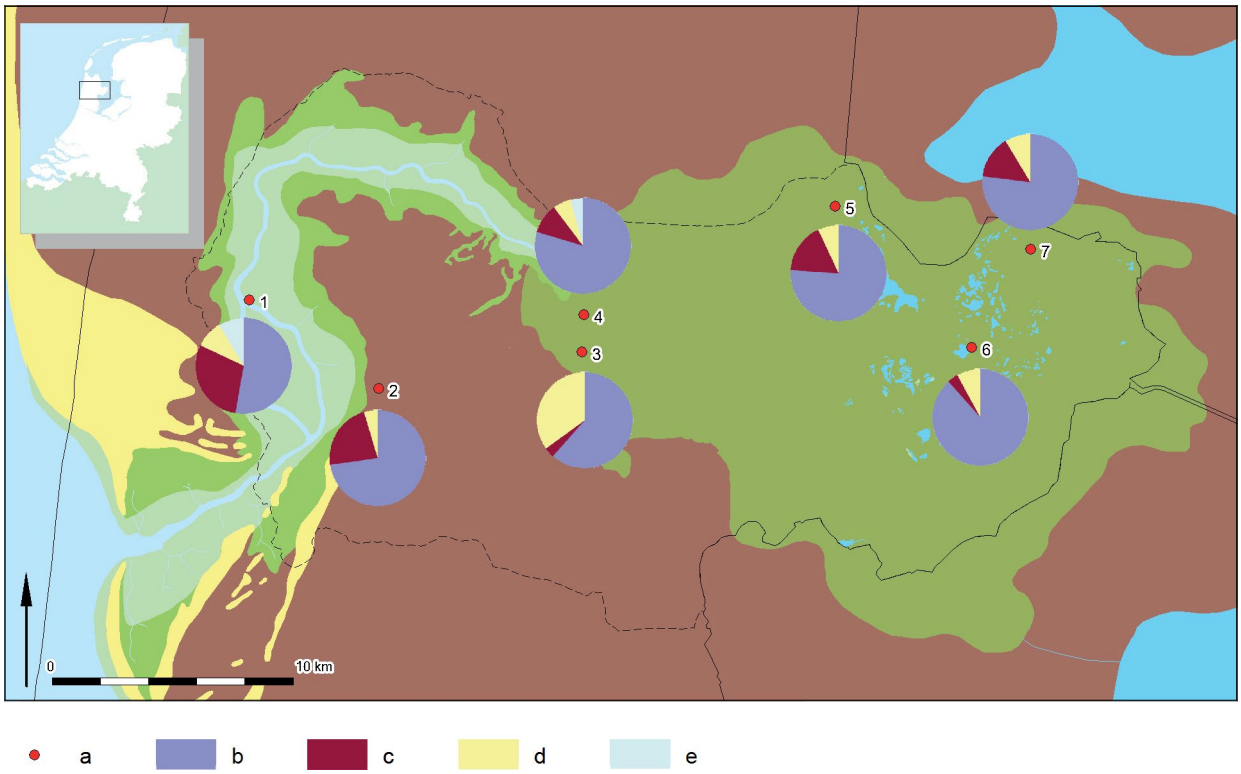


Figure 2.4. Indications for the regional landscape of West Frisia based on off-site pollen data. For the legend of the underlying map, see Figure 2.1b. a: location of an excavated site; b: upland trees and shrubs; c: oligotrophic peat; d: upland herbs; e: salt marsh; 1: Warmenhuizen; 2: Zuid-Scharwoude; 3: Opmeer; 4: Hoogwoud; 5: Medemblik; 6: Klokkeweel bog; 7: Andijk.

ratios (section 2.4.5.2). The pie diagrams should therefore only be used as a general indication of available habitats.

2.3 ARCHAEOBOTANICAL RESULTS

2.3.1 Pollen

The results of both the on-site and off-site pollen analyses are shown in Figure 2.3 and Figure 2.4, respectively. The on-site pollen deriving from settlement contexts, including Medemblik, Enkhuizen, Bovenkarspel, and Zwaagdijk, all demonstrate a very open landscape, which is a similar conclusion to that drawn in the current model. However, some of the settlement contexts of Medemblik, as well as all the burial mounds indicate a higher presence of trees in the surroundings. Seemingly, based on this new analysis of regional indicators, on-site pollen does reflect that trees grew in the surroundings of the settlements, although they do not appear to have been present in high numbers. Moreover, at several locations the presence of oligotrophic peat can also be observed, such as in burial mound and ard mark contexts, but this seems largely absent within actual settlement contexts (*e.g.* pits, ditches). Finally, no clear indicators for saline conditions are present at any of the sites.

The off-site pollen analyses almost show the reverse image of the pollen from on-site locations. Upland trees and shrubs constitute a large portion of every diagram, indicating that the surroundings of the Bronze Age settlements were indeed far from treeless. In several of the diagrams, indicators of oligotrophic peat were present, suggesting that this type of peat did exist in the further surroundings of the settlements, although nearly none was found within settlement contexts. Finally, indicators of salt marsh

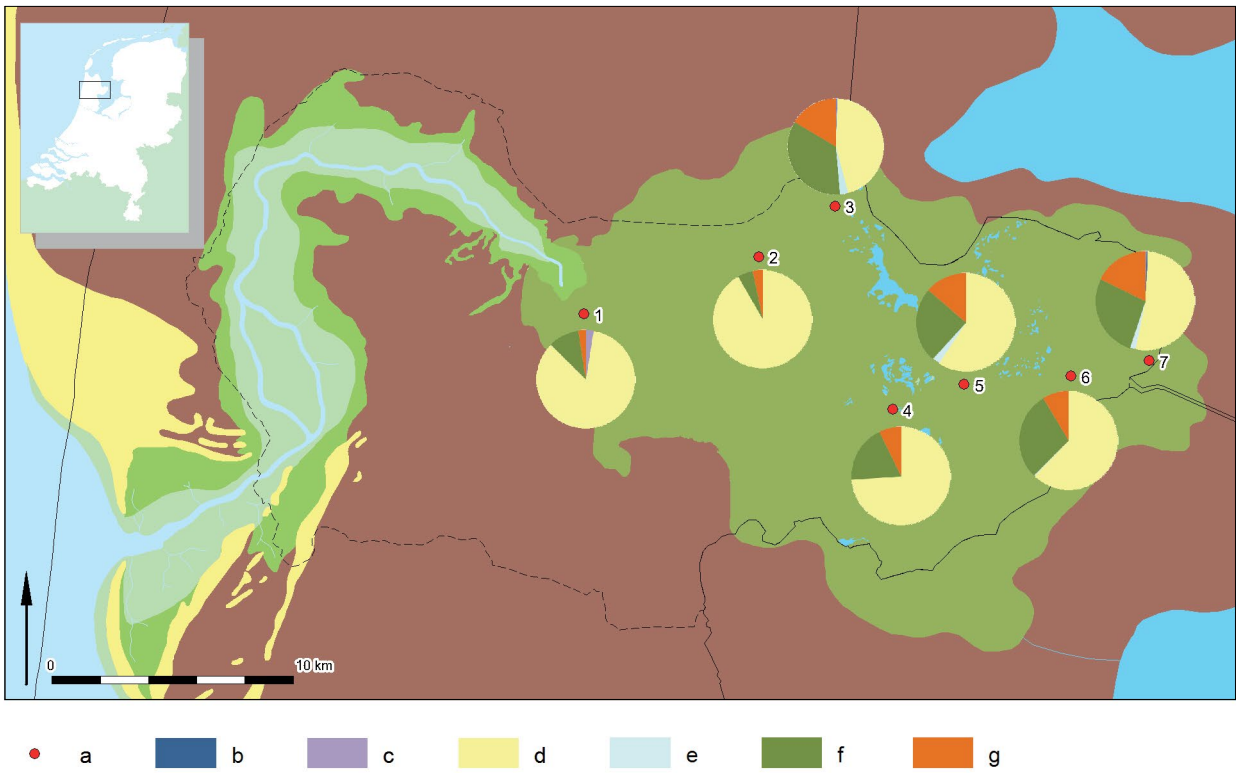


Figure 2.5. Indications for the regional landscape of West Frisia based on macro botanical data. For the legend of the underlying map, see Figure 2.1b. a: location of an excavated site; b: upland trees and shrubs; c: wetland trees and shrubs; d: upland herbs; e: salt marsh; f: wetland herbs; g: wet, trodden soils; 1: Hoogwoud; 2: Twisk; 3: Medemblik; 4: Westwoud; 5: Hoogkarspel; 6: Bovenkarspel; 7: Enkhuizen.

were mainly present in Hoogwoud and Schagen. One salt marsh indicator was also found in the Klokkeweel bog (near Hoogkarspel), but this was not a definitive identification (*i.e. Plantago* cf *coronopus*), so it does not necessarily reflect (local) saltwater conditions. Other proxies will have to indicate whether salt marshes existed in the eastern part of West Frisia.

2.3.2 Botanical macro remains

In Figure 2.5, the results of the botanical macro remains analysis are plotted. For this analysis, all the remains from the Middle and the Late Bronze Age are pooled. Besides these remains, remains of wood are relatively scarce in West Frisia, but at Bovenkarspel and Westwoud, several wood remains were found, which are summarized in Figure 2.6.

The major share of each of the pie diagrams consists of upland herbs, followed by wetland herbs, and herbs from wet, trodden soils. Although this by no means signifies a mainly dry landscape, it does show that both wet (freshwater) and dry open areas were present in the surroundings of the settlements. Again, no indications for peat are found at any of the researched locations.

Salt marsh indicators were observed on several occasions. However, upon closer inspection, these plant remains were all found in deep pits or deep ditches, which were dug into former tidal marsh deposits. They can therefore be interpreted as contamination from earlier periods, and do not signify the presence of a salt marsh in the surroundings of the settlements.

Trees and shrubs, both of upland and wetland origin, are very sparsely represented in the macro botanical record by catkins, and some fruits and nuts. Their near-absence is often interpreted as evidence for the presence of an open landscape (*i.e.* the current

model). In the wood record however, although limited in quantity, it is clear that a wide variety of tree species must have been available during the Bronze Age in West Frisia.

2.3.3 Vegetation reconstruction of eastern West Frisia

The vegetation reconstruction of eastern West Frisia was divided into the Middle and Late Bronze Age periods. This division was made because a supposed deterioration of the climate occurs in the Late Bronze Age (section 2.1), and this may only become apparent when comparing the two periods.

Middle Bronze Age

The general indications for different types of habitat present in the surroundings of the settlements obtained from the archeaobotanical remains was researched in finer detail by creating an actual vegetation reconstruction.

The vegetation of West Frisia in the Middle and Late Bronze Age was reconstructed by Van Zijverden by using a combination of disciplines (van Zijverden forthcoming). Physical geography was employed to reconstruct the properties of the existing soils in the Bronze Age. Important soil characteristics and processes which influence the growth of vegetation include relief, hydrology, subsoil, and water fluctuation. Each of these factors was reconstructed for the West Frisian situation in the Middle and Late Bronze Age, thus creating a soil suitability map (van Zijverden forthcoming). Subsequently, this map, with its reconstructed combinations of indicator values for plant growth, was used to predict the possible vegetation types at different locations in the landscape. However, possible vegetation types were not only selected based on their preferences for the reconstructed soil conditions. The second selection step was based on the availability of plant species in the Bronze Age. With the aid of phytosociology, the presence of diagnostic species for certain vegetation types in the macro remains from settlements was used, since these diagnostic species can, per definition, signify either general phytosociological vegetation classes, or even specific plant associations. However, it must

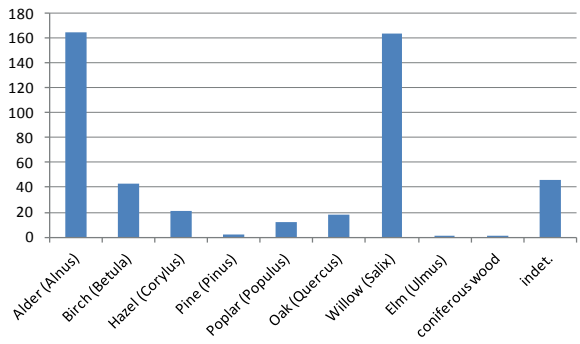


Figure 2.6. Frequency of wood remains from different species found at both Bovenkarspel and Westwoud. Data is pooled for the entire Bronze Age.

be kept in mind that the name of a vegetation class is not necessarily linked to the diagnostic species within the underlying plant associations, so class names can be very misleading when not further examined. For example, the class *Querco-Fagetea* would suggest a forest with both oak and beech trees. However, several of the subdivisions within this class do not require beech at all. These aspects of phytosociology should be taken into consideration when applying vegetation to different soil types, since the different phytosociological classes and associations are often specific for certain soil conditions. They can therefore provide additional information on all the different succession stages which can occur on such soils. When diagnostic species cannot be identified, especially for multiple stages of succession, there is a possible indication for the absence of certain vegetation types in the surroundings.

Based on this approach, the following vegetation types were reconstructed based on the different soil properties within the Middle and the Late Bronze Age landscape, here exemplified by the area around Westwoud, with a focus on the climax succession stages where possible (van Zijverden forthcoming; Figure 2.7 and Figure 2.8):

In the Middle Bronze Age (Figure 2.7), alder carrs would cover lower lying areas with high ground water and stagnant, eutrophic water conditions. This class (*Alnetea-Glutinosae*), can further be subdivided in alder carr with an undergrowth of ferns (*Thelypterido-Alnetum*) or sedges (*Carici*

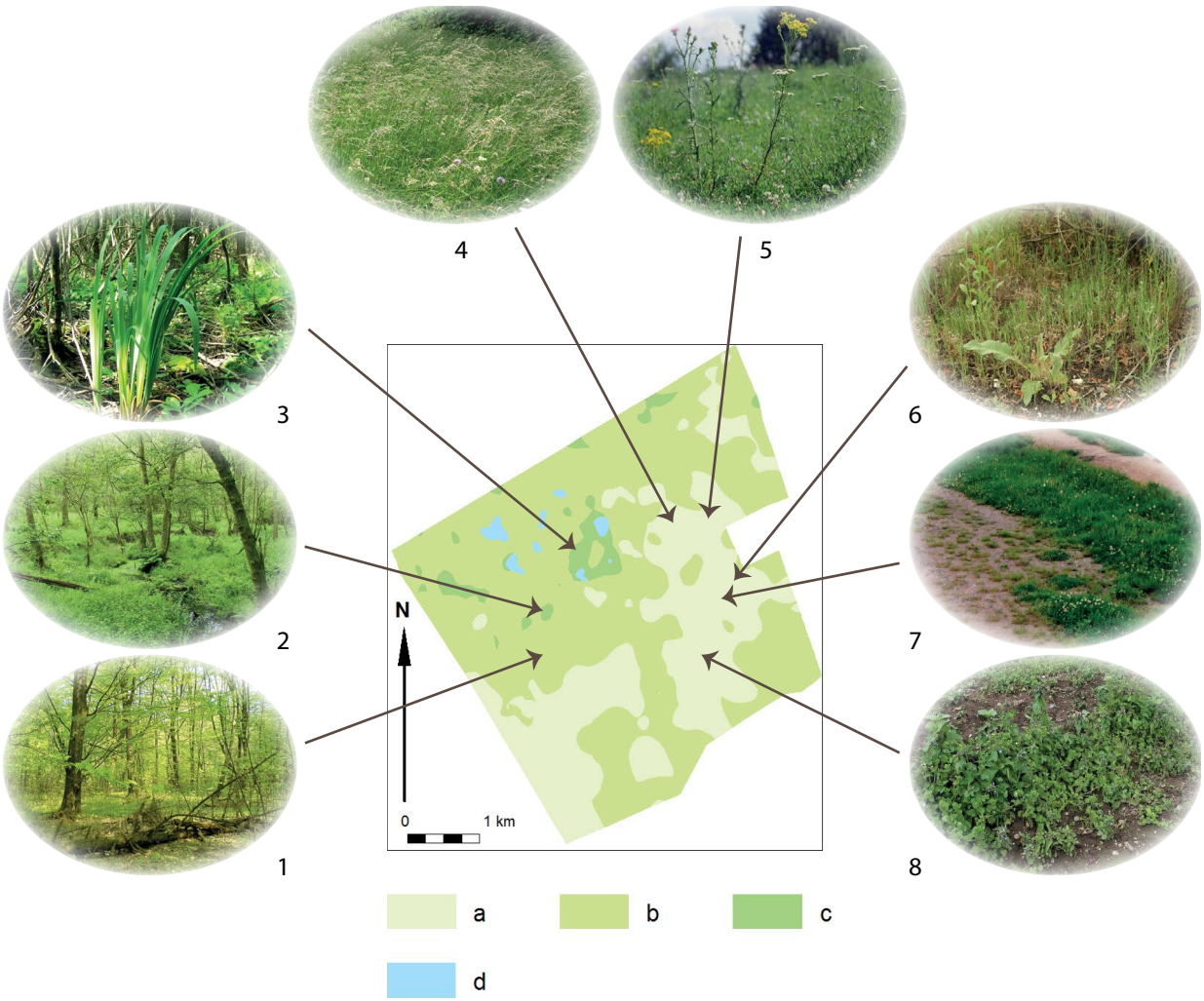


Figure 2.7. Overview of the different vegetation types[3] present in the Middle Bronze Age, exemplified by the area around Westwoud (map from: van Zijverden forthcoming). a: medium clay content in top and subsoil; b: high clay content in top soil and medium clay content in subsoil; c: medium clay content in top soil and high clay content in subsoil; d: high clay content in top and subsoil; e: fresh water lake; 1: *Fraxino-Ulmetum*; 2: Thelypterido-Alnetum; 3: *Carici elongatae-Alnetum*; 4: *Arrhenatherion elatorius*; 5: *Cynosurion cristati*; 6: *Salsolion ruthenicae*; 7: *Polygonion avicularis*; 8: *Fumario-Euphorbion*.

elongatae-Alnetum). Both of these remain a possibility since no specific indications for each of these subdivisions were available in West Frisia.In the slightly drier areas of the landscape, the forest type *Querco-Fagetea* could exist. Further subdivisions of this class were possible based on the specific soil conditions of West Frisia. The high calcium carbonate content, local high ground water level, and presence of several diagnostic species led to the identification of a *Fraxino-Ulmetum* forest type. Alternatively, a *Viola odorata-Ulmetum* forest could have developed, although no diagnostic species for this association were present in the West Frisian data.

3. Photos adapted from: *Carici elongatae-Alnetum* 2006; *Fraxino-Ulmetum* 2006; *Polygonion avicularis* 2006; Thelyptherido-Alnetum 2006; Arrhenatheretea elatioris 2007; *Artemisio-Salicetum albae* 2007; *Cynosurion cristati* 2007; Oenanthion-aquaticae 2007; Chytrý 2009, 129, fig 94; *Sparganio-Glycerion* 2010; *Fumario-Euphorbion* 2016

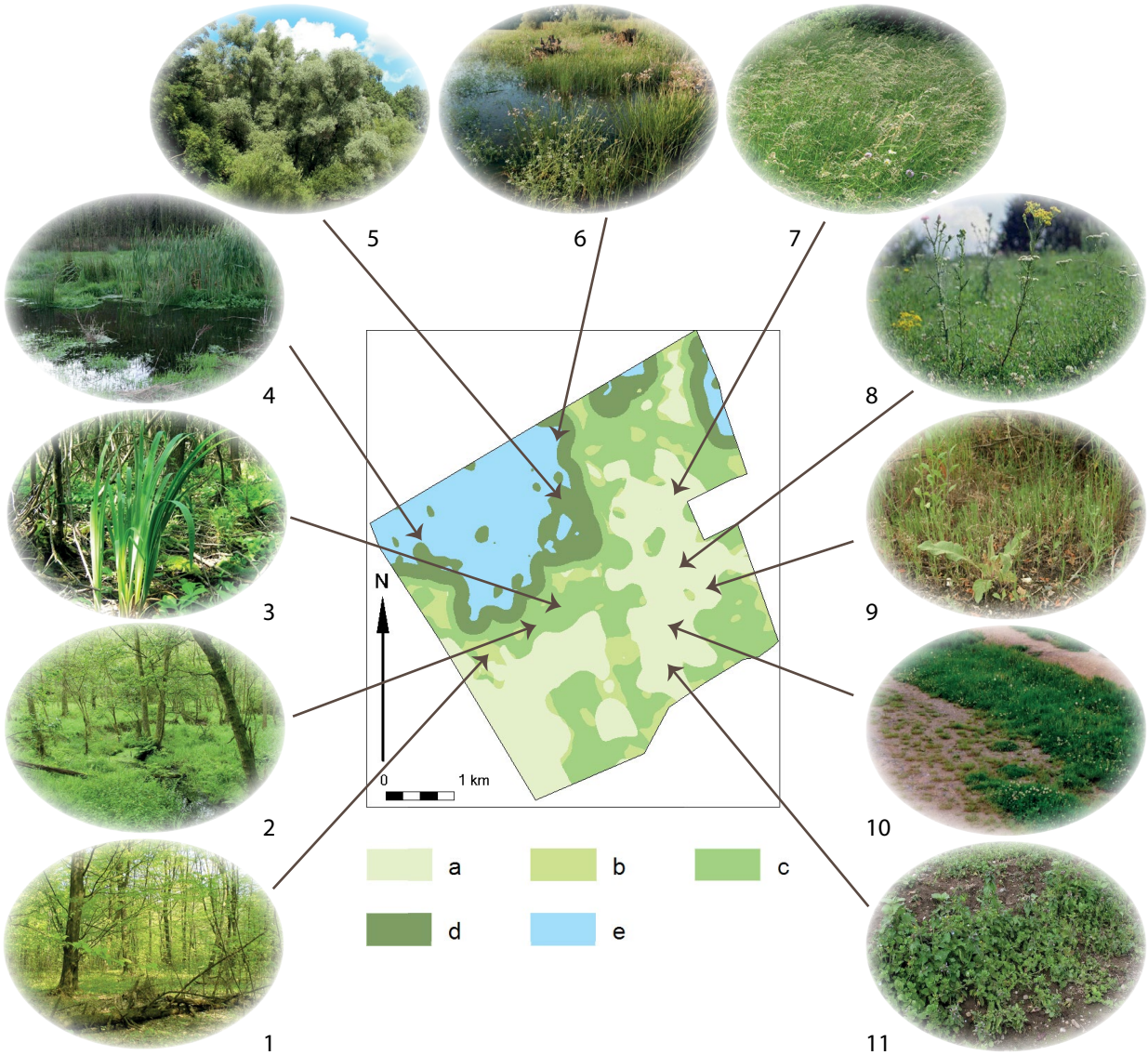


Figure 2.8. Overview of the different vegetation types[4] present in the Late Bronze Age, exemplified by the area around Westwoud (map from: van Zijverden forthcoming). a: medium clay content in top and subsoil; b: high clay content in top soil and medium clay content in subsoil; c: medium clay content in top soil and high clay content in subsoil; d: high clay content in top and subsoil; e: fresh water lake; 1: *Fraxino-Ulmetum*; 2: Thelyptherido-Alnetum; 3: *Carici elongatae-Alnetum*; 4: Oenanthion-aquaticae; 5: *Artemisio-Salicetum albae*; 6: *Sparganio-Glycerion*; 7: *Arrhenatherion elatorius*; 8: *Cynosurion cristati*; 9: *Salsolion ruthenicae*; 10: *Polygonion avicularis*; 11: *Fumario-Euphorbion*.

At the driest areas in the landscape, again a *Querco-Fagetea* type forest could develop, and based on the soil nutrition and the relatively lower ground water table at these locations, a *Carpinion-Betuli* forest subdivision was expected here. However, no diagnostic species for this succession stage were present in the pollen and macro botanical data. Diagnostic species for the edges of this type of forest, including sloe (*Prunus spinosa*) were also absent in West Frisia, although remains of its fruits

4. Photos adapted from: *Carici elongatae-Alnetum* 2006; *Fraxino-Ulmetum* 2006; *Polygonion avicularis* 2006; Thelyptherido-Alnetum 2006; Arrhenatheretea elatioris 2007; *Cynosurion cristati* 2007; Chytrý 2009, 129, fig 94; *Fumario-Euphorbion* 2016

are commonly found on Bronze Age settlements in other areas of the Netherlands. Clear diagnostic species of the plant community occurring in a succession stage before that of the forest edge (*Galio-Alliarion*), were also absent. Definite evidence of the succession related to the *Carpinion-Betuli* forest was only present in the form of moderately nutrient-rich grasslands (*Molinio-Arrhenatheretea*). These grasslands could be further subdivided into two possible grassland associations (*Arrhenatherion elatorius* and/or *Cynosurion cristati*). The definite absence of most of the succession stages towards climax vegetation on the driest soils of West Frisia indicates that this type of slow growing forest may never have had the chance to fully develop in the Bronze Age, or at least not to the extent that remains are visible in the researched settlement contexts. Although some patches of this forest type may have remained in some areas, overall, grasslands will have prevailed.

Human influence could be very well be the reason for this absence of dry forest, which becomes apparent based on the presence of human-induced open areas. Ruderal vegetation could be identified (*Artemisietea vulgaris*, *Salsolion ruthenicae*), as well as arable-related vegetation (*Stellarietea mediae*, *Fumario-Euphorbion*), and trampled, moderate nutrient-rich grassland (*Plantaginetea majori*, *Polygonion avicularis*).

Late Bronze Age

The Late Bronze Age landscape (Figure 2.8) largely contains the same vegetation types as the Middle Bronze Age. However, since during this time both ground water levels as well as surface water fluctuations increase, additional vegetation types appear, and previously present vegetation types sometimes experience a shift in location within the landscape.

In the Late Bronze Age, the lowest areas in the landscape develop into shallow lakes characterised by reed swamp vegetation (*Phragmitetea*), which could be further subdivided into two possible orders (*Sparganio-Glycerion* and/or *Oenanthion aquaticae*). Along the lake borders, wood willow shrubs thrived (*Artemisio-Salicetum albae*). The influence of the increased water table height and increased water fluctuation caused the remaining (drier) vegetation types to condense into smaller areas. The influence of the landscape on the subsistence farming economy and vice versa will be further explored in Chapters 4-8.

2.3.4 Summary

The use of off-site pollen has yielded several new results and insights. Off-site pollen reflects a very different image than the current model, showing the definite presence of trees in the (further) surroundings of the settlements. Also, based on the comparison with on-site pollen, it is clear that peat growth does occur in the Bronze Age, but not on such a large scale that it covered the settlement areas. Excessive peat growth can therefore not be viewed as the cause for abandonment of the area, since even in Late Bronze Age contexts, such as the deep pit sample from Bovenkarspel, almost no indicators for peat are present. Finally, some indications for saline influence in West Frisia are observed, mainly in Schagen and Hoogwoud. Other proxies will have to clarify whether this influence can be placed before or after 1550 BC, since such exact dates for the pollen diagrams were not available.

Botanical macro remains have provided information on several aspects related to the landscape as well. First, there is an absence of clear saltwater indicators throughout West Frisia, seemingly confirming the presence of a freshwater environment. However, the animal proxies need to be consulted before finally drawing this conclusion. Also, the obvious lack of peat indicators appears to confirm the conclusion based on pollen remains, namely that peat did not grow to the extent that it covered the settlements. Finally, the presence of a range of available tree species was only indicated well by the wood finds, rather than by the macro botanical finds.

The vegetation reconstruction finally, has provided a clear image of the possible vegetation types present around the settlements in each time period. In addition, it has enabled the identification of human influence through the absence of certain succession stages, and the presence of human-induced vegetation types. In this manner, the reconstruction has created

an idea of both the natural and cultivated landscapes during the Bronze Age.

2.3.5 Discussion

In order to assess the reason why the present results are so different from the past view of the West Frisian landscape, several aspects related to past and recent methodology regarding the archaeobotanical record will be discussed. In addition, possible indicators for the cultural landscape will be discussed, in order to identify markers of human impact on the environment based on the archaeobotanical proxies.

2.3.5.1 Methodology

Pollen

The striking difference in the amount of trees present in the surroundings represented by on-site and off-site pollen samples can mainly be explained by the applied methodology in the field. The sampling location of on-site pollen is often restricted to deep pits and deep ditches, where preservation conditions are relatively good. However, these contexts consist of a basin (*i.e.* location in which pollen can precipitate) with a very small diameter in which pollen can accumulate. Since a basin with a small diameter can, by definition, only be used to interpret the area surrounding the sampled location (Sugita 1994; Sugita *et al.* 1999), the resulting pollen diagram will therefore reflect only a very local image of the landscape. Ideally, pollen samples for interpretation of the wider surroundings of the sampled location should derive from basins of more than 5 meter in diameter (Sugita 1994; Sugita *et al.* 1999). Since the on-site sampled contexts all consist of a small diameter and all lie well within the settlement, the analysed pollen diagrams will naturally represent an open landscape, which is the settlement landscape itself. Samples from the peat layers present within the StiBoKa data from off-site locations, allow for a clear regional picture, indicating that trees formed a definitive part of the (wider) surroundings of the settlement. Therefore, in order to create a reliable regional vegetation reconstruction, pollen samples should preferably be taken from off-site locations or basins with an appropriate diameter. Furthermore, the usual methodology applied within palynological research could also be modified in order to more precisely identify regional vegetation, such as was performed here by creating a pollen sum of regional versus local vegetation, rather than tree versus herb pollen.

Macro remains

Trees and shrubs, both of upland and wetland origin, are very sparsely represented in the macro botanical record, including only the remains catkins, and some fruits and nuts. In the past, their near-absence has often been interpreted as evidence for the presence of an open landscape (*i.e.* the current landscape reconstruction model). Conclusions based on this single proxy have proven not to be adequate in reconstructing the presence of trees in the wider landscape. However, by combining this information with the remains of wood and off-site pollen, a clearer picture can be obtained of the variety of tree species available to people in the area.

2.3.5.2 Indicators for the cultivated landscape

Pollen

Indicators for the cultivated landscape within the pollen record may include several types of pollen. For example, pollen from cereals (*Cerealia*) and crop weeds can indicate cultivation in the near surroundings, declining tree pollen and increasing pollen of pioneer vegetation can indicate increased pressure of humans on the (forest) environment, and finally the occurrence of nitrophilous plants, can indicate use of manure (for an overview see Li 2008 and references therein). A combination of this pollen can be used to identify human activity. In general, several of these indicators were recognized in the West Frisian pollen diagrams. The on-site pollen showed the presence of cereal pollen, which is an extra confirmation of crop cultivation in the surroundings of the settlements. Off-site pollen showed a decreasing trend of tree pollen towards the end of the Subboreal period. The combination of on-site and off-site pollen does seem to indicate that throughout the Bronze Age, people were increasingly cultivating the available land at the expense of surrounding forests. The extent of this impact will be researched in Chapter 8, section 8.2.

Macro remains
Cereals and chaff provide the most direct indications for cultivation, and these are found in high frequencies in the archaeobotanical record (Chapter 5: Crop husbandry). Other indications for the cultivation of the landscape include many plants that signify wet, trodden environments (Figure 2.5), many nitrophilous plant species, as well as pioneer vegetation. The remains of wood from several different species from both the Middle and Late Bronze Age also confirm the use of the surrounding forest in both periods. No clear change in the use of wood could be established between these periods, indicating that even though people were impacting the forests in the Late Bronze Age, they were still present.

2.4 ARCHAEOZOOLOGICAL RESULTS

As shortly introduced at the beginning of this chapter, the new approach here is mainly concerned with the comparison between expectation and data. In addition, the use of three different groups of animals (fish, birds, and mammals) is presented and discussed, which is a rich, but often neglected potential source of information for landscape reconstruction.

2.4.1 Fish

Three main topics will be discussed here regarding the environment related to fish, firstly whether the fish species present in West Frisia match with what was expected (Appendix A1.2), so that outliers or missing species will become apparent. Secondly and thirdly, the water type preference as well as the maximum salinity tolerance of all the species from the West Frisian sites will be discussed, also in relation to the location where these fish remains were excavated. These three factors together will provide information on the aquatic landscape surrounding the settlements. An overview will be created for the entire Bronze Age, as well as for the Middle Bronze Age (MBA) and Late Bronze Age (LBA). This separation into two periods is necessary to be able to identify possible changes in the aquatic landscape through time.

2.4.1.1 Observed species and habitat types

A list of all the fish species found in West Frisia is shown in Table 2.4 and an overview of their presence per site in Table 2.5. In Table 2.4, the fish are sorted according to their preferred habitat type, and subsequently by alphabetic order. To increase the readability of the table, the different habitat types are identified by different colours. In addition, the general trends in water salinity and water flow are denoted by arrows alongside the axes of the table. The references for the information acquired on habitat type and salinity level are also included in the table. Species that do not list a reference for maximum salinity tolerance live under saline conditions and are therefore considered to have a salinity tolerance value of > 30 ppt (cf. Table 2.3).

The fish species found have representatives of all the expected aquatic habitats, so it is clear that there was great diversity in fish species present in West Frisia. Many of the fish species seem to prefer stagnant to slow-flowing waters. The open water habitat is also relatively well represented. Species that have an additional preference for fast-flowing water were also found, but many species preferring solely this habitat type were not uncovered. Migratory fish species, requiring a connection to the sea, are abundant and can be divided into two groups: anadromous fish, which travel from saltwater to fresh water to reproduce, and catadromous fish, travelling in the other direction. Another nine fish species prefer an open sea habitat, which are all the expected species for this habitat type (Appendix A1.2). Only two fish species have a non-specific habitat preference. Maximum salinity tolerances finally, range from very low salt levels to saline conditions. Interestingly enough, no salt-intolerant fish species were found.

To the right: General increasing salinity is denoted on the y-axis, whereas general increasing water flow is denoted on the x-axis. Differently coloured captions indicate different habitat types. f: fast-flowing water; sea conn: sea connection; sl: slow-flowing water; st: stagnant water; open: open water; ref: reference; 1: Vissengids 2016; 2: Marine Fish Map 2016; 3: Copp *et al.* 2009. Species that do not list a reference for maximum salinity tolerance can live under saline conditions and are therefore considered to have a salinity tolerance value of > 30 ppt.

Table 2.4. Overview of all the fish species found in West Frisia arranged by preferred water type and maximum salinity tolerance.

Water type preference	open sea	open sea	open sea	open sea	open sea	open sea	open sea	open sea	open sea
Taxa	*Clupea harengus*	*Dasyatis pastinaca*	*Dicentrarchus labrax*	*Eutrigla gurnardus*	*Gadus morhua*	*Pleuronectus platessa*	*Raja clavata*	*Solea solea*	*Sprattus sprattus*
English name	Atlantic Herring	Stingray	Sea bass	Grey gurnard	Atlantic Cod	Plaice	Thornback ray	Sole	Sprat
fish type (migratory)									
max. salinity (ppt)	saline	saline	saline	saline	saline	saline	saline	saline	saline
ref water	1	2	1	2	2	2	2	2	1

Water type preference	sea conn	sea conn	sea conn	sea conn, sl	sea conn, sl	sea conn, sl	sea conn, f	sea conn, f	sea conn, f	sea conn, f
Taxa	*Anguilla anguilla*	*Osmerus*	*Platichthys flesus*	*Alosa fallax*	*Liza aurata*	*Liza ramada*	*Acipenser sturio*	*Alosa alosa*	*Coregonus sp*	*Salmonidae* indet.
English name	Eel	Smelt	Flounder	Twaite shad	Golden grey mullet	Thinlip mullet	Sturgeon	Allis shad	Whitefishes	Salmon-family
fish type (migratory)	catadrome	anadrome	catadrome	anadrome	catadrome	catadrome	anadrome	anadrome	anadrome	anadrome
max. salinity (ppt)	saline	saline	saline	saline	saline	saline	saline	saline	saline	saline
ref water	1	1	1	1	1	1	1	1	1	1
ref salinity										

Water type preference	open	open, st, sl	open, st, sl	open, sl
Taxa	*Gymnocephalus cernuus*	*Perca fluviatilis*	*Siluris glanis*	*Alburnus alburnus*
English name	Ruffe	Perch	Catfish	Bleak
fish type (migratory)				
max. salinity (ppt)	10-12	4.4-8.3	<15	10
ref water	1	1	1	1
ref salinity	1	1	3	1

Water type preference	open, f
Taxa	*Leuciscus idus*
English name	Ide
	15
	1
	1

Water type preference	st,sl	st,sl	st,sl	st,sl	st,sl	st,sl
Taxa	*Abramis brama*	*Blicca bjoerkna*	*Esox lucius*	*Pungitius pungitius*	*Scardinius erythrophthalmus*	*Tinca tinca*
English name	Bream	Silver bream	Pike	10-spined Stickleback	Common rudd	Tench
fish type (migratory)						
max. salinity (ppt)	10	1-10	5-15	<15	1-10	<12
ref water	1	1	1	1	1	1
ref salinity	1	1	1	1	1	1

Water type preference	non-specific, sea conn	non-specific
Taxa	*Gasterosteus aculeatus*	*Rutilus rutilus*
English name	3-spined Stickleback	Roach
fish type (migratory)	anadrome	
max. salinity (ppt)	saline	4-5 (adults)
ref water	1	1
ref salinity		1

Increasing maximum salinity tolerance

Increasing water flow preference

Table 2.5. Overview of the frequency of fish species found at each of the Bronze Age sites.

Taxa	English name	Boven-karspel	Enk-huizen	Medem-blik	West-woud	Hoog-woud	Schagen	Freq.
Anguilla anguilla	Eel	x	x	x	x	x	x	6
Esox lucius	Pike	x	x	x	x	x	x	6
Abramis brama	Bream	x	x	x	x	x		5
Perca fluviatilis	Perch	x	x	x	x		x	5
Abramis bjoerkna	Silver bream	x	x	x				3
Gasterosteus aculeatus	3-spined Stickleback	x			x		x	3
Rutilus rutilus	Roach	x	x	x				3
Alburnus alburnus	Bleak	x	x					2
Dicentrarchus labrax	Sea bass					x	x	2
Liza ramada	Thin-lipped mullet					x	x	2
Platichthys flesus	Flounder					x	x	2
Pungitius pungitius	10-spined Stickleback	x			x			2
Raja clavata	Thornback ray					x	x	2
Scardinius erythrophthalmus	Common rudd		x	x				2
Siluris glanis	Catfish	x	x					2
Acipenser sturio	Sturgeon						x	1
Alosa alosa	Allis shad						x	1
Alosa fallax	Twaite shad						x	1
Alosa alosa/fallax	Allis/Twaite shad						x	1
Clupea harengus	Herring						x	1
Clupea harengus/ Sprattus sprattus	Herring/Sprat						x	1
Dasyatis pastinaca	Stingray						x	1
Eutrigla gurnardus	Grey gurnard		x					1
Gadus morhua	Cod					x		1
Gymnocephalus cernuus	Ruffe	x						1
Leuciscus idus	Ide	x						1

Taxa	English name	Boven-karspel	Enk-huizen	Medem-blik	West-woud	Hoog-woud	Schagen	Freq.
Liza ramada/aurata	Thin-lipped/ Golden mullet						x	1
Osmerus eperlanus	Smelt						x	1
Pleuronectus platessa	Plaice					x		1
Solea solea	Sole						x	1
Tinca tinca	Tench	x						1

Presence of a species is denoted by an 'x'. Salmonidae indet. could be either Atlantic salmon (Salmo salar) or sea trout (*Salmo trutta*). Cyprinidae, or cyprinids, could include the species bream, silver bream, roach, bleak, common rudd, ruffe, ide, and tench.

2.4.1.2 Bronze Age overview

The species, as shown in Table 2.4, are grouped together independent of their location in West Frisia, and also independent of the time period to which the site at which these fish were found was dated. This grouping was performed in order to first obtain a general idea of the habitat types present in West Frisia. This general idea allows for the recognition of major habitat types which were present throughout the Bronze Age. In Table 2.5, representing the Bronze Age overview of fish at the different sites, the species are arranged for each site to show which of the habitat type and salinity preferences were present in each area of West Frisia. The Bronze Age overview in addition allows for the inclusion of Schagen, an Early Bronze Age site.

A clear difference in habitat type preference can be seen between sites in the west and the sites in the east. Schagen and Hoogwoud mainly show preferences for open sea and a sea connection, whereas Medemblik, Enkhuizen, Westwoud, Bovenkarspel show preferences for stagnant-slow and open water.

Again, a clear difference can be seen between sites in the west and the sites in the east. Schagen and Hoogwoud show an abundance of saltwater tolerant species, whereas in Medemblik, Enkhuizen, Westwoud, and Bovenkarspel the fish overall show lower salinity tolerance levels.

In Figure 2.9, pie diagrams are plotted of the species composition of every site. The colours in these diagrams are related to the colours used in Table 2.4, denoting the different habitat type preferences. In this figure, no distinction in date of the sites was made, so the entire Bronze Age is included. Schagen, which is the only site dated to the Early Bronze Age, can only give indications for habitat types that existed before the occupation of the other sites. Although water habitat types of fish from Schagen might have remained relatively unchanged throughout the Bronze Age, there is no fish data available from that area during later periods, so this remains inconclusive.

It becomes clear from Figure 2.9 that a distinction can be made between sites in the west and the east of West Frisia. At Schagen and Hoogwoud, in the west of West Frisia, the most frequently preferred habitat types are the open sea and a connection to the sea. In Schagen, however, a wider range of habitat types is present than in Hoogwoud.

In the eastern sites, Medemblik, Enkhuizen, Westwoud, and Bovenkarspel, there is a tendency towards a preference for stagnant to slow-flowing water. In Enkhuizen and Bovenkarspel, the additional preferences for open water appear to be more prevailing than in Westwoud and Medemblik. Finally, fish that prefer a connection to the sea also appear at every site in the east of West Frisia.

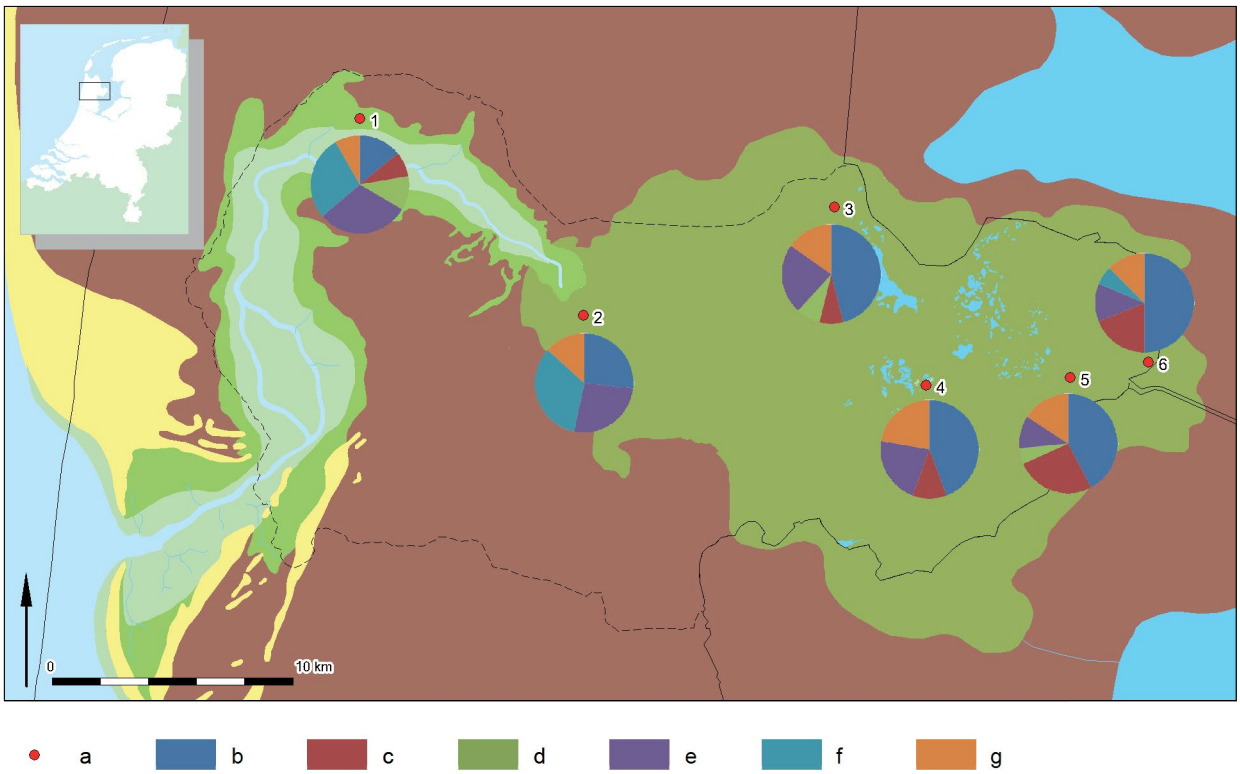


Figure 2.9. Map of Bronze Age West Frisia with the water habitat preferences of the fish species found at each site. N denotes the number of species found at each site. For the legend of the underlying map, see Figure 2.1b. a: location of an excavated site; b: stagnant to slow-flowing water; c: open water; d: fast-flowing water (river); e: sea connection; f: open sea; g: non-specific preference; 1: Schagen, n=23; 2: Hoogwoud, n=11; 3: Medemblik, n=9; 4: Westwoud, n=6; 5: Bovenkarspel, n=13; 6: Enkhuizen, n=12.

Only one aberrant habitat preference (*i.e.* outlier) was observed, in the fish assemblage of Enkhuizen. Here, a preference for the open sea was apparent, represented by one bone of grey gurnard (*Eutrigla gurnardus*) found at this location. No indications for the direct influx of sea water in this area (yet) exist (including results based on other proxies), and no other open sea species were found here or at any of the other eastern sites. This one fish bone is considered an outlier that does not reflect the local environment of Enkhuizen in the Bronze Age because this saltwater species does not fit in the prevailing habitats based on the other species and proxies.

The diagrams for maximum salinity tolerance of the fish species found depict a similar trend, as seen in Figure 2.10. In Schagen and Hoogwoud, the maximum salinity tolerance of species is high; most species tolerate saltwater conditions. Conversely, in the eastern sites, the maximum tolerated levels of salinity are mostly light to medium brackish. Overall, in eastern West Frisia, the maximum tolerance level in Medemblik and Enkhuizen seems to be relatively lower than in Westwoud and Bovenkarspel.

2.4.1.3 Middle Bronze Age

Figure 2.11 shows the water type preference of fish from Middle Bronze Age (MBA) contexts.

From this figure, it is apparent that the trend observed in the general Bronze Age situation is maintained; Hoogwoud reflects a mostly saltwater environment. The maximum salinity tolerance diagrams for the Middle Bronze Age (Figure 2.12) show the division between Hoogwoud and the eastern sites during this time even more clearly. The presence of both saltwater fish species as well as migratory

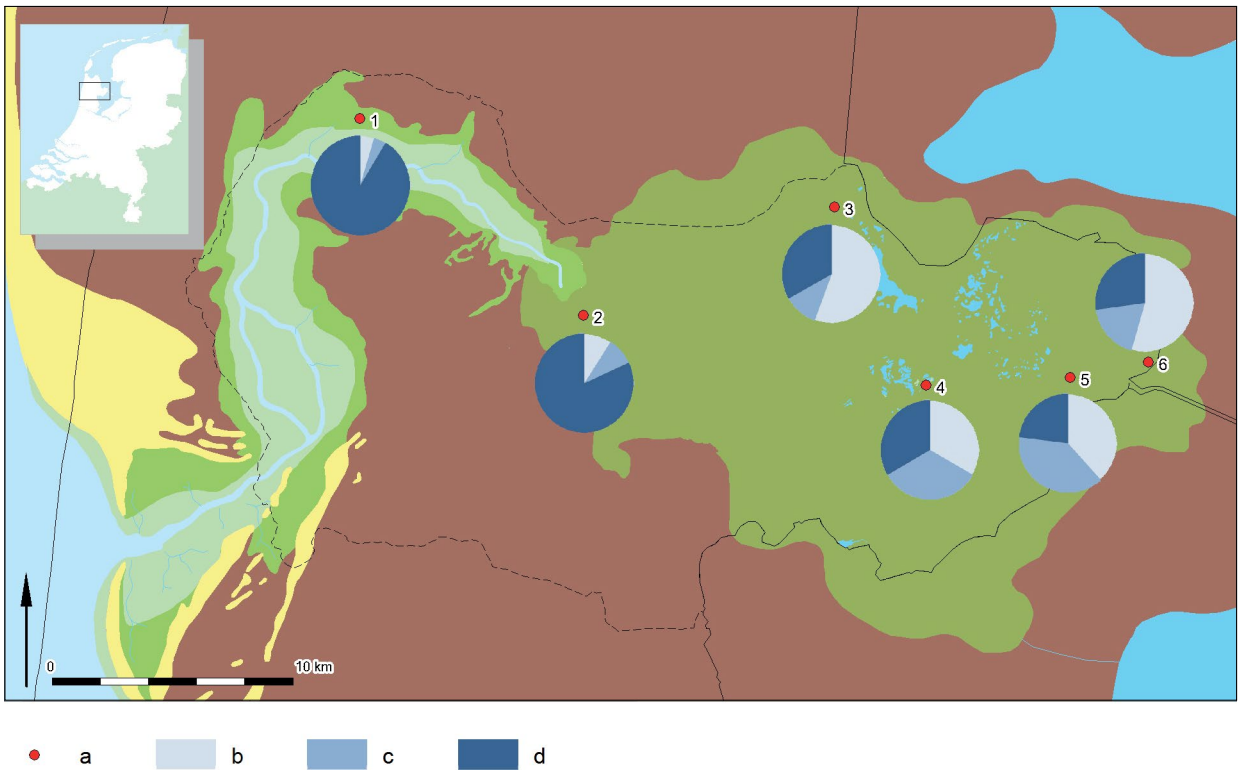


Figure 2.10. Map of Bronze Age West Frisia with maximum salinity tolerance of fish species found at each site. N denotes the number of species found at each site. For the legend of the underlying map, see Figure 2.1b. a: location of an excavated site; b: fresh to slightly brackish water (0-10 ppt); c: medium brackish water (10-15 ppt); d: salt water (more than 30 ppt); 1: Schagen, n=23;2: Hoogwoud, n=11; 3: Medemblik, n=9; 4: Westwoud, n=6; 5: Bovenkarspel, n=13; 6: Enkhuizen, n=12.

fish species inherently means that saline influence in the hinterland (*i.e.* at least until Hoogwoud) was still present until at least 1300-1100 BC. This new observation starkly contrasts with the conclusions of the current model, which place the closure of the seacoast around 1550 BC. In this case, fish as an environmental proxy have provided clear evidence for the new sea coastal model[5].

The fish from the eastern sites of West Frisia, including Medemblik, Enkhuizen, Westwoud, and Bovenkarspel, display a maximum tolerance of only low levels of salinity. However, no species were uncovered that can only live in purely freshwater conditions, such as barbel (*Barbus barbus*) (Appendix A1.2). Therefore, (very) low levels of salinity are proposed for the surrounding waters of the eastern West Frisian sites, possibly even reflecting the salinity levels of the large lakes east of this area during this time (Figure 2.13). Rather than the previously proposed purely freshwater environment, there seems to have been a variety of freshwater and slightly brackish environments in the surroundings of the sites in the eastern part of West Frisia.

Related to this observation, another interesting trend is recognizable in Figure 2.11. At every eastern site of West Frisia there are examples of fish that require a connection to the sea. Species that prefer this habitat type are mostly eel and salmonids (*Salmonidae* spec., including salmon and trout species). Salmon or trout are known to travel far upriver to spawn, and during this time, they can migrate tens of kilometres inland. Eel on the other hand, spends most of its

5. For further reference regarding the dating of the closure of the seacoast at the Bergen inlet and the new sea coastal model, see Van Zijverden (in prep.).

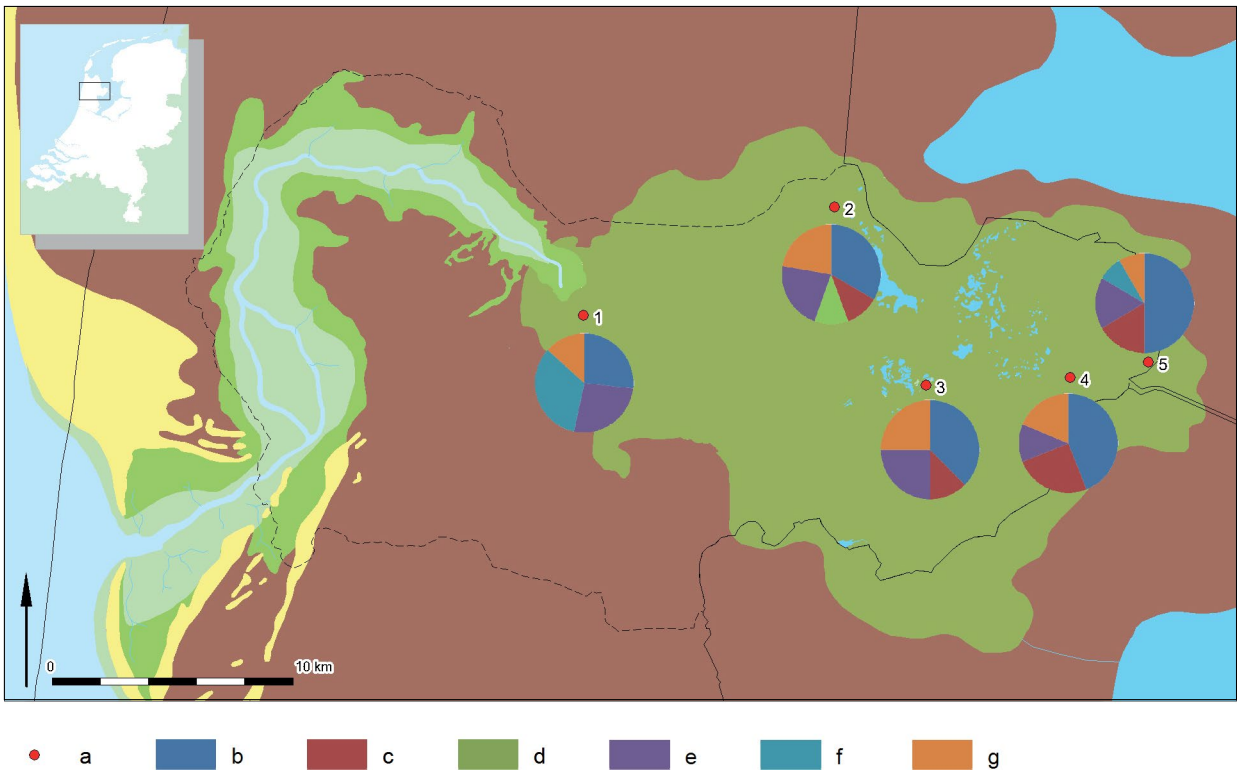


Figure 2.11. Map of Middle Bronze Age West Frisia with the water habitat preferences of fish species found at each site. N denotes the number of different fish species found. For the legend of the underlying map, see Figure 2.1b. a: location of an excavated site; b: stagnant to slow-flowing water; c: open water; d: fast-flowing water (river); e: sea connection; f: open sea; g: non-specific preference; 1: Hoogwoud, n=11; 2: Medemblik, n=6; 3: Westwoud, n=5; 4: Bovenkarspel, n=11; 5: Enkhuizen, n=8.

early years in fresh water, only returning to the sea when mature enough to reach its spawning grounds in the Atlantic Ocean (Vissengids 2016). These two species thus signify that migratory fish were able to reach waters in the vicinity of the eastern sites through a connection with the sea. However, if it is assumed that the Bergen inlet only reached as far as Hoogwoud, and fishing occurred relatively close to the settlement, the question of how these migratory species reached eastern West Frisian sites remains.

Since a(n) (in)direct connection to the sea with the eastern sites has never been established during excavations, another route for these migratory fish can also be postulated. One option could be that the saltwater influence did indeed reach much further inland than was previously proposed, for example during spring tides. Alternatively, a migratory route may have existed via the inland lakes east of West Frisia, which were in close proximity to the eastern sites, and were connected to the North Sea via the Oer-IJ estuary (Figure 2.13). The distance travelled by migratory fish via this route seems very long, but Atlantic salmon for example has been recorded to swim upriver, when unhindered by modern obstacles, as far as the Badem-Württemberg province in south-western Germany, roughly 700 km from the North Sea (Froehlich-Schmitt 2004, 4).

This latter route would explain the presence of both anadrome and catadrome fish species near the eastern sites. Such an indirect connection to the North Sea would also explain the slightly to medium brackish water conditions of the lakes to the east of West Frisia and the waters connected to them. Fish remains from a site bordering the eastern edge of the upper large lake, Emmeloord (Figure 2.13, number 9; Van Zijverden forthcoming), also seem to confirm this

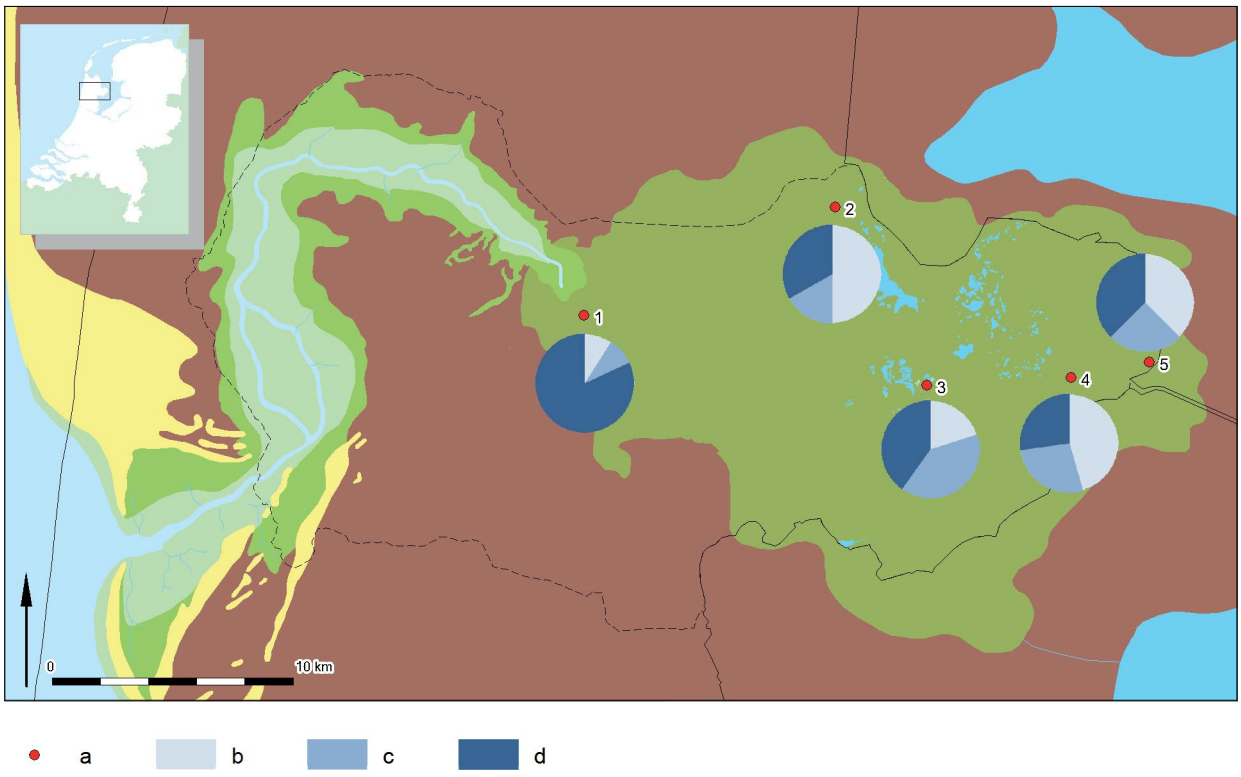


Figure 2.12. Map of Middle Bronze Age West Frisia with the maximum salinity tolerance of fish species found at each site. N denotes the number of different fish species found. For the legend of the underlying map, see Figure 2.1b. a: location of an excavated site; b: fresh to slightly brackish water (0-10 ppt); c: medium brackish water (10-15 ppt); d: salt water (more than 30 ppt); 1: Hoogwoud, n=11; 2: Medemblik, n=6; 3: Westwoud, n=5; 4: Bovenkarspel, n=11; 5: Enkhuizen, n=8.

image. The species from this site (Kerklaan 2012) very closely resemble the composition of species found at Bovenkarspel and Enkhuizen, and mostly show preferences for open water and a connection to the sea. Interestingly, Medemblik does not show such clear indications for open water, although it is supposedly closely situated to the upper lake.

2.4.1.4 Late Bronze Age

For the Late Bronze Age period, only the most eastern sites yielded fish remains. In Figure 2.14, the water type habitat preferences of fish from the Late Bronze Age are shown. In general, a slight increase in fish species preferring stagnant to slow-flowing water is visible, especially in Medemblik. Overall however, no apparent other major differences in water type ratios have occurred between the Middle and Late Bronze Age situation.

The salinity tolerance pie diagrams for the Late Bronze Age are shown in Figure 2.15. Again, species that prefer slight to medium brackish water prevail. Compared to the Middle Bronze Age however, there seem to be more species indicating slightly brackish water at the expense of water with higher salinity levels, with the largest difference observed at the sites Medemblik and Enkhuizen. It is difficult to interpret these observed differences, since they could be the result of an increased freshwater content in the eastern lakes.

2.4.2 Birds

Similar to the fish species, the bird species found will be compared with the expected species per habitat (Appendix A1.1). Also, indications for the habitats present near the sites will be discussed, and an overview of the environment in the Bronze Age as a whole will

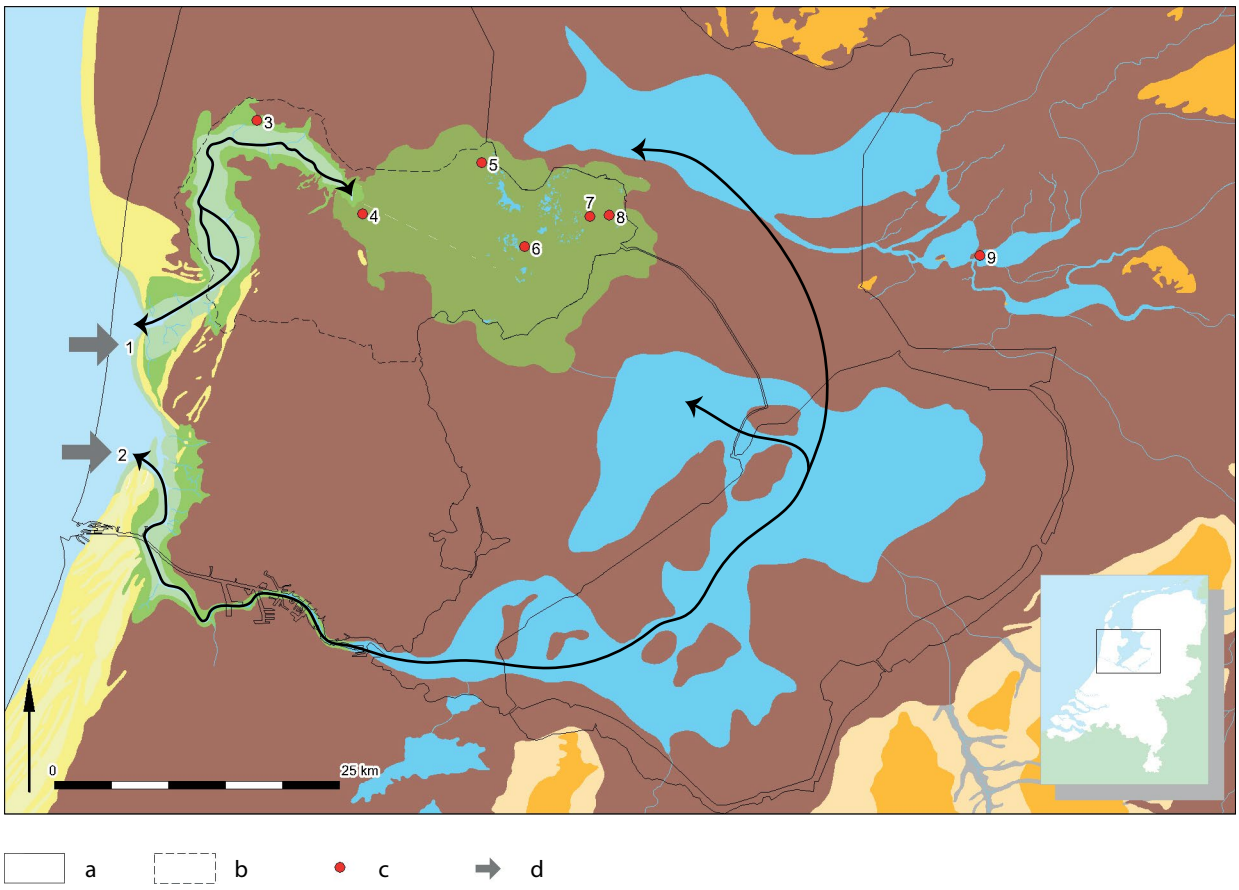


Figure 2.13. Overview of the possible migratory routes (black arrows) between the different sites in West Frisia and the North Sea. For the eastern West Frisia sites, it is proposed that fish most likely travelled via the Oer-IJ estuary, since the Bergen inlet supposedly did not allow saltwater to be transported far enough inland to reach these sites. For the legend of the underlying map, see Figure 2.1b. a: outline of the recent Netherlands; b: outline of the recent area of West Frisia; c: location of an excavated site; d: coastal inlet/estuary; 1: Bergen inlet; 2: Oer-IJ estuary.: 1: Bergen inlet; 2: Oer-IJ estuary; 3: Schagen; 4: Hoogwoud; 5: Medemblik; 6: Westwoud; 7: Bovenkarspel; 8: Enkhuizen; 9: Emmeloord.

be made, since remains were too few to distinguish between the Middle and Late Bronze Age periods.

2.4.2.1 Observed species and habitat types

In Table 2.6, the observed bird species with their preferred habitat types are shown and an overview of presence per site in Table 2.7. Similar to Table 2.4, the different habitat types are represented by different colours. Birds that specifically prefer a combination of two habitat types are placed in between those types in Table 2.6.

As becomes clear from Table 2.6, all of the expected habitats have representative species, indicating a varied landscape, although some habitats are represented by more species than others. Since most birds can live in many different habitat types, and many were expected for each habitat type (Appendix A1.1), the comparison made here between the expected and observed species will be very general. The majority of found species prefer a habitat that includes wetlands, although many species of waders were not found. Other birds, which also prefer wetlands in general, can live near the seacoast. Birds indicative of the presence of the seacoast, however, including many different species of gull, were not present in the bird assemblage. Water-related habitat types including both grassland and wetlands are also represented by birds.

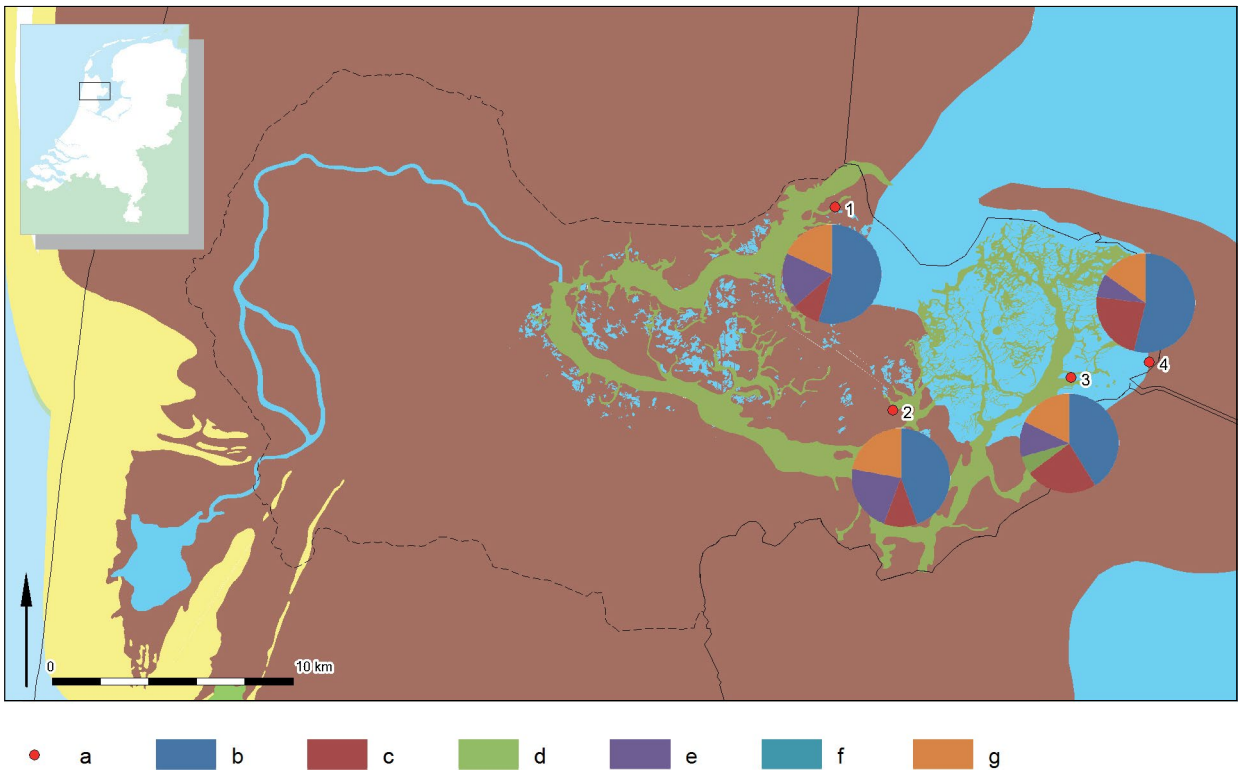


Figure 2.14. Map of Late Bronze Age West Frisia with the water habitat preferences of fish species found at each site. For the legend of the underlying map, see Figure 2.1b. a: location of an excavated site; b: stagnant to slow-flowing water; c: open water; d: fast-flowing water (river); e: sea connection; f: open sea; g: non-specific preference; 1: Medemblik, n=8; 2: Westwoud, n=6; 3: Bovenkarspel, n=12; 4: Enkhuizen, n=9.

When Table 2.6 is observed, it is clear that birds that do not require wetlands in their habitat are present as well. Bird species that prefer grassland, both grassland and shrub land, or shrub land and trees are apparent as well.

Finally, of each of the specific habitats, trees, shrub land, and open sea, only one representative bird species was found in West Frisia. Since representatives for every expected habitat were found, it can in general be expected that more species preferring such habitats were present in West Frisia as well, provided that these species existed in these regions during this time.

2.4.2.2 Bronze Age overview

Only one site, Schagen, yielded information on the Early Bronze Age. However, unfortunately no distinction could be made between the Middle and Late Bronze Age, due to the limited number of bird remains found on the other sites. Therefore, only a general overview with a comparison between the Early Bronze Age and the Middle/Late Bronze Age is presented here. In Figure 2.16, the pie diagrams of the bird habitat preferences of the sites of West Frisia are presented. The colours used to denote the different habitat types in the pie diagrams are the same as those applied in Table 2.6.

Figure 2.14, which was composed in a similar manner to the research towards fish, indicates that the available bird species indicate a clear distinction between the eastern and western part of West Frisia, similar to what was observed based on fish species. In the west, in Early Bronze Age Schagen, all the expected habitat types are represented, with clear indications for saltwater environments. In Middle Bronze Age Hoogwoud, situated in the middle of West Frisia, only wetlands are represented by the bird species. The sites in the eastern part of West Frisia, in

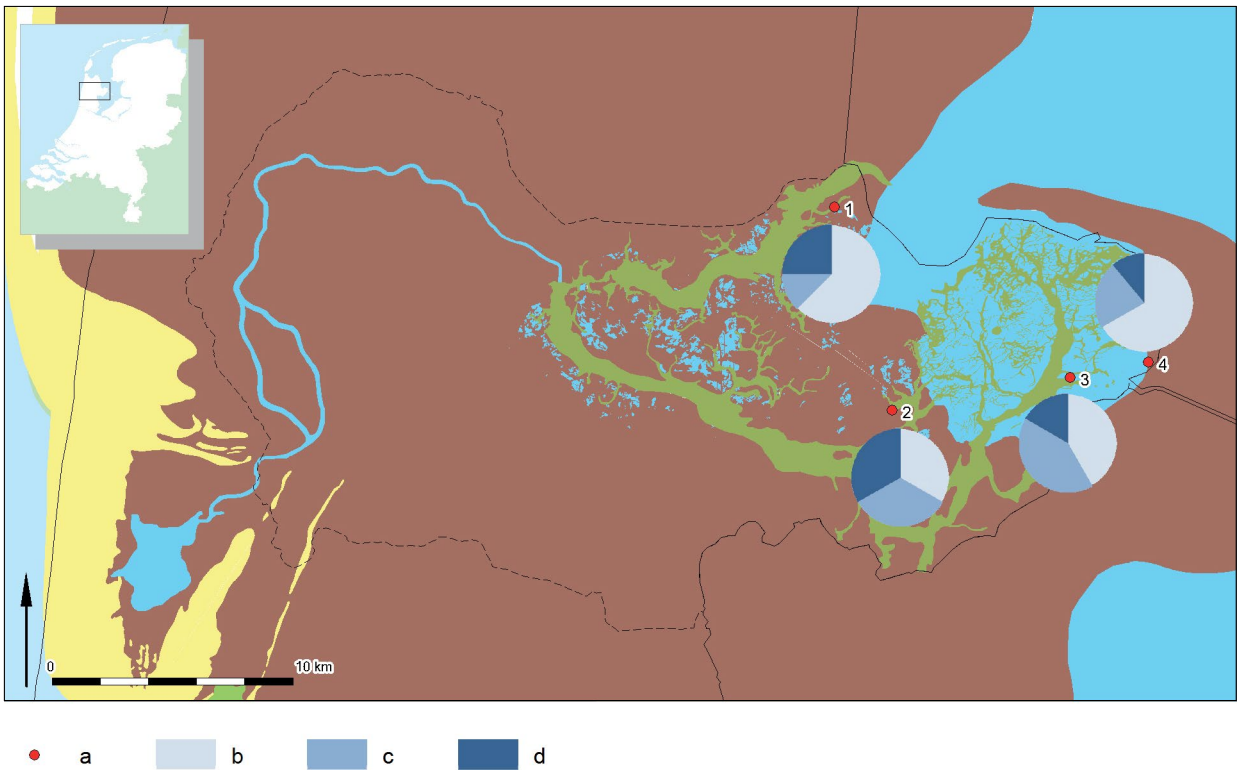


Figure 2.15. Map of Late Bronze Age West Frisia with the maximum salinity tolerance of fish species found at each site. For the legend of the underlying map, see Figure 2.1b. a: location of an excavated site; b: fresh to slightly brackish water (0-10 ppt); c: medium brackish water (10-15 ppt); d: salt water (more than 30 ppt); 1: Medemblik, n=8; 2: Westwoud, n=6; 3: Bovenkarspel, n=12; 4: Enkhuizen, n=9.

this case Medemblik, Enkhuizen, and Bovenkarspel, each show a comparable image of the habitats present: wetlands, grassland, shrub land, and trees. However, each site shows a slight variation in ratio between these different habitats. In Bovenkarspel, a trend towards more wetlands can be observed, and in Medemblik it is towards more shrub land. Enkhuizen on the other hand, shows mostly indicators for trees.

Birds that have a preference for more than one habitat type are placed in between the two types. These are: crane, ruff, widgeon, brent goose, barnacle goose, and dunlin.

The group of birds that is most highly represented in the eastern part of West Frisia is waterfowl. At least 50% of the species on each site consists of aquatic birds, and even more when the families of ducks and geese are included, which could not be identified to species level.

The large lakes to the east of West Frisia would be an ideal habitat for such birds, but there must have been wetlands and smaller lakes reaching closer to the settlements in the east as well (van Zijverden forthcoming).

The presence of these bird species confirms the presence of freshwater wetlands in the east of West Frisia. However, the salinity level of these waters may also have been slightly brackish, since freshwater birds can often tolerate low levels of salinity (*e.g.* mallard: United States Department Interior 1998: 131, 133).

Hoogwoud only yielded species with a preference for wetlands, which means that wetlands were also present in the middle of West Frisia. Interestingly, there were no clear indicators for a saltwater environment, which was expected based on fish remains (section 2.4.1.3). This difference in indicators for salinity may very

Table 2.6. Overview of all the bird species found in West Frisia arranged by preferred habitat type.

Habitat preference	PRESENCE OF TREES
Taxa	*Scolopax rusticola*
English name	Eurasian Woodcock

Habitat preference	TREES/SHRUBLAND	TREES/SHRUBLAND
Taxa	*Accipiter gentilis*	*Bubo bubo*
English name	Northern Goshawk	Eagle owl

Habitat preference	SHRUB LAND
Taxa	*Sylvia spec.*
English name	Warblers

Habitat preference	SHRUB LAND/GRASSLAND	SHRUB LAND/GRASSLAND	SHRUB LAND/GRASSLAND
Taxa	*Corvus corone*	*Corvus frugilegus*	*Turdus spec.*
English name	Carrion crow	Rook	Thrushes

Habitat preference	GRASSLAND	GRASSLAND
Taxa	*Alauda arvensis*	*Coturnix coturnix*
English name	Skylark	Quail

Habitat preference	GRASSLAND/WETLANDS	GRASSLAND/WETLANDS	GRASSLAND/WETLANDS
Taxa	*Grus grus*	*Philomachus pugnax*	*Hirundinidae* indet
English name	Crane	Ruff	Swallows

Habitat preference	WETLANDS	WETLANDS	WETLANDS	WETLANDS	WETLANDS	WETLANDS	WETLANDS
Taxa	*Anas crecca*	*Anas querquedula*	*Anas platyrhynchos*	*Anser anser*	*Cygnus cygnus*	*Cygnus olor*	*Rallus aquaticus*
English name	Common teal	Garganey	Mallard	Greylag goose	Whooper swan	Mute swan	Water rail

Habitat preference	WETLANDS/COAST	WETLANDS/COAST	WETLANDS/COAST	WETLANDS/COAST	WETLANDS/COAST
Taxa	*Anas penelope*	*Branta bernicla*	*Branta leucopsis*	*Calidris alpina*	*Gavia arctica/stellata*
English name	Widgeon	Brent goose	Barnacle goose	Dunlin	Black-/ Red-Throated Loon

Table 2.7. Overview of the frequency of bird species found at each of the Bronze Age sites.

Taxa	English name	Boven-karspel	Enk-huizen	Medem-blik	Hoog-woud	Schagen	Freq.
Anas platyrhynchos	Mallard	x			x	x	3
Anas crecca/ querquedula	Common Teal/ Garganey				x	x	2
Anas penelope	Widgeon		x		x		2
Anser anser	Greylag goose	x	x				2
Bubo bubo	Eagle owl	x		x			2
Cygnus cygnus	Whooper swan	x		x			2
Rallus aquaticus	Water rail		x			x	2
Scolopax rusticola	Eurasian Woodcock		x			x	2
Turdus spec.	Thrush spec.		x			x	2
Accipiter gentilis	Northern Goshawk		x				1
Alauda arvensis	Skylark					x	1
Anas crecca	Common Teal	x					1
Anatidae indet	Duck-family					x	1
Anatinae	Ducks and Geese		x				1
Anser spec.	Grey geese			x			1
Branta bernicla	Brent goose					x	1
Branta bernicla/ leucopsis	Barnacle goose					x	1
Branta spec.	Black geese		x				1
Calidris alpina	Dunlin					x	1
Corvus corone	Carrion crow	x					1
Corvus corone/ frugilegus	Carrion crow/Rook			x			1
Coturnix coturnix	Quail					x	1
Cygnus olor	Mute swan	x					1
Gavia arctica/stellata	Black-/Red-throated loon					x	1
Grus grus	Crane	x					1
Passeriformes indet	Songbirds	x					1
Philomachus pugnax	Ruff		x				1
Sylvia spec.	Warbler spec.					x	1

Presence of a species is denoted by an "x".

well be related to human selection of specific species rather than actual absence of saline influence in this area, and this observation underlines the importance of multi-proxy research. The presence of trees was indicated by no less than three bird species, which is a relatively high number considering that the number of bird remains found throughout West Frisia was limited. This clear presence of tree indicators again seems to undermine the conclusions of the current model, which envisioned West Frisia as consisting of an open, treeless landscape.

Although birds appear to have provided several clues for the presence of habitat types, some remarks must be made nonetheless. It must for example be kept in mind that the range in which a certain bird can be found differs per species. Some birds have vast ranges in which they hunt, whereas others stay in the same small area year-round. The home range of birds furthermore, can include different areas for feeding, sleeping, breeding, and hunting. These grounds will mostly be located relatively close to each other, but for birds of prey and geese these different areas may lie several tens of kilometres apart. Such species can thus only provide regional indications for the environment. On the other hand, when birds have a particularly small home range, they can form excellent local habitat indicators. When these characteristics are considered, more detailed information about for example available forest cover can be obtained. Northern goshawk (*Accipiter gentilis*) and eagle owl (*Bubo bubo*), found in Enkhuizen, and Bovenkarspel and Medemblik, respectively (Table 2.7), both possess large living and hunting territories, and can travel many kilometres in search of food (Eifelnatur 2011). Therefore, the presence of these birds can provide regional indications for forest in the eastern part of West Frisia. The other forest indicator, Eurasian woodcock (*Scolopax rusticola*), found in both Enkhuizen and Schagen (Table 2.7), does not travel far within its home range (Houtsnip n.d). It prefers to remain in (wet) uninterrupted forests with dense undergrowth to forage and breed. Woodcock, therefore, does provide a firm local indication for trees, provided that it was not caught during migration. It is clear that only the combination of local and regional bird indicators for trees, such as present at Enkhuizen, really provide clues that at least patches of uninterrupted forest must have been located relatively close to a settlement.

2.4.3 Mammals

Mammal remains were divided into two groups: small and large mammals. In this research, mammals are considered small when they are smaller than a hare (*Lepus europaeus*). This distinction was made based on the size of the home range; mammals smaller than a hare usually possess a very small home range and can therefore only provide very local information about the environment.

Similar to the previous sections on fish and birds, all the found mammal species will first be compared to those expected for each habitat (Appendix A1.1), and small and large mammals will be discussed in separate paragraphs. Furthermore, based on the preferred habitats of the mammal species found, the environment of the sites will be discussed. This discussion will include both the Bronze Age in its entirety, as well as the separate Middle and Late Bronze Age periods. However, since very few finds were available from the latter period, only Late Bronze Age data from Bovenkarspel will be discussed here.

2.4.3.1 Observed species and habitat types

Table 2.8 shows a list of all the small and large mammal species found as well as their characteristic preferred habitat types, whereas Table 2.9 displays an overview of the presence of the small and large mammals at each site. Again, the different habitat types are denoted by different colours which correspond to the colours and habitat types used for birds in section 2.4.2.1. Mammals preferring multiple characteristic habitat types are placed in between the respective habitat types.

Small mammals

None of the small mammal species found seem to have a characteristic preference for the presence of trees. Instead, the species are evenly divided between shrub land, grassland, and wetlands, or a combination of these. Apart from one species of small mammal (*i.e.* yellow-necked mouse), no small mammals that were expected are missing from the assemblage.

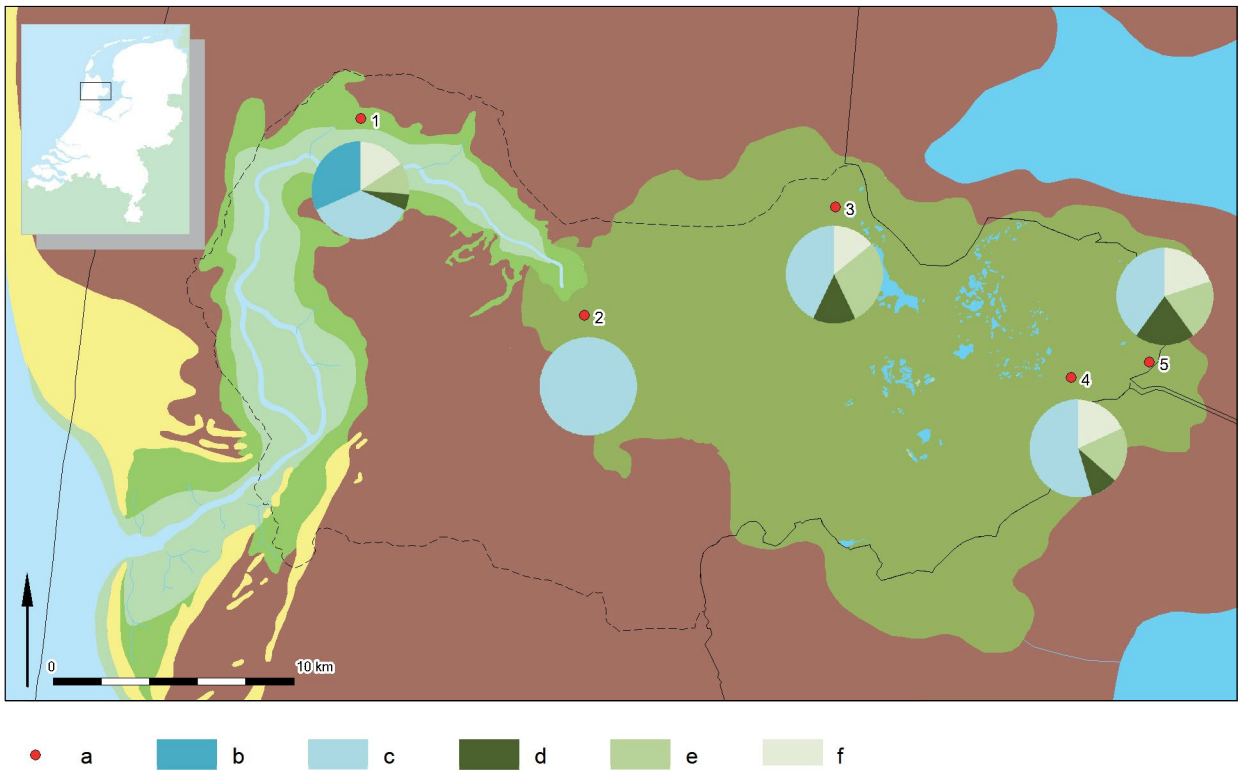


Figure 2.16. Map of Bronze Age West Frisia with the general habitat preference of the birds found. For the legend of the underlying map, see Figure 2.1b. a: location of an excavated site; b: seacoast; c: wetlands; d: presence of trees; e: shrub land; f: grassland; 1: Schagen, n=13; 2: Hoogwoud, n=3; 3: Medemblik, n=4; 4: Bovenkarspel, n=8; 5: Enkhuizen, n=7.

Large mammals

Table 2.8 immediately shows that all expected habitat types are represented by large mammals, even grassland. In contrast to the small mammals species however, it can be seen that the majority of species actually prefer a habitat which contains trees. Many large mammals clearly have a need for the presence for trees, albeit it for food, protection, or both. Still, many species that were expected for the forest habitats were not amongst the finds (Appendix A1.1). Besides a preference for trees, three large mammal species also prefer wet environments, including habitats with both (freshwater) wetlands and the seacoast. Again however, several species representing such habitats were not found.

2.4.3.2 Bronze Age overview

The relatively low numbers of (wild) mammal bones found on each site in West Frisia did not allow for a comparison between the Middle and Late Bronze Age, apart from the site of Bovenkarspel. At the site Schagen however, the Early Bronze Age is represented so therefore, this site can be used for comparison with the Middle and Late Bronze Age combined.

Since not all sites yielded remains from both small and large animals, several pie diagram maps were made: Figure 2.17 shows the pie diagrams of the habitat preferences of the small mammals, in Figure 2.18 the pie diagrams for the sites yielding large mammal remains can be seen, and in Figure 2.19, the small and large mammal remains were combined for the sites which contained remains of both small and large mammals. The colours of the diagrams correspond to the colours used for the different habitat types in Table 2.8. However, as for birds, mammals preferring a combination of two habitats are included in both habitat types in the diagrams.

Small mammals
The image obtained of the surroundings of the sites based on the preference of small mammals found in West Frisia is fairly similar for most of the sites, as can be seen in Figure 2.17. Hoogwoud, Westwoud, and Bovenkarspel have a similar ratio of small mammal species that prefer shrub land as well as equal parts for the habitats grassland, and/or wetlands. Schagen, Hoogkarspel, and Enkhuizen are also similar in their small mammal habitat preferences, with a slight tendency towards more shrub land than wetlands. Due to the fact that the small mammals were not selectively caught by humans (cf. Chapter 4), they are thought to be indicative of the immediate surroundings of the settlement only. Therefore, the immediate surroundings of the settlement appear to consist of mostly open, but also some wetlands: a similar conclusion as was obtained from on-site pollen (section 2.3.1).

Large mammals
The sites yielding large mammal remains are more abundant than those that yield small mammal remains, which is most likely due to differences applied in sieving strategies (Table 2.1). From Figure 2.18 it becomes apparent that on all the sites species are found that are indicative of the presence of trees. However, although some indications for trees can be found in both Schagen and Hoogwoud, definite indicators for large(r) forested areas, such as elk, wild boar, and brown bear, are not present. This absence of forest-dwelling large mammals at these sites could be the result of the saline influence on these sites, preventing the growth of (larger) patches of trees. Still, the presence of trees in the surroundings of many of the West Frisian settlements is confirmed: a similar conclusion to what was obtained from off-site pollen (section 2.3.1).

Other habitat preferences of the uncovered large mammal species include wetlands, shrub land, grassland, and the seacoast. In Andijk and Schagen, a relatively large portion of the large mammals include species that prefer wetlands, such as beaver and otter. Since both species can be found under both freshwater and brackish water conditions (Twisk *et al.* 2010, 206; Hood 2012), nothing in particular can be said about salinity levels of the water surrounding the settlements based on this single proxy. It does however indicate that in Schagen, sources of water also existed that possessed a salinity level of fresher than saline conditions, which was also indicated by the present fish species (Figure 2.9, Figure 2.10). More specific information about the water salinity surrounding the settlements is sadly not possible based on large mammal remains, but they do provide more information on the size of the present water bodies than small mammals and fish, since they require more space for their home ranges (Cronau 2015). Based on the presence of wetland-preferring large mammal species at Schagen, Medemblik, Andijk, Enkhuizen, and Bovenkarspel as seen in Figure 2.18, these sites appear to have possessed larger water bodies in the settlement surroundings. Hoogkarspel, Zwaagdijk, and Hoogwoud do not provide this image, but this may be due to the relatively low numbers of large mammal species and bones found at these sites. Therefore, these latter sites may provide a less representative image of the surroundings than the former sites. Nonetheless, the presence of the large lakes east of West Frisia seem to be confirmed by the large mammal remains of beaver and otter at eastern sites. Schagen will also have had larger water bodies in the environment, with salinity levels ranging from saline to brackish/freshwater, indicated by the presence of harbour seal, and beaver and otter, respectively.

As stated, the only larger assemblage of large mammal remains dating to the Late Bronze Age were found at Bovenkarspel (data not shown). From this data it has become clear that not many changes have occurred in the indications for the different habitats. Wetlands are still represented, as are shrub land and forest. Grassland is no longer represented, but this could be the result of the fewer species found for this time period.

Small and large mammals combined
Due to the fact that small mammals are mainly indicative of grassland, shrub land, and wetlands, and large mammals mainly prefer the cover of trees, the most representative image of the terrestrial environment will be obtained by combining both mammal groups for the sites at which they are both found. The results of this combination are shown in Figure 2.19.

Table 2.8. Overview of all the small and large mammal species found in West Frisia arranged by preferred habitat type. Names of the animals are according to the taxonomy used in the field guide of Twisk *et al.*, Van Diepenbeek and Bekker 2010. In Eurasia, *Alces alces* signifies elk, not moose.

LARGE MAMMALS

Habitat preference	PRESENCE OF TREES	PRESENCE OF TREES	PRESENCE OF TREES
Taxa	*Alces alces**	*Sus scrofa*	*Ursus arctos*
English name	Elk*	Wild boar	Brown bear

Habitat preference	TREES/SHRUBLAND	TREES/SHRUBLAND	TREES/SHRUBLAND	TREES/SHRUBLAND	TREES/SHRUBLAND
Taxa	*Capreolus capreolus*	*Cervus elaphus*	*Felis silvestris*	*Mustela putorius*	*Vulpes vulpes*
English name	Roe deer	Red deer	Wild cat	European Polecat	Fox

SMALL MAMMALS

Habitat preference	SHRUBLAND	SHRUBLAND
Taxa	*Mustela nivalis*	*Sorex minutus*
English name	Weasel	Pygmy shrew

Habitat preference	SHRUBLAND/GRASSLAND	SHRUBLAND/GRASSLAND	SHRUBLAND/GRASSLAND	SHRUBLAND/GRASSLAND
Taxa	*Apodemus sylvaticus*	*Micromys minutus***	*Microtus arvalis*	*Sorex araneus*
English name	Wood mouse	Harvest mouse**	Common vole	Common shrew

Habitat preference	GRASSLAND	GRASSLAND	GRASSLAND	SHRUB/GRASS/WETLAND
Taxa	*Lepus europaeus*	*Talpa europaea*	*Mus musculus***	*Microtus agrestis*
English name	Hare	Mole	House mouse**	Field vole

Habitat preference	WETLANDS	WETLANDS	WETLANDS	WETLANDS	WETLANDS
Taxa	*Castor fiber**	*Lutra lutra*	*Arvicola amphibius*	*Microtus oeconomus*	*Neomys fodiens*
English name	Beaver*	Otter	Water vole	Nordic vole	Water shrew

Habitat preference	COAST
Taxa	*Phoca vitulina*
English name	Harbor seal

* Although main habitat preference is as stated, Elk prefers wetter areas in summer, and Beaver requires the presence of trees.
** These mice can also have adapted to living in the presence of humans and can therefore also be found living within settlements.

Table 2.9. Overview of the frequency of mammal species found at each of the Bronze Age sites.

Taxa	English Name	Hoog-woud	Boven-karspel	West-woud	Enk-huizen	Medem-blik	Andijk
Small Mammals							
Capreolus capreolus	Roe deer	x	x			x	x
Castor fiber	Beaver		x		x	x	x
Cervus elaphus	Red deer		x		x	x	x
Vulpes vulpes	Fox	x	x			x	
Alces alces	Moose		x		x	x	
Sus scrofa	Wild boar				x	x	x
Lepus europaeus	Hare		x	x			
Lutra lutra	Otter					x	x
Cervus elaphus/ Alces alces	Red deer/Moose	x	x				
Ursus arctos	Brown bear				x		
Felis sylvestris	Wild cat					x	
Mustela nivalis	Weasel						
Mustela putorius	European polecat						
Phoca vitulina	Harbor seal						
Large Mammals							
Arvicola amphibius	Water vole	x	x	x	x	x	
Microtus oeconomus	Nordic vole	x	x	x	x		
Apodemus sylvaticus	Wood mouse	x			x		
Microtus agrestis	Field vole	x	x				
Microtus arvalis	Common vole		x		x		
Sorex araneus	Common shrew			x	x		
Mus musculus	House mouse		x	x			
Neomys fodiens	Water shrew		x				
Micromys minutus	Harvest mouse						
Sorex minutus	Pygmy shrew						
Talpa europaea	Mole	x					

Taxa	Schagen	Hoogkarspel Watertoren	Zwaagdijk	Zwaagdijk-oost	Oostwoud	Freq.
Small Mammals						
Capreolus capreolus		x	x		x	7
Castor fiber	x	x		x		7
Cervus elaphus	x			x		6
Vulpes vulpes	x	x	x			6
Alces alces		x		x		5
Sus scrofa			x			4
Lepus europaeus					x	3
Lutra lutra	x					3
Cervus elaphus/ Alces alces						2
Ursus arctos		x				2
Felis sylvestris						1
Mustela nivalis		x				1
Mustela putorius	x					1
Phoca vitulina	x					1
Large Mammals						
Arvicola amphibius	x					6
Microtus oeconomus	x					5
Apodemus sylvaticus	x					3
Microtus agrestis		x				3
Microtus arvalis		x				3
Sorex araneus	x					3
Mus musculus						2
Neomys fodiens	x					2
Micromys minutus	x					1
Sorex minutus	x					1
Talpa europaea						1

Presence of a species is denoted by an “x”.

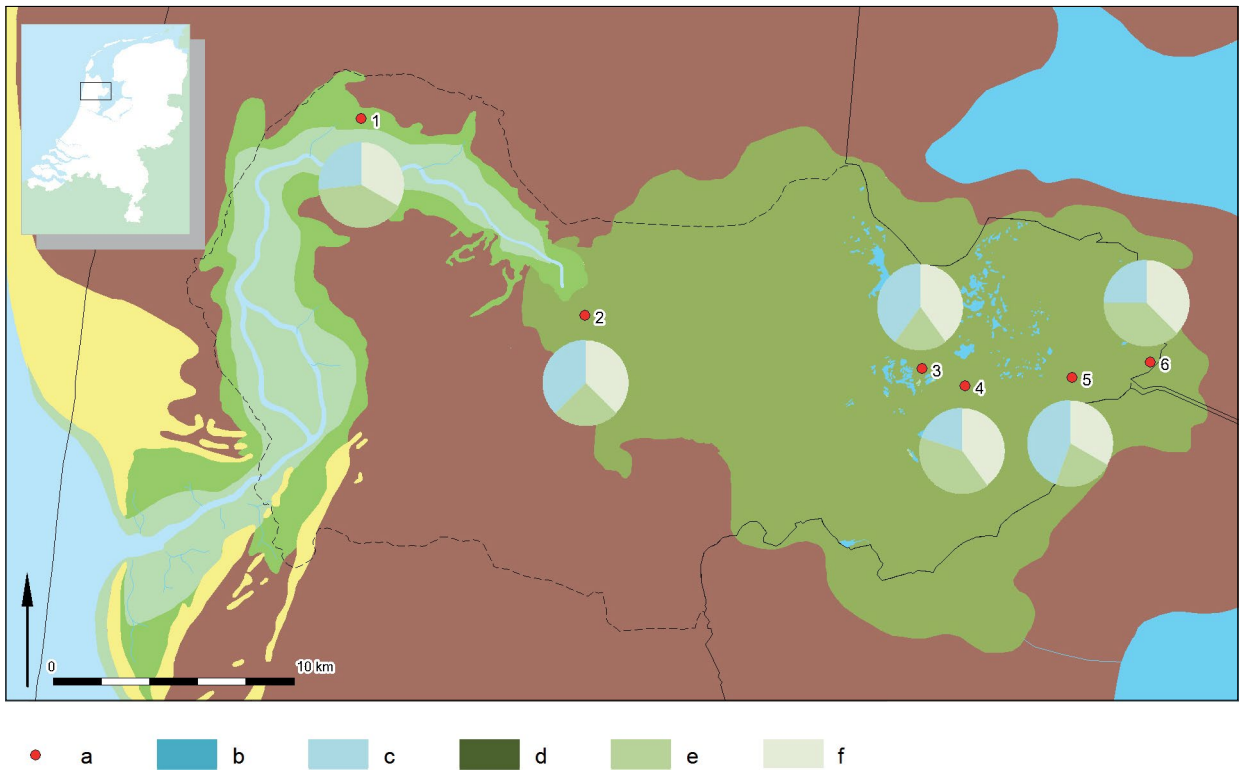


Figure 2.17. Map of Bronze Age West Frisia with the general habitat preferences of the small mammals found at each site. N denotes the number of different small mammal species found. For the legend of the underlying map, see Figure 2.1b. a: location of an excavated site; b: seacoast; c: wetlands; d: presence of trees; e: shrub land; f: grassland; 1: Schagen, n=7; 2: Hoogwoud, n=5; 3: Westwoud, n=4; 4: Hoogkarspel, n=2; 5: Bovenkarspel, n=6; 6: Enkhuizen, n=5.

It is clear that although in Figure 2.17 and Figure 2.18 some sites resemble each other based on habitat preferences of either small or large mammals, Figure 2.19 shows a different trend. Here, Hoogwoud, Enkhuizen, and Bovenkarspel are the most similar, with a relatively equal combination of habitat types representing wetlands, grassland, shrub land, and the presence of trees.

At Hoogkarspel, it seems that there are less indicators for wetlands, and more for shrub land. Schagen finally, has less indicators for trees, but does show an additional indicator for the seacoast. What these five sites show is that the landscape in Bronze Age West Frisia was apparently very varied, but generally composed of similar habitats depending on the salinity of the surrounding water. Exactly how these different types of natural landscape are situated in relation to the cultivated landscape of the settlements, and what impact each of these landscapes will have on the appearance of the other will be discussed in Chapter 8: Bronze Age farming in West Frisia.

2.4.4 Summary

The West Frisian fish species have shown a preference for a variety of water types and salinities, underlining the range of different aquatic habitat types present in the surroundings of the settlements: indeed, the east of West Frisia did not consist of a purely freshwater environment. Fish species have furthermore provided clear indications that the North Sea influenced West Frisia, both in a direct manner in the west until after 1550 BC, and in an indirect manner in the east, possibly via the Oer-IJ estuary. The available bird species deriving from the West Frisian sites have provided mostly general, but also some detailed indications for the environment. Most birds indicate the presence of wetlands in the surroundings, but also other habitat types such

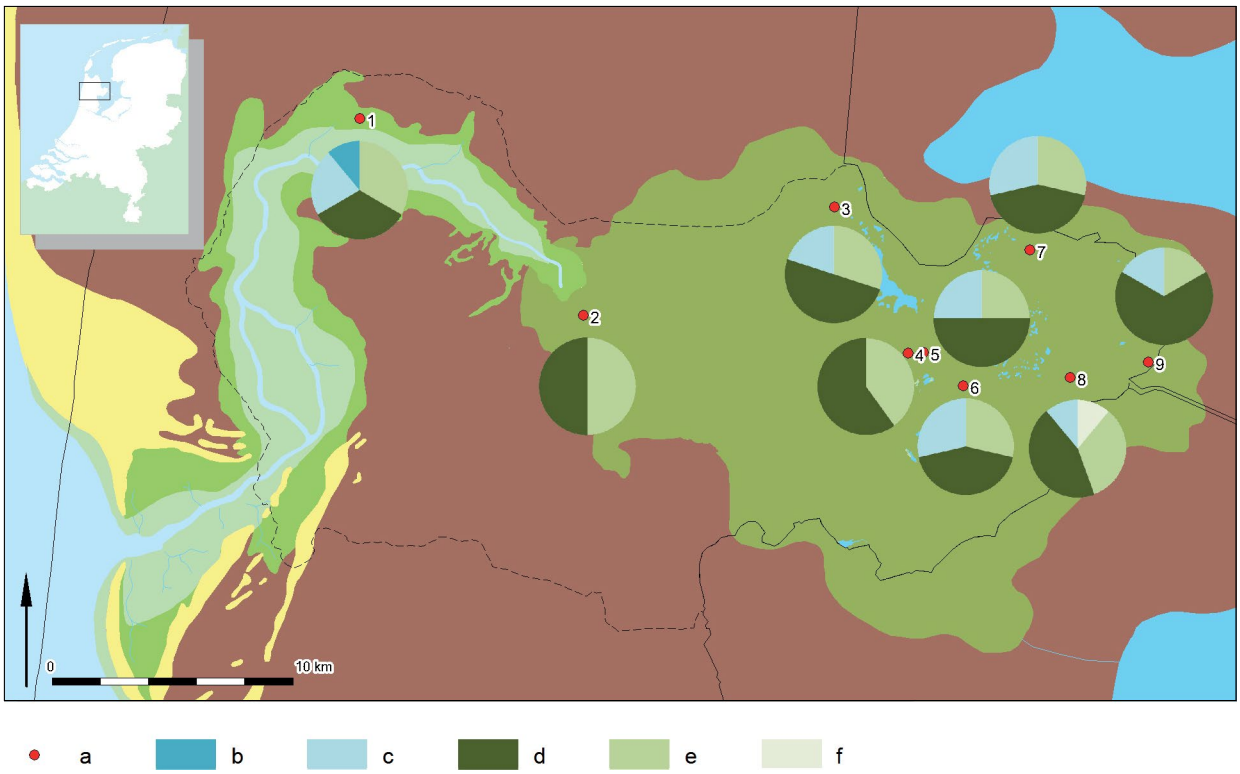


Figure 2.18. Map of Bronze Age West Frisia with the general habitat preferences of the large mammals found at each site. N denotes the number of different large mammal species found. For the legend of the underlying map, see Figure 2.1b. a: location of an excavated site; b: seacoast; c: wetlands; d: presence of trees; e: shrub land; f: grassland; 1: Schagen, n=6; 2: Hoogwoud, n=2; 3: Medemblik, n=7; 4: Zwaagdijk, n=3, 5: Zwaagdijk-Oost, n=3; 6: Hoogkarspel, n=3; 7: Andijk, n=5; 8: Bovenkarspel, n=6; 9: Enkhuizen, n=5.

as grassland, shrub land, and the presence of trees. Again, a varied landscape around all the settlements throughout West Frisia could be identified, and, for the surroundings of the eastern sites in particular, the presence of freshwater to slightly brackish habitats could be confirmed. The presence of trees could furthermore be identified on a regional, but also on a local level based on the different home ranges of three bird species. The presence of saline influence, such as was expected at Hoogwoud based on fish remains, could not be established based on bird remains. Mammals finally, can be considered a valuable addition for the reconstruction of the terrestrial landscape, providing both regional and local indications for the presence of different habitat types. Based on large mammals in particular, a general distinction can be made between the presence of saline and freshwater conditions present around the settlements, as well as a rough estimation of the size of the present (fresh)water bodies. Furthermore, due to the preference of most large mammals for cover, which needs to be high enough to remain unseen, these animals can also provide information on the presence of trees.

Small mammals can only provide very local information, probably only reflecting the habitats (in the near surroundings) of the settlements. Nevertheless, since small and large mammals have different main habitat preferences, the combination of these groups can provide a general insight into the composition of habitats present in the landscape.

2.4.5 Discussion

Similar to the discussion on methodology in section 2.3.5.1 for plants, factors affecting the zoological record will be discussed, which may influence

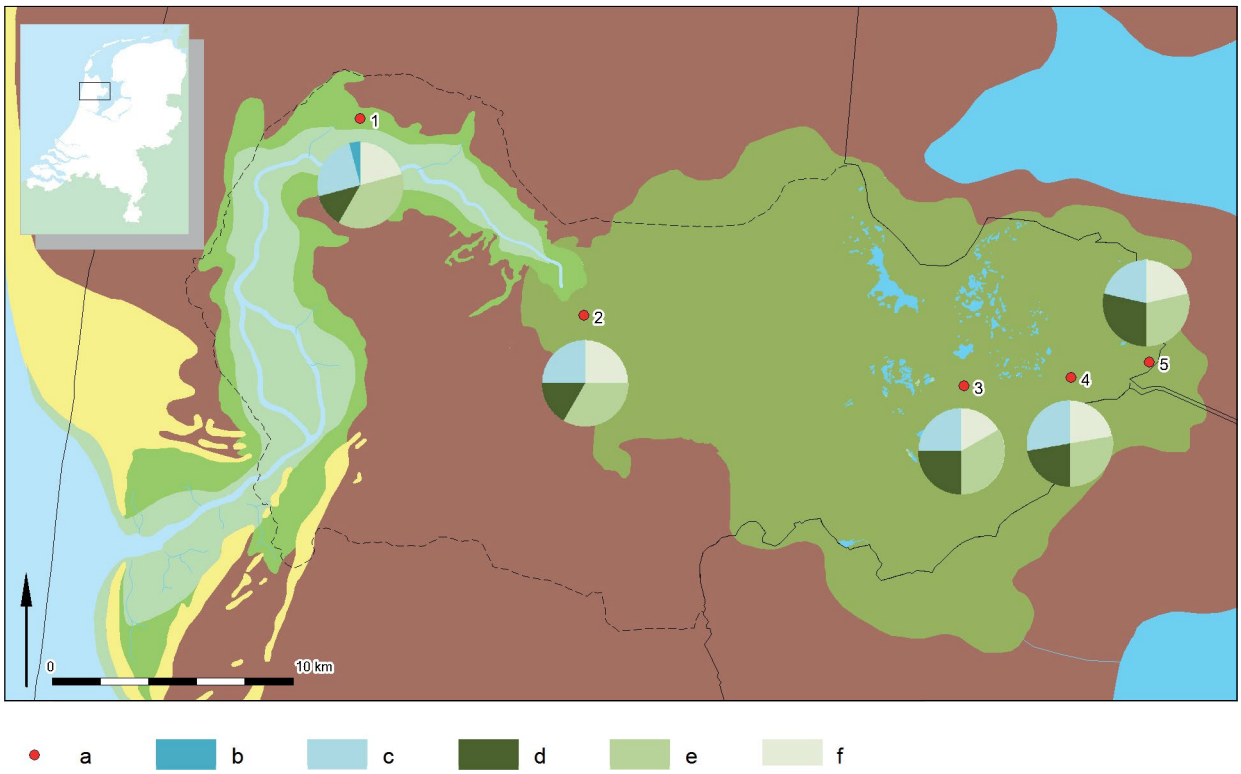


Figure 2.19. Map of Bronze Age West Frisia with the general habitat preferences of mammals found at each site yielding both small and large mammals. N denotes the combined number of different small and large mammal species found. For the legend of the underlying map, see Figure 2.1b. a: location of an excavated site; b: seacoast; c: wetlands; d: presence of trees; e: shrub land; f: grassland; 1: Schagen, n=13; 2: Hoogwoud, n=7; 3: Hoogkarspel, n=5; 4: Bovenkarspel, n=12; 5: Enkhuizen, n=10.

interpretation when not taken into consideration. The effects of (past and recent) methodology and taphonomy on the archaeozoological record will be examined first. In addition, two different cultural landscape indicators will be mentioned, which allow for the recognition of possible mutual changes in behaviour between wild animals, and humans living in a farming community.

2.4.5.1 Methodology

The main methodological issue which can greatly affect the assemblage of fish remains, is the practice of sieving (or lack thereof). When sites are sieved with different sieving methodologies, comparing the species composition on a quantitative level between such sites becomes impossible; the absence of species could have resulted solely from a difference in methodology, not from original past human practices. The difference in fish species composition observed in West Frisia for example (Table 2.5), can most likely be explained by the varying mesh sizes of sieves used at the sites, which range from 0.5-1.0 to 4.0 mm. Many fish and small mammal species possess such small bones, that sieving on a 4.0 mm mesh size results in a great loss of observed species diversity. Van Neer & Ervynck (1993) have used sieves as fine as 0.5 mm in mesh size for their research on fish remains, but sieves with 2.0 mm mesh sizes should suffice to uncover most of the fish species present in an assemblage. However, when as many fish species as possible need to be uncovered, a 1.0 mm mesh size is recommended (Meadow 1980, 69; Figure 2.20). Conversely, a sieving mesh size of 4 mm should be adequate to retrieve most of the bird and large mammal species, the number of obtained species only marginally increasing with the use of smaller mesh sizes. Still, when a complete picture of

the available species, and therefore habitat types, is required, sieves with mesh sizes ranging from 2.0-4.0 mm should be employed to retrieve bird remains, and 4.0 mm sieves to retrieve large mammal remains.

Besides sieving practices, a second problem related to the analysis of wild animal remains is that sampling is often performed in a non-specific manner. Often, samples are only taken when remains, especially of fish or birds, are identified within a feature with the naked eye. This kind of sampling thus only focuses on the find-rich features, which are often the features which are the result of much human influence in the past. In order to obtain a better understanding of the natural environment, including contexts located further away from the settlement, preferably natural waterways, should be sampled.

A final problem with the methodology applied to the analysis of large mammal remains in particular, is the probable presence of an identification bias that is specific for the Bronze Age period. Wild animals are often not deemed to be of relevance within a Bronze Age farming system (cf. IJzereef 1981, 24; Chapter 4). Since they are not expected to be present during this time period, the remains of some large mammals (*e.g.* red deer) may have therefore been falsely identified as cattle, which has similar proportions, reducing the visibility of wild large mammals in the archaeozoological record.

The methodological examples above indicate that sampling location, sieving practices, and identification biases can influence the interpretation of archaeozoological remains to a great extent. By adapting the sampling and sieving practices to match environmental questions, as well as maintaining an open mind towards the presence of wild animal species will considerably improve the reconstruction of past landscapes based on animal remains, especially when more than one animal proxy is employed before drawing final conclusions.

The analytical methodology applied in this research has shown that by using the habitat preferences of wild animals, past aquatic and terrestrial landscapes can be reconstructed, with both presence of different water types, water salinity levels, and vegetation. In addition, by comparing the expected and observed species, more insight was gained in presence and sometimes also absence of certain habitat types. So, by ensuring a wide range of wild animal species through adequate sampling and sieving methodologies, a more accurate understanding of the past environment may be obtained.

2.4.5.2 Taphonomy

Past human selection is one of the most important pre-depositional taphonomical processes, which should be taken into account when interpreting wild animal remains. Several reasons may exist for the absence or presence of certain species, and therefore habitat types, in the archaeological record. These reasons may include the human preference for some species over others, differences in (the ease of) their procurement, or (seasonal) abundance. Because this selection process can greatly affect the resulting deposited bone assemblage, definite conclusions on (the absence of) a certain habitat type in the past environment should only be drawn when several indications exist based on the frequency of species and the employment of multiple proxies. The bird remains from Hoogwoud (Figure 2.16) for example, showed the presence of only aquatic birds. This, however, by no means signifies that a site was situated amidst only wetlands. Human selection can severely affect the formation of the bird remains assemblage, and in the case of Hoogwoud, the presence of habitat types other than wetlands were indeed only confirmed by other proxies (cf. Figure 2.17 and Figure 2.18).

Specific taphonomical processes can diversely affect wild animal remains, depending on the species. Salmonids (including salmon and trout species) for example, are rarely found in archaeological contexts, because of their poor preservation characteristics. Salmon and trout possess bones which consist mainly of fat, which increases their susceptibility to degradation (Beerenhout 2005, 49; Beerenhout 2010, 134). The major manner in which these remains can be preserved is after contact with fire, which removes the fat. However, although it can be assumed that when salmonids are available to people, they will be caught and consumed, and most likely come in contact with fire during the process,

this burning process renders the salmonid bones very brittle. This brittleness also increases their chance of being lost by taphonomic processes. Therefore, because preservation of salmonid bone is so rare in general, it is hard to draw any conclusions about their prevalence and abundance. Furthermore, since the preservation of salmonid bones most likely occurs through contact with fire, this also inherently means that the chance of procuring salmonid bones from natural contexts is highly unlikely. Adequately sampling at on-site locations may be one of the few chances in which such fish, and their habitat types, can be identified.

Bird bones are adversely affected as well, as they are hollow and therefore also prone to degradation via mechanical pressure, hindering subsequent identification to species level.

The low numbers of large wild mammal bones furthermore, might also to some extent be related to taphonomical processes. Although in general, all large mammal bones should presumably be similarly affected by taphonomical processes in the soil, pre-depositional processes may very well have been very different for domestic and wild animal species, which could mainly be based on human selection. One such example was obtained from an interview with a present-day huntress who also has experience in taking care of livestock (Mrs. Van Hoey-Smith). Wild animal bones were treated very differently than bones from domestic animals in the recent past and sometimes even in the present: hunting dogs are fed with wild animals bones, to sustain their alertness towards this smell (pers. comm. Mrs. Van Hoey-Smith). However, raw cattle and other domesticated animal bones are not given to the hunting dogs, since they might initiate attacks towards livestock. This practice inevitably results in the complete consumption of wild animal bones, whereas domestic animal bones are largely spared, thus resulting in an under-representation of wild animal bones preserved in the archaeozoological record. Moreover, the purpose of the hunt could also affect the reflection of wild animals in the bone assemblage. When large animals are hunted for meat or raw material and need to be transported back to the settlement, the carcass could be left behind at the hunting location, considerably lowering the transport weight. Therefore, low numbers of wild animal bones as opposed to the large numbers of bones from livestock could have resulted from treating both animal groups differently before deposition, and this would not reflect the original ratios.

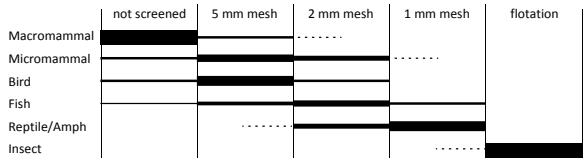


Figure 2.20. Overview of the sieving mesh sizes affecting the recovery of each of the animal groups mentioned (after: Meadow 1980, 69, Figure 2). Thicker bars reflect a higher chance of finding bones of an animal group related to mesh size. Amph: amphibians.

Small mammals finally, can occur at a settlement for several reasons, including natural occurrence and being transported to the settlement by man or animal. The occurrence of several species of small mammal from different habitats within one context for example, increases the likelihood of human (or animal) influence rather than natural occurrence (*e.g.* Lohof & Vaars 2005, 45). However, since small mammals are the prey of many larger animal species, their remains could have alternatively reached the settlement in the form of pellets (*e.g.* from owls; IJzereef 1981, 117) or by gutting a carnivorous animal. For example, a polecat has consumed several small mammals from different habitat types and is subsequently caught by humans and taken to the settlement. There, it is gutted, skinned and cleaned, and the discarded offal containing the stomach and intestinal content (and therefore the small mammals from different habitat types) ends up in the ditch within the settlement. Such a process may be recognised by identifying particular corrosion on the bones from stomach juices (cf. Payne & Munson 1985). When identified, the different small mammal species might thus be preserved in on-site contexts depending on the diet of a hunted carnivorous animal species, and may not always necessarily reflect all the different habitat types present on the settlement itself.

All animal groups have provided examples of the effects of pre-depositional and depositional

taphonomical processes, such as human selection in the past, but also species-specific preservation characteristics on the formation and composition of the archaeozoological record, as well as its interpretation. Therefore, continuous care should be exercised in future research towards landscape reconstruction based on animal remains. In conclusion, the most accurate analysis of available habitat types in the surroundings can be performed by combining different proxies and using the frequency of remains rather than numbers.

2.4.5.3 Indicators for the cultivated landscape

Fish
No clear indications for the cultivated landscape could be recognised among the fish species.

Birds
Some present-day birds display a clear preference for the presence of human-influenced vegetation, such as agricultural fields, fallow fields, and/or meadows. This habitat preference can be regarded as a sub-category within the habitat type grassland and similar preferences might have already existed in the Bronze Age. When such species are uncovered at settlements, and when they prefer such human-bound habitats, it can be assumed that they lived in relatively close proximity to the settlement, and can in a way be regarded as local habitat indicators. Crane and different species of goose and swan, which were all found in West Frisia, graze on the stubbles and remnants of crops on arable fields in autumn and winter (Birdlife International 2012). Skylark, quail, ruff, thrush, and swallow (also all found in West Frisia) profit from these fields all year long.

Especially quail and skylark show a strong preference for a specific height of grass/crop during their breeding seasons. Quail prefers vegetation no higher than one meter (Kwartel n.d.) and for skylark it is important to have areas of extensively used pasture, meadows or arable fields in order to breed successfully in the high vegetation (Willems 2008). Both species show a preference for the summer variety of crops because these provide appropriate shelter and food options at the right time. Winter varieties of crops are not preferred, as they are already too high and dense during the time the breeding season commences (Poulsen 1998; Koffijberg 2002; Willems 2008). The presence of these bird species can therefore provide possible indications for the cultivated landscape and can even provide information on the type of field used as well the type of crop. In the case of West Frisia, this means that both extensively used fields, including pasture, meadows, and arable fields, may have been present, as well as summer crops.

Small mammals
Two species of small mammal have adapted to human habitation in a specialised manner. Both the house mouse (*Mus musculus*) and harvest mouse (*Micromys minutus*) (both found in West Frisia, Table 2.8), can thrive within a settlement or even a house context, and can completely abandon their original habitat preferences. Such species can therefore be used as possible indicators of the cultivated landscape.

2.5 LANDSCAPE RECONSTRUCTION

The main components of the current model listed at the beginning of this chapter have all been challenged with the application of multiple proxies and an analysis based on the combined types of information they provide. A short summary (section 2.5.1) highlights the contribution of each of the used proxies and the approach of this thesis in general to the analyses of the data. The results of the analyses performed in this chapter are subsequently compared to each of the main components of the current model, after which it will become clear if and how they should be re-formulated into new main components (section 2.5.2). In turn, these new main components are combined into a new environmental model for West Frisia based on the integrated use of archaeobotanical and archaeozoological remains (section 2.5.3).

2.5.1. Contributions of proxies and approach to landscape reconstruction

The analysis of off-site pollen has provided information on the regional landscape including the presence or absence of indications for salt marsh, oligotrophic peat, and upland trees and herbs at

different locations within West Frisia. This type of analysis, which had not been performed in the past for West Frisia, provided a clearer image of the vegetation outside the settlements.

Among the macro botanical remains from the settlements there were indications for the regional landscape as well, represented by the presence or absence of remains of trees, peat, salt marsh, and upland vegetation. Fish remains, although not always included in landscape reconstructions, have provided a wealth of information on the aquatic landscape including the available water types in the surroundings of the settlements, as well as their salinity. Also, the observed fish species have provided indirect indications for the required presence of connecting waterways with the sea, based on migratory species. Remains of birds have provided mostly general, but also some detailed indications regarding the environment. A varied terrestrial landscape could be confirmed, as well as the presence of both freshwater and saltwater environments. The presence of trees especially, could be identified on a regional, but also a more local level based on home range size of different species.

Mammal remains finally, also provided evidence for both the regional and local landscape. Large mammals were used for the distinction between the presence of saline and freshwater conditions, as well as for a rough estimation of the size of the water bodies present in the surroundings of the settlement. Moreover, they were able to make the presence of trees in the settlements' surroundings very plausible. Small mammals provided very local information, probably only reflecting the habitats (in the near surroundings) of the settlements, and small and large mammals combined provided a more general and overall insight into the surrounding landscape.

The combination of both botanical and zoological remains used in this chapter has yielded a much more detailed picture than before of the variety of landscape and habitat types present in the surroundings of the settlements of West Frisia. This detail would not have been possible to such an extent if only one of the proxies were considered, or multiple proxies without integration of the individual results.

2.5.2 Assessing Previous Main Components

It is clear that the approach applied in this chapter has given new results regarding the landscape of West Frisia. In this section, to evaluate whether the previous main components are still appropriate to describe this landscape, the main components of the current model are compared to the new results of this chapter.

Main component 1 was formulated as follows:

(1) The seacoast to the west of West Frisia is closed around 1550 BC therefore making influx of marine water impossible after this time.

Based mainly on the fish remains and physical geographical information (van Zijverden forthcoming), but also on pollen remains, it has become clear that the seacoast to the west of West Frisia was connected to the hinterland until at least 1300-1100 BC, possibly even later. Since the new results do not match main component 1, a new main component 1 is formulated:

(N1) The seacoast to the west of West Frisia was at least open until 1300-1100 BC, and the inland influx of marine water was possible up to at least the settlement of Hoogwoud.

Main component 2 was formulated as follows:

(2) A purely freshwater environment existed around the settlements in eastern West Frisia throughout the Bronze Age.

The analyses of pollen remains, macro botanical remains, and animal remains have revealed that the settlements in the east of West Frisia were surrounded by a varied aquatic landscape, consisting of water bodies with varying (low) salinity levels. Most water bodies surrounding the eastern sites can be characterised as freshwater to slightly brackish, possibly due to their indirect connection with the North Sea via the Oer-IJ estuary and the large lakes to the east of West Frisia. Again, the new results and the current main components are not compatible and main component number 2 is therefore newly formulated:

(N2) An aquatic landscape with varying low salinity levels existed around the settlements in eastern West Frisia throughout the Bronze Age.

Main component 3 was formulated as follows:

(3) Wide-spread peat growth occurred in the Late Bronze Age, resulting in the abandonment of West Frisia.

Based on the pollen remains and the macro botanical remains, no evidence for the wide-spread growth of peat on settlements could be discerned, neither for the Middle Bronze Age, nor the Late Bronze Age. These results suggest that also main component number 3 should be reformulated:

(N3) No wide-spread peat growth occurred at the Late Bronze Age settlements, so this phenomenon cannot be regarded as a reason for the alleged abandonment of West Frisia during this time.

Main component 4 was formulated as follows:

(4) The terrestrial landscape of Bronze Age West Frisia is characterized by treeless, open areas.

Species observed among the pollen remains, macro botanical remains as well as animal remains show clear preferences for the presence of shrubs and trees in the surroundings of the Bronze Age settlements. Since this hardly reflects a treeless landscape, main component number 4 is also reformulated:

(N4) The terrestrial landscape of Bronze Age West Frisia can be characterised as a mosaic of habitat types including grassland, shrub land, trees, and wetlands.

All the previous main components are clearly no longer accurate to describe the West Frisian situation regarding the landscape. Therefore, the new main components, as well as the other new results are combined into a new model below.

2.5.3 New model for the Bronze Age West Frisian landscape

The new model for the West Frisian landscape presented here is mostly based on the research of Van Zijverden (forthcoming), which covers the Early, Middle, and Late Bronze Age. Where applicable, additions to his model are made based on the results of the analyses of organic remains from this chapter.

Aquatic landscape

In the Early Bronze Age, the Bergen inlet was open and saltwater influxes could reach as far inland as Emmeloord (van Zijverden 2002). Since West Frisia is situated between the North Sea and Emmeloord, the eastern sites of West Frisia thus also experienced these influxes (van Zijverden forthcoming, Chapter 3). The Early Bronze Age site Schagen was located near the seacoast along a large water way, evidenced by the many marine indicators found here (Vos 2015). Based on geology and ecology, the site of Schagen was most likely located in an intertidal habitat, with smaller, more freshwater bodies present in the surroundings as well.

Insight into the Early Bronze Age landscape in the eastern part of West Frisia was obtained by analysing multiple proxies on an off-site location, the site Noorderboekert (van Zijverden forthcoming). The Early Bronze Age landscape (*i.e.* from 2100-1600 BC) could be reconstructed y analysing samples deriving from a natural flood basin area. The investigated proxies include pollen, botanical macro remains, ostracods, diatoms, forams, and molluscs. The general landscape type in this part of West Frisia can be regarded as a large area of flood basins and tidal creeks with varying salinity levels ranging from brackish to saline (Figure 2.21). Throughout the Early Bronze Age, the aquatic landscape was very dynamic, with both water depth and flow speed varying enormously. The environment at the start of the Early Bronze Age is characterized by presence of a deep tidal channel transporting marine organisms, which changes into a marsh dominated by stagnant and fresher water conditions. However, this local presence of fresh(er) water is periodically, but irregularly influenced by saltwater influxes, which indicates the possible occurrence of storm surges

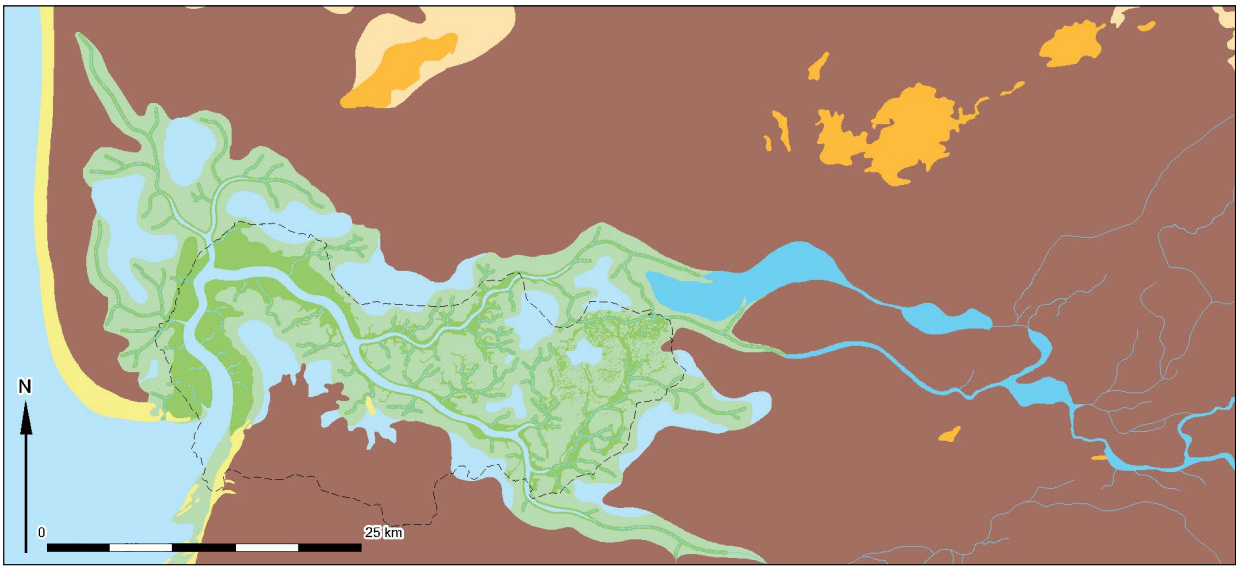


Figure 2.21. The Early Bronze Age landscape of West Frisia (from: van Zijverden forthcoming) For the legend of the underlying map, see Figure 2.1b.

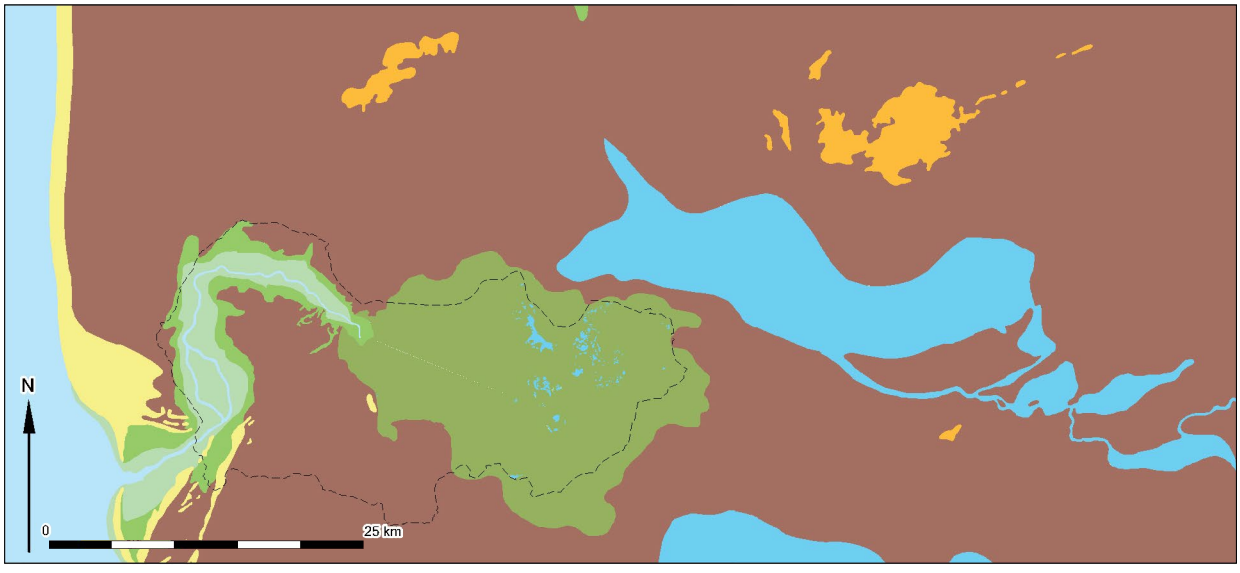


Figure 2.22. The Middle Bronze Age landscape of West Frisia (from: van Zijverden forthcoming). For the legend of the underlying map, see Figure 2.1b.

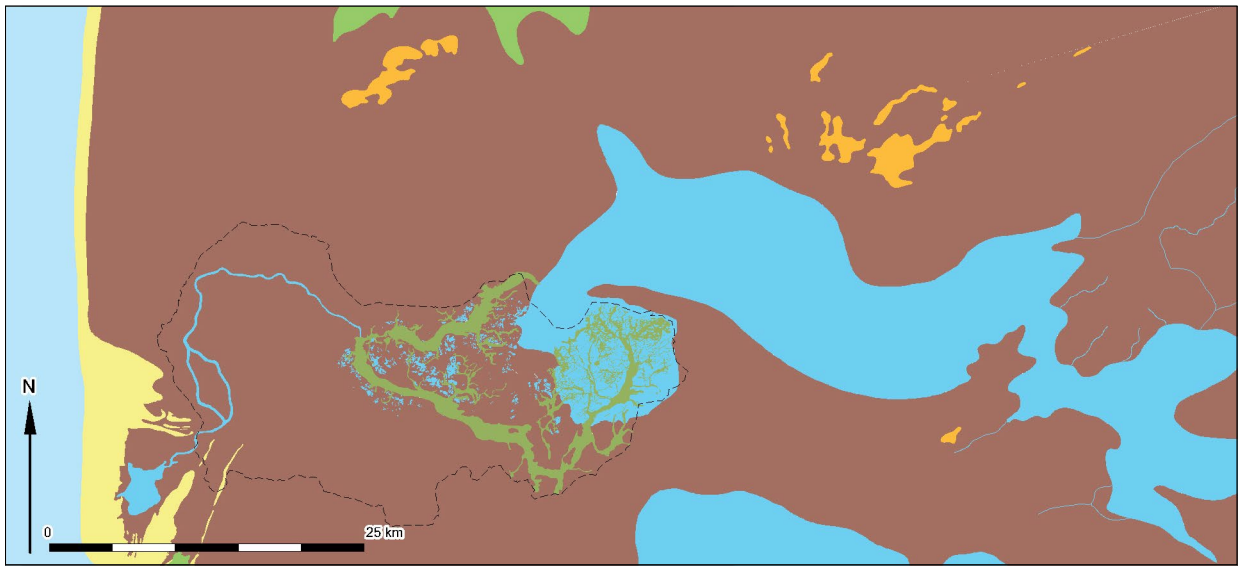


Figure 2.23. The Late Bronze Age landscape of West Frisia (from: van Zijverden forthcoming). For the legend of the underlying map, see Figure 2.1b.

and/or spring tides during this time. Near the end of the Early Bronze Age, water flow again increases, reverting the landscape back to being dominated by flood basins and tidal creeks, although the water is no longer saline (van Zijverden forthcoming).

The Middle Bronze Age is characterized by a decreased size of the Bergen inlet, with saltwater influxes still reaching as far as Hoogwoud. In the east, large lakes are fed by rivers from the east of the Netherlands and via the northern branch of the river Rhine discharging in the Oer-IJ estuary (Figure 2.22). Hoogwoud can be regarded as being dominated by an intertidal habitat, with the additional presence of water bodies with less saline conditions in the area. The eastern sites of Medemblik, Enkhuizen, Westwoud, and Bovenkarspel can be characterised by a combination of water types present in the surroundings, mostly consisting of stagnant to slow-flowing water and open water. The water will have been fresh to slightly brackish. In addition, there appears to be an absence of actual fast-flowing water types (*i.e.* rivers) within the eastern part of West Frisia.

In the Late Bronze Age, the Bergen inlet is probably closed entirely, but possibly, a residual opening was still present. The main inflow of saltwater now only occurs via the opening of the Oer-IJ estuary, which is also starting to decrease in size, leaving less room for the passage of sea water into the hinterland. This phenomenon, in combination with the fact that the large lakes in the east are still being fed with fresh water from rivers further east, means that the eastern large lakes are expanding, and that the overall salinity level of the lakes decreases. Still, several different types of water bodies will have remained present around the settlements (Figure 2.23).

Terrestrial landscape

The Early Bronze Age terrestrial landscape in the west of West Frisia was an intertidal landscape (Figure 2.21). The uncovered terrestrial animal species in Schagen reflect a varied landscape, consisting of a combination of grassland, shrubs, and trees. The eastern part of West Frisia consists of creek ridges amidst large bodies of water (Figure 2.21; Knippenberg in prep.). Since large fluctuations in water table and salt content occur, only marsh dominated by reed vegetation, and willow shrubs can survive. The usual wetland vegetation types, including alder carr and sedges, do not develop here. In the Middle Bronze Age, the landscape surrounding the settlements throughout West Frisia can be viewed as a mosaic of different landscape types,

including grassland, shrub land, trees, wetlands in the east, and, more towards Hoogwoud in the west, saltwater areas (Figure 2.22). The vegetation in the eastern part of West Frisia during this time more particularly consisted of alder carrs in wetlands, ash-elm forests in drier areas, and moderately nutrient-rich grassland in the driest areas, probably caused by grazing of livestock.

The Late Bronze Age is characterised by an increase of the ground water table by as much as one metre (van Zijverden forthcoming). In combination with an increase in surface water fluctuation, this results in a change in wet vegetation types, which now consist of reed vegetation and soft willow shrub along shallow lake shores. The habitat types from the Middle Bronze Age still exist in the Late Bronze Age, but are now more condensed into smaller areas with remaining suitable soils (Figure 2.23). This condensed state of vegetation types and shortage of suitable land will ultimately have restricted the exploitation, habitation, and migration by people and animals living in West Frisia at this time, although some areas remained habitable until the Iron Age.

3. Reconstruction of subsistence

This chapter is meant as a general introduction for the following five chapters, which all relate to the reconstruction of the subsistence economy of Bronze Age West Frisian farmers. Also in this chapter, the new approach of this thesis towards the reconstruction of subsistence is introduced, as well as its main assumptions for the model for the West Frisian Bronze Age situation.

3.1 SUBSISTENCE ECONOMY

The subject of this thesis was pre-defined to research the subsistence economy of West Frisian farmers. Before further investigating this subject, it is important to establish what a subsistence economy actually entails. A subsistence economy is defined as an economy which produces only enough output for its own consumption and does not attempt to accumulate wealth (Merriam Webster dictionary 2016). Clearly, if it is assumed that Bronze Age West Frisian people were indeed part of a subsistence economy, it means that they can therefore be characterised as practicing subsistence farming, at least until other observations contradict this assumption. Subsistence farming, in turn, is defined as farming or a system of farming that provides all or almost all the goods required by the farm family, usually without any significant surplus (Merriam Webster dictionary 2016). Thus, for West Frisian Bronze Age farmers, it is assumed that they produced goods for the household and settlement to remain above the survival threshold, but not much more.

It is also an important aspect of this thesis to clarify the main components of subsistence, since it provides a better focus for the research. Defining such main components, however, is a difficult task, since no clear definitions exist. In an attempt to identify the main components of subsistence, and to create a plausible platform for the reconstruction of the subsistence economy, basic subsistence was viewed as a form of survival. By viewing subsistence in this manner, it was possible to elucidate the most basic principles required for survival: basic needs. These basic needs, which form the absolute minimum to uphold a subsistence and to survive, include food, fire, housing and clothing (shelter against the elements), and water (United States Dept. of the Army 2009). Although the Bronze Age situation may not have been as dire as a pure survival situation, these five subjects are essential to life in general and form a good starting point for the research on subsistence. Of these basic needs, shelter in the form of the farm is already researched in another sub-project of the Farmers of the Coast project (Roessingh in prep.). Water and fire, which will have formed a definite part of Bronze Age subsistence as well, will not be researched extensively in this thesis but will be remarked upon when appropriate. Therefore, food is the basic need that will form the main focus in the reconstruction of the subsistence economy in this research. Nonetheless indications for other basic needs are also discussed in Chapter 4-7. Examples of tools and other equipment required in and around the house, as well as for the construction of clothing will also be summarized, integrated, and discussed in Chapter 8.

3.2 FOOD PROCUREMENT

Food can be procured in different ways, ways which have shifted in relative importance throughout (pre) history. The main food procuring strategies, or subsistence strategies, can be roughly divided into wild resource exploitation and domestic resource production. Wild resource exploitation, often the main form of subsistence in earlier prehistory but also various cultures later in time, includes the gathering of plants and the hunting of animals, where the latter can be further sub-divided into fishing, fowling (*i.e.* hunting birds), and game hunting (*i.e.* hunting mammals). Domestic resource production has increasingly become the more prominent form of procuring food. The cultivation of crops and the breeding of animals have ensured the availability of nutrients for the settlement, and crop and animal

husbandry have allowed people to control their access to food in an unprecedented manner.

Although the above divide seems rather definitive, mixed forms of subsistence which include all four subsistence strategies also exist, and contribute in different ratios. Since it is unknown what the contribution of each may have been to farmers in West Frisia, the four food procurement strategies are investigated individually, after which a combination is made to view the subsistence economy as a whole. This being said, because the Bronze Age subsistence is first and foremost characterised by farming, crop and animal husbandry are assumed to have been the main subsistence strategies, providing the staple food for the settlements. Therefore, in this thesis Bronze Age West Frisian people are assumed to be (full-time) farmers, and the extent of the other two subsistence strategies is evaluated accordingly.

3.3 FARMING IN THE BRONZE AGE

Farming, including animal and/or crop husbandry, can either be specialised towards one of the two subsistence strategies, or be a combination of both. Two extreme examples of specialised farming systems may include pastoralism (*i.e.* herders with flocks/herds pursuing grazing areas, no crops), or specialised crop husbandry (*i.e.* only practicing the cultivation of crops, no livestock).

In West Frisia, evidence for both crop and animal husbandry practices were uncovered at every site in the form of remains of crops and domestic animals, and the presence of plough marks (IJzereef 1981; Buurman 1996). In cases where both the breeding and keeping of livestock and the cultivation of crops are encountered on a settlement, it is assumed that this signifies the presence of a mixed farming system, where both practices are combined and integrated (Schiere & Kater 2001, Ch 2).

3.3.1 Mixed farming

Mixed farming systems are characterised by a sedentary lifestyle (*i.e.* a permanent residence), from which activities regarding crop and/or animal husbandry are practiced. Mixed farming systems can further be distinguished by the fact that both crops and animals have multiple important functions within the system, in which each can be used to support the other's existence: crop (residue) can be used to feed livestock, and dung from livestock can be used to fertilise arable fields. This integrated combination of individual components and recycling of resources is what supplies the mixed farm with its yields. When the single components of the system are not integrated or not balanced, the system is not viable. This means that farmers need to adjust their farming strategy on an annual basis depending on the changes which occur with regard to harvest and youngstock yields. Mixed farming is therefore not only a balanced, but also a dynamic system. Due to the fact that the overall system needs to be balanced, short-term dynamic practices may be averaged towards an overall long-term practice or strategy, which is investigated in the following animal and crop husbandry chapters. In addition, the synergetic aspect of the mixed farming system requires the research of all separate aspects relating to subsistence (*i.e.* subsistence strategies) to understand the whole system and the "factors that drive farmers and influence their decisions" (Schiere & Kater 2001, Ch 2). This observation underlines the importance of the following four chapters, and the summarizing and integrating Chapter 8 in understanding the subsistence economy as an intricate interplay of dynamic decisions which are dependent on both environmental and social conditions.

For farmers, one of the main advantages of having a mixed farming system is that the management of multiple species of livestock as well as the cultivation of crops can be regarded as a form of risk reduction. By practicing both subsistence strategies with multiple species, the chance of losing all resources during years of less successful animal and crop yields is reduced (Schiere & Kater 2001, Ch 2; Dose 2007, 6-8; Pica-Ciamarra *et al.* 2011, 4). Another advantage is that the combination of multiple species of animal on a farm can result in the efficient usage of the surrounding pasture (Reijntjes *et al.* 1992), reducing the total acreage of pasture required. A final advantage of mixed farming is that labour can be spread over several activities (Schiere & Kater

2001, Ch 2). However, this division of attention over multiple resources and activities inherently results in a limited total potential scale of the subsistence economy (Schiere & Kater 2001, Ch 2).

3.3.2 Small-scale farming

At mixed farms, by definition, crop and animal husbandry are practiced on a much smaller scale than when specialisation towards one of the two subsistence strategies occurs (Schiere & Kater 2001, Ch 2). Mixed farming therefore matches very well with the definition of subsistence farming (as outlined in section 3.1), and these two are often closely interlinked. Therefore, West Frisian farmers are assumed to have been small-scale mixed subsistence farmers, who produce solely what they need for their subsistence and rarely produce surplus. They are further assumed to have possessed both arable fields and flocks and herds of livestock of limited size. Any imbalance in the relative size of either one, and the mixed system would collapse.

The investigation of prehistoric subsistence farming needs a good and plausible starting point for what can be expected of past practices. In this research, the starting point was the search for basic elements which occur consistently in subsistence farming systems regardless of time period, geographical location or climate. Such recurring basic elements, for example certain practices in crop and animal husbandry, would therefore form plausible parallels for what can be expected for the West Frisian situation.

The examples of subsistence farming systems used in this thesis consist of ethnographic parallels in developing countries throughout the world, where traditional small-scale mixed subsistence farming is still being practiced. Locating these appropriate parallels proved, however, to be a difficult task. Small mixed farms are increasingly being replaced by large specialised production farms in many parts of the world (*e.g.* FAO 2012), and at a rapid rate: parallels with enough quantitative data on small-scale mixed subsistence economies are scarce. The discovered parallels applied in the following chapters are for now sufficient, but there is an urgent need for more quantitative research towards the different elements of which small-scale mixed subsistence systems are composed.

So, based on a combination of the observed evidence from the excavated West Frisian sites and the above literature studies, the model for the farming in West Frisia during the Bronze Age is defined as small-scale mixed subsistence farming. More detailed characteristics of this system, hypothesized based on ethnographic parallels, are elaborated upon in the respective following Chapter 5 and 6 on animal and crop husbandry.

3.3.3 The role of hunting and gathering in small-scale farming communities

The role of hunting and gathering within the small-scale mixed subsistence farming communities is also explored in this thesis. The exploration is based on similar ethnographic parallels as mentioned in the previous section as well as on other, more specific ethnographic examples. In addition, biological information is employed to analyse the contributions that wild plants and animals may make to subsistence.

Although it is assumed that the largest part of subsistence consists of farming practices, the contribution of wild resource exploitation within farming communities should not be underestimated *a priori.* Especially in small-scale communities, it might not be possible to maintain subsistence solely based on the production of the settlement. Depending on the extent of wild resource exploitation being practiced in the Bronze Age, subsistence farming on its own may not be a sufficient term to describe the West Frisian subsistence situation. This however, will have to be revealed from the analyses of the respective following Chapters 4 and 7 on hunting and gathering.

3.3.4 Family size

In small-scale mixed farming systems, many hands are required to perform all kinds of subsistence-related activities. The possible size of herds and arable fields is also dependent on the size of the family. It is therefore important to establish a range of possible sizes of farming families. Several of the

aforementioned ethnographic parallels were used to estimate family size and it appears that in many rural areas throughout the world, the family size ranges from 1 to 10 individuals, with an average of 6 to 8 persons per household (Doran & ILRI 1995, §2.2; Ajala *et al.* 2007, 185; Dose 2007, 13; Laski 2007, 3-4; Lemke & Valle Zarate 2008, 209; Kongolo & Dlamini 2012, 104; Umeh *et al.* 2013, 108-9). This relatively high number of people in a household seems adequate to perform all the necessary tasks around the farmstead. However, this average number of people comprises the entire household, which also includes old people and (young) children. These two demographic groups are not expected to (already) contribute labour in a manner comparable to healthy (young) adults. In addition, a probable high child and adult mortality within these communities and its inherent consequences (Sherbinin *et al.* 2009, 9), in reality results in a significant reduction of the actual number of people per household contributing labour to farming activities. It should therefore be kept in mind that family size does not necessarily reflect the number of family members able to contribute to performing activities in and around the farm.

3.3.5 Action radius

Since small-scale mixed subsistence farming communities consist of relatively few people (section 3.3.4), and many activities related to both crop and animal husbandry still need to be performed, the action radius around the settlement will, on average, also be limited. Many studies have recorded action radii of differently sized communities, such as hunter-gatherer (10 km), pastoral-herder (7.5 km), and true farming communities (5 km) (*e.g.* Bakels 1978, 6-9 and references therein). These action radii are considered adequate for each community to acquire their daily supplies: the further one travels away from the settlement, the less time can be spent at that location due to loss of time for the return trip. The average values for each settlement type are not all applicable to the West Frisian farming situation, however, so only the radius value of around 5 km related to farming communities is considered here. This means that on average, both domestic and wild resource-related activities around the settlement are expected to be characterized as local practices.

3.4 RESEARCH QUESTIONS AND MAIN COMPONENTS

In order to investigate the extent to which each of the subsistence strategies may have aided the Bronze Age subsistence economy, all four strategies, including hunting, animal husbandry, crop husbandry, and gathering of wild plants are first researched separately in the following Chapters 4-7. The analysis of each subsistence strategy includes, amongst other factors, the impact on the landscape, the activities related to the strategy, as well as the seasonality of these activities.

As has become clear from this chapter, however, these strategies can in reality not be considered as separate entities: their interconnectedness is what upholds the mixed subsistence farm. So, where normally only one element of subsistence is researched in detail, or separate researched elements are left un-integrated, in this thesis the results of the separate Chapters 4-7 are re-integrated and distilled into three themes in Chapter 8. These themes can be considered to form essential parts of subsistence and include: the landscape in which people operate, the manner in which basic needs are fulfilled, and the activities that need to occur in order to accomplish this. It is only through these overarching themes that the interdependency and role of each subsistence strategy in the Bronze Age subsistence economy truly becomes clear.

The order of the next four chapters is not random, but rather chosen to improve the flow of subjects. In Chapter 4, the role and praxis of hunting is discussed, followed by Chapter 5, which discusses animal husbandry practices. Both Chapter 4 and 5 therefore include analyses and discussions on animal remains. Subsequently, in Chapter 6 crop husbandry practices are researched, so Chapter 5 and 6 combined investigate the domestic resource production aspect of farming. In Chapter 7, the role and praxis of wild plant gathering is established, so in both Chapter 6 and 7 the botanical remains are analysed and discussed. To complete the circle, the results from Chapter 7 are compared with the results from Chapter 4 in order to investigate the full range of exploited wild resources.

Per chapter, the analysis of each subsistence strategy is approached in a similar manner. In the introduction of each chapter the previous research performed is mentioned, as well as the current models constructed for the respective subsistence strategy. Then, a summation of these previous investigations and interpretations is distilled into a set of main components of the current model. These main components are challenged in each chapter by comparing them to the new results (cf. Chapter 2). The methods with which the subsistence strategies are researched differ per chapter and are therefore discussed separately each time, but are mainly rooted in ethnography and biology. Ethnographical parallels are, as mentioned in the previous sections, employed to create an expectation of basic practices in small-scale mixed subsistence farming communities, and biological information provides more indirect indications for the practices of each subsistence strategy. The results of this ethnographical and biological research forms the first half of the results section in each chapter. New and/or additional potentially important main components deriving from these ethnographical parallels will be added to the list of main components of the current model, to include in the comparison with the data. The second half of the results section comprises the analysis of the West Frisian data on each of the basic elements of the researched subsistence strategy based on the ethnographic parallels. These basic topics are structured in a similar manner for both the expectation and the data analysis and are related to the selection of and composition of species, praxis, use, location, and seasonality. The subsequent comparison of the main components based on the old data and the ethnographic research with the West Frisian data will provide indications for choices made by the West Frisian farmers in their subsistence strategies and economy. Finally, each chapter is concluded with a new model for each of the different subsistence strategies.

4. Reconstruction of subsistence: Hunting

4.1 INTRODUCTION

In this chapter, the role of hunting in subsistence farming is evaluated. Although hunting is not normally associated with farming life, its contribution to subsistence is investigated in order to confirm or contradict its importance in the Bronze Age. This investigation is achieved by a re-evaluation of the available old and new data. In the introduction to this chapter, an overview of the previous research and ideas on hunting in the Bronze Age is provided. Since no clear inconsistencies between recent data and the current model exist, only the general statements related to the current model are reiterated, each followed by a number between brackets. These numbers are presented as the starting main components which are challenged in this chapter. It is good to note that throughout this chapter, the general term hunting incorporates the capture of fish (*i.e.* fishing), birds (*i.e.* fowling), and wild mammals (*i.e.* game hunting), unless further specified. Possible collection of fungi, molluscs, amphibians, and reptiles is not included in this thesis, although it is by no means denied that the hunting of these organisms may have aided subsistence as well.

4.1.1 Previous research

Hunting has formed an integral part of human subsistence for hundreds of thousands of years. People hunted animals and gathered plants, thus maintaining their livelihoods. With the onset of farming however, people could control the animals and plants they consumed in a more direct manner, via cultivation and husbandry. These new subsistence strategies, making their definite appearance in the Neolithic, are often viewed as replacements for hunting and gathering. From this time period onwards, the amount of wild animal bones found at settlements seems to decrease rapidly (Louwe Kooijmans 1993, 78, figure 6.6). Late Neolithic farmers are progressively portrayed as becoming more rigid self-sufficient farmers who start to disregard wild resources in favour of mixed farming (1). Especially in the western Netherlands, these people are characterized as people that "started (..) to live with their backs to nature" (Louwe Kooijmans 1993, 80), a statement which is mainly based on the fewer numbers of wild animal bones uncovered in comparison to previous periods. This trend of decreased numbers of wild animal bones found at settlements is also observed in the Bronze Age. Both in the western Netherlands in general, as in West Frisia in particular, the occurrence of remains of wild animals in this period is linked directly to their relative (economic) importance for subsistence (2) (IJzereef 1981, 110-111; Louwe Kooijmans 1993, 80-3; Buurman 1996, 193; Roessingh & Lohof 2011, 210; Brinkkemper 2013, 186). Following this reasoning, since remains from wild mammals (*i.e.* game) and birds (*i.e.* fowl) are scarce throughout the Bronze Age, although fish remains are comparatively numerous (Louwe Kooijmans 1993, 104), hunting and fowling were assumed not to have been practiced, but fishing remained of some importance (3). Large game was apparently only hunted on a very opportunistic basis, without specialisation or concentration on a particular species or the surrounding available richness (4) (Louwe Kooijmans 1993, 81). Clearly, the above examples illustrate the current view of hunting within a Bronze Age farming community: hunting was either not practiced at all, or only on a very opportunistic basis, thus signifying the full reliance on and confidence in domestic animal production.

4.1.2 The proxies and the sites

The current view on hunting within a farming community is re-evaluated by gathering and combining the data from the old as well as the more recent excavations for analysis. The new approach of creating an expectation and comparing it to the analysed data is also applied in this chapter. Both were achieved by using a combination of different proxies, including ethnography, ecology, biology and archaeology (section 4.2, 4.3, and 4.4). Furthermore,

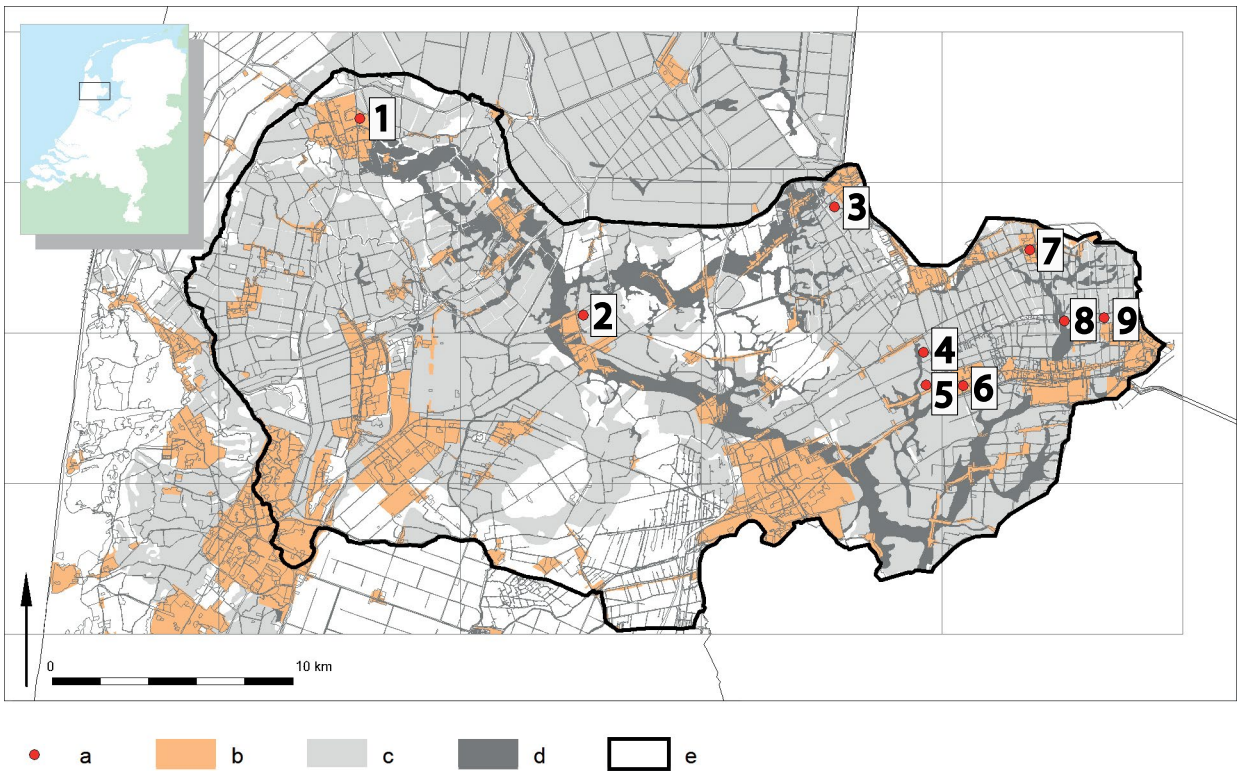


Figure 4.1. Overview of the sites of West Frisia that yielded wild animal remains. 1: Schagen de Hoep-Noord; 2: Hoogwoud Opmeer; 3: Medemblik Schepenwijk II; 4: Zwaagdijk 1961 and Zwaagdijk Oost; 5: Westwoud; 6: Hoogkarspel Tolhuis and Hoogkarspel Watertoren; 7: Andijk Zuid and Noord; 8: Bovenkarspel 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.

the critical evaluation of the processes affecting the wild animal bone data and their resulting influence on the consecutive interpretation are given considerable attention (section 4.4.5). By examining hunting in detail, important aspects have come to the forefront which are missed when writing broad summarizing overviews of a practice. These aspects together with the results of the analysis are combined to form a new model for hunting in Bronze Age West Frisian subsistence (section 4.5).

The information on the sites used in this chapter which yielded wild animal remains are shown in Figure 4.1 and Table 4.1, including their location, name, date, dating method, and sieving mesh size. Since not every site contained remains of each animal group (*i.e.* fish, birds, and small and large mammals), Table 4.1 additionally shows which animal groups were found, as well as the references related to each group. Finally, 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.

4.1.3 Main current model components

The main components of the current view of hunting, which are challenged in this chapter, are as follows:

(1) Bronze Age people are self-sufficient full-time farmers with no apparent need for wild resource exploitation.

(2) Frequency of wild animal remains can be linked directly to the relative (economic) importance of hunting in aiding subsistence in Bronze Age farming communities.

(3) Hunting of mammals and birds was not practised in the Middle and Late Bronze Age, but fishing remained of some importance.

(4) Large game was only hunted on a very opportunistic basis, without specialisation or concentration on a particular species or the surrounding available richness in the area.

Although the above main components are mostly constructed for the Bronze Age in the western Netherlands in general, they also inherently apply to West Frisia and the West Frisian data is therefore employed to challenge these main components.

4.2 METHODS

A combination of methods is presented here, which together is employed to evaluate the role and praxis of hunting in Bronze Age West Frisia. In order to understand the praxis of hunting as a whole, the different activities related to hunting are discussed separately (Table 4.2). A detailed analysis of these different parts shows the complexity of hunting, as well as the possibilities for its integration with farming practices. For the creation of an expectation of hunting practices (section 4.3), each of the basic components of hunting (*i.e.* preparation, hunting, processing, and storage and long-distance travel) is analysed in order. Each hunting component in turn is discussed separately for each animal group concerned (fish, birds, and small and large mammals) when analysing the West Frisian data (section 4.4). In this manner, it becomes clear what the scope, logic and importance of different hunting activities is, how they are executed, what the possible reflection of these activities in the archaeological record may be and which aspects of hunting may in fact remain invisible to archaeology.

The analysis of hunting incorporates the use of four main disciplines: ethnography, biology, ecology, and archaeology, which are elaborated upon in this section.

4.2.1 Ethnography

The ethnographical work by Murdock (1981) was employed to create a general idea of the importance of hunting for the subsistence of small-scale mixed subsistence farmers. A selection was made of the available culture groups researched by Murdock (Appendix A1.4), so that only cultures that most closely resemble the assumed Dutch Bronze Age situation remained. The selection criteria were: more than 50% of the food economy needed to consist of crop and animal husbandry (*i.e.* full-time farmers); the type of agriculture needed to be intensive agriculture on permanent fields with short fallow (cf. Chapter 6); crops needed to consist of cereals (cf. Chapter 6); settlement size needed to be relatively small, consisting of homesteads, hamlets, or compact settlements (cf. Roessingh in prep); animal husbandry should be focused on bovine animals (cf. Chapter 5).

More specific information on hunting practices in small-scale farming communities was obtained via detailed ethnographical studies summarized by Kent (1989). In these studies, the effects of hunting in a sedentary society, as well as the cross-cultural social organisation of hunting are highlighted. Kent aims to understand pan-cultural view of the role of hunting, hunters, and meat in groups with disparate economies and organizations (Kent 1989, 1). These examples provide information on the praxis of farming as well as on the mobility of hunting farmers.

4.2.2 Ecology

The possible locations and seasonality of hunting are analysed with the aid of ecology, which, as a discipline, researches the interaction between organisms and their environments. Habitat preferences of the animals uncovered at the excavated sites (Europese Vogelgids Online 2012; Nederlands Soortenregister 2015; Marine Fish Map 2016; Vissengids 2016; Soortenbank Nederland n.d.) provided information on the possible locations people visited for hunting, as well as indirect information on mobility. It is assumed that the animals present on the settlement were hunted by people, and because people are assumed to be full-time farmers, it is assumed that hunting occurred in relatively close proximity to the settlements in order to remain combinable with farming practices (cf. Chapter 3, section 3.3).

4.2.3 Biology

The main biological sub-discipline consulted for the analysis of the praxis of hunting was behavioural biology. Behaviour of animals can be animal group

Table 4.1. Information on the sites of West Frisia used for the analysis of hunting.

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 (fish, birds, mammals)
Enkhuizen	Kadijken	2007-2009	1500-800 cal BC	14C-dating and pottery typology	4.0 mm	Zeiler & Brinkhuizen 2011, 191-216 (fish, birds, and mammals)
Hoogkarspel	Watertoren	1973-1978	1500-800 cal BC	14C-dating	unknown	Clason 1967 (mammals)
Hoogkarspel	Tolhuis (DEF)	1964-1969	1500-800 cal BC	14C-dating and pottery typology	unknown	Smits 1978 (mammals) Suwijn 1981 (mammals)
Hoogwoud	Opmeer	2004	1300-1100 BC	pottery typology	4.0 mm	Beerenhout 2005, 43-50 (fish) van Dijk 2005, 36-43 (birds and mammals)
Medemblik	Schepenwijk II	2007	1450-800 cal BC	14C-dating and pottery typology	1.0 and 4.0 mm	Beerenhout 2010, 105-20 (fish) Groot 2010a, 83-104 (birds and mammals)
Schagen	de Hoep-Noord	2003-2004	2200-1600 cal BC	14C-dating	1.0, 2.0, 5.0 mm	Zeiler *et al.* 2007 (fish, birds, and mammals)
Westwoud	1988	1988	1400-800 cal BC	AMS-dating	0.5-1.0 mm	Buurman 1996, 107-56 (fish, small mammals)
Zwaagdijk	1961	1961	1500-1100 cal BC	14C-dating and pottery typology	unknown	Clason 1964 (mammals)
Zwaagdijk	Oost	2003	1500-1100 cal BC	14C-dating	unknown	Halici & Buitenhuis 2003, 155-88 (mammals)

Table 4.2. Basic activities related to hunting.

Preparation
locating worthy hunting spots
gathering/making tools/equipment/bait
Hunting
setting of catching equipment
(passive hunting)
checking catching equipment (passive hunting)
active hunting
collecting (passive or active hunting)
Processing
short-term (gutting, cooking, etc.)
long-term (drying, salting, smoking, etc.)
Optional
storage
long-distance travel

or even species specific and can provide a wealth of indirect indications for hunting (Europese Vogelgids Online 2012; Nederlands Soortenregister 2015; Marine Fish Map 2016; Vissengids 2016; Soortenbank Nederland n.d.)): the preferred food of an animal can give information about the use of possible baits or lures; reproduction and migration of animals can give insight into seasonality, availability and abundance. In turn, these preferences and seasonal activities of animals can be further translated into different appropriate catching techniques for each animal species, which may have varied from season to season. It is assumed here that the behaviour of animals, including feeding, breeding, and migration, has remained the same or at least comparable from the Bronze Age to the present.

4.2.4 Archaeology

Direct indications for hunting practices, such as the availability or presence of hunting gear, were explored in both the Dutch and north-western European archaeological Bronze Age data at large.

4.3 CREATING AN EXPECTATION OF HUNTING PRACTICES

As mentioned in the previous section, the role of hunting in small-scale mixed subsistence farming communities was first investigated with the use of the studies of Murdock (1981) and Kent (1989). An analysis of the subsistence of the selected farming communities from different cultures described by Murdock has revealed that in these recent societies, hunting (plus fishing) adds on average 11% to subsistence (Appendix A1.4). So, it is clear that hunting is still being practiced in relatively recent small-scale mixed subsistence farming communities. However, Murdock is vague on what is meant by a contribution to subsistence, only stating that values reflect: “the estimated relative dependence of the society on each of the five major types of subsistence activity” (Murdock 1981, 92). This dependence may therefore reflect hunting for consumption purposes, use of raw material, or both. Furthermore, a small percentage in the data compiled by Murdock may also signify practices that are perhaps not carried out often, but may in fact form very important aspects of subsistence. Sadly, this is not clarified either.

The research performed by Kent specifically examines the role of hunting in small-scale farming communities (Kent 1989). Many of the articles in her work underline the overlapping, complementary, and interdependent nature of wild resource exploitation and farming (*e.g.* Kent 1989, 45), and the special role hunting and meat still play in such small communities, even regardless of the necessity of this practice for subsistence.

Overall, hunting seems to be an integral part of many small-scale farming communities, but it remains unclear what the exact contribution to subsistence is. Also, it is (yet) unsure whether the above communities are directly comparable to the Bronze Age situation (Chapter 8, section 8.7.1). Therefore, in this section, each of the subsequent steps involved with hunting is carefully analysed, in order to create an expectation of hunting in the Bronze Age. This analysis will have to reveal the possible role hunting may have played in Bronze Age communities.

4.3.1 Preparation

Hunting requires careful planning and knowledge of the locations where a preferred prey resides, as well as of the seasonality of its movements to or from specific locations. This knowledge is essential for capture. Such types of knowledge include the habitat preferences of animals and different types of animal behaviour. Animal behaviour related to food, migration, and reproduction can be very helpful for a hunter in determining when an animal is absent or present, as well as provide information on what bait can be suitable for each preferred animal species. In order to be prepared for the hunt, a hunter needs to combine all his knowledge on the preferred prey. Reconstructing these preparatory steps thus involves analysing both animal preferences and animal behaviour.

Below, an overview is given of indications for hunting location and seasonality per animal group, as well as possible bait required for hunting these animals, all based on animal behaviour and preference for certain habitats. The other subject related to the preparations for hunting, involving the creating of tools or gathering of bait, is discussed in Chapter 7: Wild plant gathering.

Hunting location: habitat preferences

The preferred habitats of animals can also be interpreted as the locations where the animal was most likely caught. An overview of habitat preferences is therefore able to provide information on the range of different types of locations visited for hunting. Different animal groups however, have different preferences for their environment and possess varying degrees of informative resolution: fish can show indications for water type and salinity, birds provide a general overview of possible hunting locations, small mammals (*i.e.* smaller than hare (*Lepus europaeus*)) show a very local picture, and large mammals mainly give information on the amount of cover available in the surroundings (cf. Chapter 2). Furthermore, each animal group possesses individuals which may travel longer distances, with varying habitat preferences along this route. Such aspects need to be taken into consideration when interpreting hunting location. In general, however, the presence of different habitat types will already provide insight into the practice of hunting and the different opportunities and challenges each environment will have created. Moreover, when multiple animal groups show generally similar habitat preferences, this will give a stronger indication for a potential hunting location.

Seasonality: reproduction, migration, and animal group specific behaviour

Fish

Two types of animal behaviour that can give insight into seasonality are reproduction and migration. Reproduction of fish occurs during certain months of the year, when they are spawning in shallow waters. This period enables hunters to catch fish that are normally inaccessible.

The other major seasonal period for catching fish is migration. During migration, some fish species travel *en masse* to or from the sea, thus forming a target for fishing with potentially high yields.

Other, more general trends in seasonal fish behaviour can also be observed. For example, fish species from the open sea travel closer to shore in summer, and juveniles may even travel into estuaries looking for warmer and/or sheltered surroundings (Vissengids 2016). Fish normally living in (deep) open sea water can therefore become more accessible during summer months. During winter months, most freshwater fish are less accessible because they become lethargic due to a severely slowed-down metabolism, and saltwater fish are less accessible because they reside in the deeper parts of the sea.

From the above examples, it is clear that seasonal behaviour of fish can provide a lot of information on possible fishing strategies depending on location, the time of year, and the species targeted.

Birds

Breeding season is an important period for all birds, since appropriate nesting sites need to be located. In this season, birds are finding mates, courting, building nests, brooding, and feeding their young. Especially brooding and feeding periods require most of the bird's attention and keep it bound to the nest or busy gathering food. Knowledge of preferred nesting locations enables the hunter to exploit nests by catching either the brooding parental birds and/or by collecting their eggs (Serjeantson 1998, 24).

Another important season related to bird behaviour is migration. Birds either remain resident in an area throughout the year, or travel south to escape harsh winter conditions. Migration usually occurs twice a year, when they travel between their breeding grounds and winter habitats. The Netherlands, and especially the north-west, is still an important mid-way location on many migratory routes of birds (van Roomen *et al.* 2013). Some birds however, are resident and do not participate in migration at all, being adapted to withstand the climate in a specific area throughout the year. A third group of birds can be considered consisting of seasonal guests, only using an area as a temporary resting location on their travels further north or south.

Thus, the presence of certain species on a site can give a firm indication of the seasonality and practice of fowling, as well as the potential availability of different kinds of bird resources.

Another, bird-specific, form of seasonal behaviour is moulting. Moulting (of birds) is the shedding and replacing of old feathers. This replacement occurs multiple times in the life of a bird, which costs the bird a large amount of energy. One form of moult occurs when birds replace feathers to obtain a bright plumage for mating season, but this effects only a limited number of feathers (All about birds 2015). Since these feathers are only available for short periods of time and may consist of colours not normally observed in a species, they may form a specific target for hunting. The hunt for birds especially for their feathers in general is known as plume hunting, something which has been practiced up until recent times in many parts of the world (*e.g.* Ehrlich *et al.* 1988; Swadling 1996).

A second form of moult is also potentially very interesting for a hunter. Waterfowl, such as ducks, geese, and swans, have developed a manner of moulting that involves replacing all their wing feathers simultaneously. This means that moulting can occur in a relatively short time, but also that it renders the bird totally flightless for four to six weeks (Serjeantson 1998, 25; Roots 2006, 152; McCleery 2007, 86). This flightless period differs slightly from species to species but mainly occurs during summer, which enables the hunter to catch aquatic birds relatively easily during this time.

Finally, other, more general opportune periods for hunting birds may include the autumn and winter. In autumn, birds are well-fed and in good condition (Serjeantson 1998, 25), and become even more interesting targets for hunting for consumption reasons. In winter, some birds are more conspicuous and tend to flock together in larger numbers. In addition, since food is scarce, birds will have to venture into more open areas to forage, thus increasing their vulnerability to capture (Serjeantson 1998, 26).

Mammals

Breeding and birthing seasons are also busy periods in the life of a mammal. During these periods, a suitable mate needs to be found and, when the young are born, they need to be protected and fed. Due to these activities, mammals often appear more out in the open and will become less attentive towards possible dangers. Therefore, during these periods it may be relatively less complicated to locate and capture a mammal (Twisk *et al.* 2010).

As for the other animal groups, the second seasonal mammal behaviour which can be taken advantage of by hunters is migration. Many mammals can migrate for longer distances to search for a mate, to forage, or to avoid harsh weather conditions. The destination

of these travels, as well as the general route taken, are often the same. When these locations or travel routes are known to a hunter, migratory mammals could also become a relatively easy target for capture.

The third major type of seasonal mammal behaviour is group formation. Whereas some mammal species always occur in (small) groups (*e.g*. red deer (*Cervus elaphus*), hare, wild boar (*Sus scrofa*), and fox (*Vulpes vulpes*)), others only appear in groups during certain times of the year (Twisk *et al.* 2010). For example, roe deer (*Capreolus capreolus*) and elk (*Alces alces*) will form groups in winter, especially in areas where there is little cover by trees (Kenniscentrum Reeën 2005). In such seasons, when animals are already more conspicuous due to the absence of foliage, group formation could provide an excellent opportunity for the hunter to catch (several) individuals.

Bait: food preference and foraging

Fish
Knowledge of the food preference and foraging (*i.e.* food finding) behaviour of an animal can be an important part in understanding what type of catching equipment and bait is appropriate. For fish, diet can include either vegetative matter, insects, other animals, or a combination of these (Vissengids 2016). Bait can thus be chosen according to the specific food preferences of the targeted species, although some types of fish may not respond to bait at all because they do not feed during specific periods of the year. Migratory species for example, usually show different feeding behaviour depending on whether they reside in freshwater or saltwater environments. Salmon (*Salmo salar*) for instance, a true predatory fish, does not feed whilst residing in fresh water (de Laak 2007). Another exception is eel (*Anguilla anguilla*), which can even show two different feeding patterns within one medium (fresh water) depending on its age. Juvenile eel resides in freshwater for several years and actively hunts for food. When it has reached maturity, it migrates back to the sea in order to spawn and does not feed any longer.

Thus, for some fish species, a combination of knowledge of food preference and seasonal behaviour is necessary for selecting appropriate catching equipment and bait.

Birds
Food preference and foraging behaviour of birds can also provide essential knowledge about appropriate catching strategies and use of bait or lures. Birds can roughly be divided into two groups based on their foraging behaviour: predatory birds and non-predatory birds.

One type of predatory bird, the bird of prey, hunts by flying across their hunting grounds in search of prey, which they attack in or from the sky. Other predatory birds include birds that catch insects and other invertebrates (in the air or in/on the ground), or birds that hunt for fish from the water (as opposed to birds of prey, that hunt for fish from the air).

Non-predatory birds are basically vegetarian, feeding on plants in and around water or grazing on fields. The food preference and foraging behaviour of birds therefore gives information on applicable bait and effective catching strategies depending on preferred food type and location.

Mammals
For the preparation for hunting mammals, the food preference, foraging location and foraging behaviour of a mammal can be very important aspects as well. Mammals can roughly be divided into the groups herbivore, carnivore, and omnivore. Depending on how they acquire their food, be it by browsing, hunting, or scavenging, an appropriate baiting and/or catching technique can be applied by the hunter, including hunting actively or by using passive hunting techniques such as traps or snares.

4.3.2 Hunting

Hunting most often requires the use of tools or equipment. Which tools and equipment are appropriate for hunting certain wild animals depends on several factors. First, the time available for hunting can influence the hunting techniques applied, which may include active or more passive hunting techniques and inherent types of hunting gear. Second, the animal species and its particular preferences

Table 4.3. Overview of some of the possible active and passive hunting strategies available to people in the Bronze Age based on the US army survival manual, as well as archaeological finds.

	Hunting strategy		References	
	active	**passive**	**recent examples**	**archaeological examples**
Fish	Hooks, nets, spears, clubs, leister[1]	Fish traps/fykes, weirs, nets, baskets	United States 2009, 88-93	Brinkhuizen 1983; Bulten, Boonstra and Arnoldussen 2002, 35-9; Knight 2012
Birds	Bow and arrow, nets, gathering during moulting or nesting	Traps[3], snares[4], nets	United States 2009: 77-8, 80, 83	Mannermaa 2003; Bulten and Boonstra 2013; van der Wal 1952
Mammals	Rabbit stick[2], spear, bow and arrow, sling, club, dogs	Traps, snares, nets	United States 2009, 88-9; Huber 2012, 83	van der Wal 1952; Clark 1966, 54; Jensen 1982, 154; Bulten, Boonstra and Arnoldussen 2002; Bulten and Boonstra 2013

[1] A leister is a hunting tool to capture eel, which resembles a forked spear
[2] A rabbit stick is a throwing stick of arm-length, which is very effective against small game
[3] Traps are designed to catch and hold, or to catch and kill
[4] Snares are traps which incorporate a noose

and behaviour, are, as has become clear from the previous section, very important in identifying the use of appropriate hunting strategies and weapons. In order to clarify which techniques may have been applied in the Bronze Age, direct evidence for hunting techniques may be uncovered through actual finds of hunting gear. Indirect evidence for hunting techniques and seasonality may, as said, be inferred from the wild animal species and their behaviour, but also from (distinct marks on) the wild animal bone material. Finally, the presence of certain types of hunting equipment may be limited to the material and techniques available to a hunter, which can influence the creation of particular hunting gear. All these subjects related to the activity of hunting is discussed for each animal group in this section, but the latter is also discussed in more detail in Chapter 7: Wild plant gathering.

Available active and passive hunting tools and equipment

The distinction between active and passive hunting is mostly made based on time constraints and combinability with other activities. In active hunting, the hunter needs to be present during the entire procedure. It often involves the use of weapons in combination with active waiting (*e.g.* from a concealed or elevated position), stalking (*i.e.* quiet pursuit), or chasing (*i.e.* running pursuit). Active hunting often allows the hunter to select prey of a certain size or species. Passive hunting on the other hand, only requires the attention of the hunter at specific times, mainly during the setting and checking of traps or snares. The less selective nature of this hunting strategy often results in considerable by-catches of less desirable, or even unwanted species.

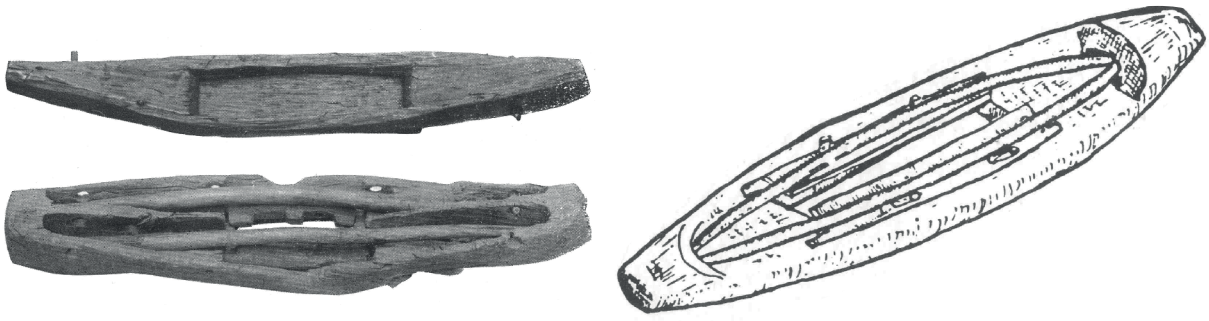


Figure 4.2. Wooden tread traps. Left: two prehistoric tread traps found in Hinge and Nisset Nørremose, Jutland, Denmark (after: Jensen 1982, Plate I); right: modern tread trap for deer from Poland (after: Jensen 1982, 53).

The range of possible active and passive hunting strategies available to people in the Bronze Age was assessed by employing the United States Army Survival Manual (United States Dept. of the Army 2009), as well as overviews of uncovered active and passive hunting gear from archaeological find compilations. The main advantage of employing the US army survival manual was that, in a survival situation, no (seasonal) restrictions to hunting exist, which may be encountered when using other (modern-day) hunting parallels. This manual therefore provided a wide overview of basic hunting techniques which do not require modern tools for their manufacture. The archaeological compilations furthermore, provided an overview of available hunting techniques in the Bronze Age, which could confirm the possibility of the use of certain tools or equipment during this time. Still, it must be emphasized that the overview provided here is kept concise and is by no means a complete list of all the hunting gear ever employed. It is merely presented as a basic overview of possibilities in order to understand differences in hunting techniques and strategies. The different general tools and equipment used for active and passive hunting techniques are summarized in Table 4.3.

Almost all of the hunting tools presented in Table 4.3 are constructed out of perishable organic materials, except for the arrowheads, which are usually made from flint. Therefore, besides these arrowheads (*e.g.* Bulten & Boonstra 2013), hunting tools are not often found archaeologically. Nevertheless, rare finds of Bronze Age hunting gear include a wooden bow (van der Wal 1952), as well as fish traps, fish weirs, fish fykes, and wooden mammal tread traps from multiple locations in the Netherlands and abroad (Clark 1966, 54; Jensen 1982, 154, fig. 49; Bulten *et al.* 2002; Knight 2012; Figure 4.2). The wooden tread traps have only been preserved in bogs and soils along old rivers (Clark 1966, 53; Figure 4.3), limiting the visibility of their original distribution (National Museum Copenhagen pers. comm.). Still, 45 examples of these traps exist, with either single or double fall mechanisms (Rasmussen 1940, 119), and measuring 61 to 122 cm (Clark 1966, 51). These traps have been employed to capture deer and bear (*Ursus arctos*) until recent times in Poland (Moszyński 1929; Rasmussen 1940), indicating their employment for trapping various large game.

All the uncovered archaeological finds indicate therefore that both active and passive hunting was still being practiced during the Bronze Age.

The use of hunting tools and equipment

Possessing the appropriate gear for hunting is essential, as well as the knowledge on how, where, and when it is appropriate to use it on which species.

Fish

General ways exist for capturing particular types of fish in different habitats. Boats are necessary on the open sea for example, possibly combined with baited (hooked) lines for capturing deep-sea fish. In an intertidal environment, flatfish can also be caught using lines with bait, or by spearing them (Brandt 1984). Most saltwater fish and migratory fish can be caught using fish fykes, traps, and weirs (Zeiler *et al.*

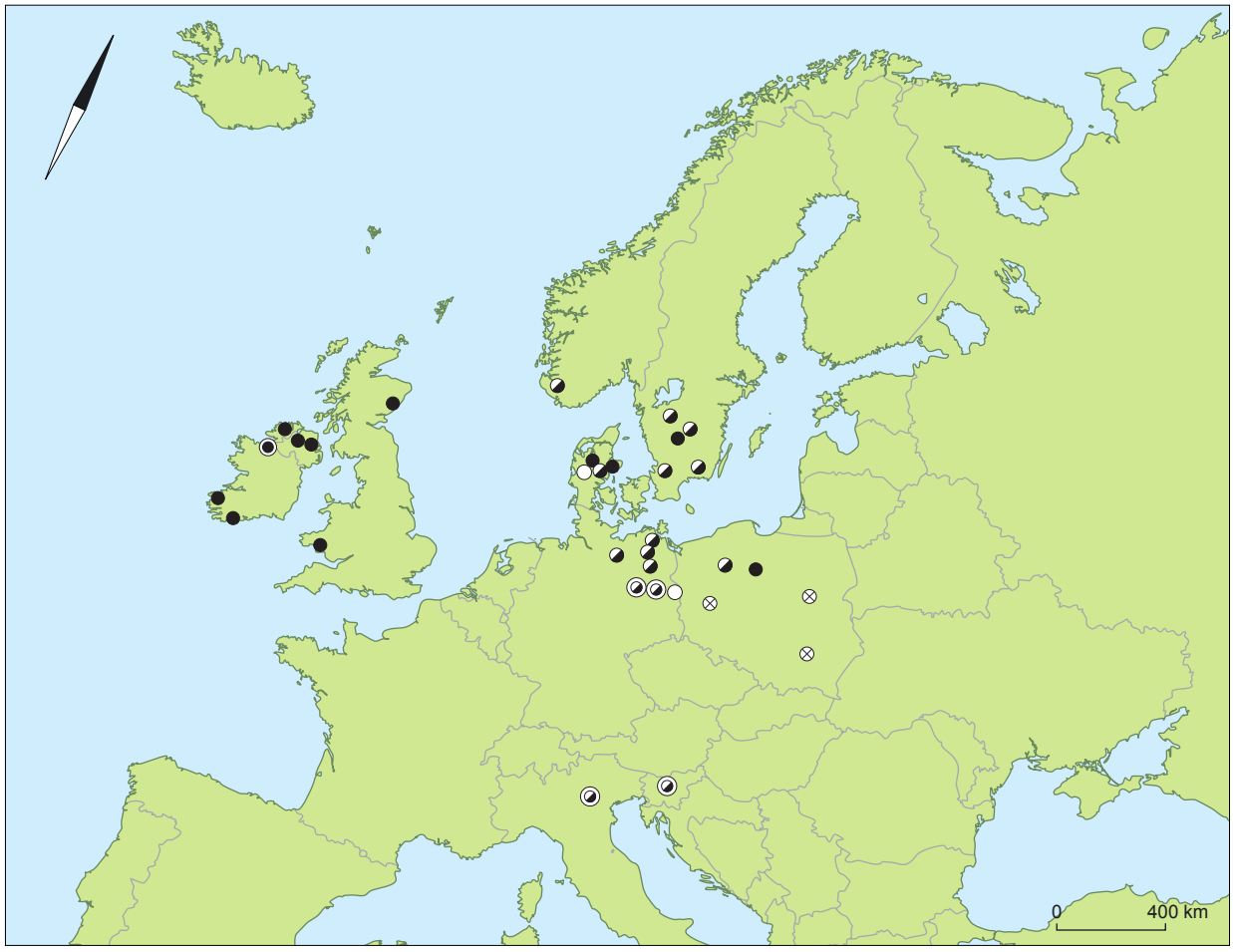


Figure 4.3. Overview of the distribution of prehistoric wooden tread traps found in Europe as well as modern-day parallels. a: traps with unknown mechanism; b: single valve traps; c: three or more single valve traps found together; d: double valve traps; e: three or more double valve traps found together; f: modern survivals of these kinds of traps in Poland, where they were used until the 20th century (after: Clark 1966, 54).

2007). By placing these traps in intertidal streams, fish are trapped at low tide.

Similar techniques are required to catch migratory fish in a freshwater environment, although here, no (strong) intertidal effects occur. Weirs and fykes can, however, still be employed, combined with additional methods such as clubbing or spearing (Lohof & Vaars 2005). Freshwater fish in general can be caught using a range of possible techniques. Carnivorous fish can be caught using bait on hooked lines or in fykes. Throwing nets, baskets, clubs, and spears can be employed to catch spawning fish in shallow waters. Some fish species, such as eel, can be caught in different ways depending on its age. Fykes with bait can be applied on young eel, which still feeds in order to become mature; weirs and nets can be applied to capture mature eel during migration. Finally, an eel "fork" or leister can be used; a tool that is lowered into the water around which an eel will wrap itself (*e.g.* Meurers-Balke 1981; Table 4.3).

Birds

Birds can travel across land, through water, and through the air. Possible catching techniques are therefore very varied, depending on the species, but also on location, and seasonality. Two syntheses of several types of fowling methods have revealed a range of different fowling possibilities, which may also have been used in prehistory for capturing different bird types (Mannermaa 2003; Whitworth 2007, 33-50).

Most birds can be caught using general catching methods such as nets, traps, and snares, depending on their particular food preference and foraging behaviour. Flying birds can be shot using arrows for example. Alternatively, relatively small flying birds such as warblers and thrushes can be caught with nets; even dead birds might have been collected directly after *e.g.* storm surges.

Ground dwelling birds hide in plant cover and can be caught using snares or other, more active forms of fowling. Birds of prey can be captured by for example employing a baited "net of nooses" (Whitworth 2007, 49). Aquatic birds can be gathered, or driven into nets during moulting season with or without the aid of dogs (Mannermaa 2003, 21). In addition, night fowling can be practiced, during which nocturnally active birds are caught by using a light source for disorientation and roosting birds can be taken from the nest by hand (United States 2009, 77).

Mammals

Multiple hunting techniques exist to capture mammals of different size and with different habitat preference. The rabbit stick (Table 4.3) can be employed for prey that freezes as a form of defence, such as small mammals (United States 2009, 88). Other game, such as hare, can also be jabbed with a spear. Bow and arrow allows a hunter to attack from a longer distance, for example to kill large prey or prey that is normally difficult to approach, such as beaver (*Castor fiber*). Slings can be used to hunt small game such as hare, weasel (*Mustela nivalis*) or polecat (*Mustela putorius*). Dogs can also aid in the hunt and can capture mammals such as fox, polecat, and weasel. Other hunting techniques include different types of traps of varying construction, and several variations of snares. Since a wide variety of these types of hunting equipment exists, the interested reader is referred to the Survival Manual (United States 2009).

The use of bait, lures and calls

Baiting a trap or snare can increase the chance of capture, and can even draw animals to the capturing device (United States 2009, 79). The bait used should be familiar to the animal, but not so common that it can readily be obtained somewhere else; *e.g.* salt (United States 2009, 79). Bait can be useful for both active and passive hunting techniques, although not all animals will be attracted to bait to the same extent. Apart from the use of food as bait, animals can also be attracted to certain locations through the employment of lures and calls. When a hunter is able to successfully mimic the sound of an animal species, it will approach the location where the hunter is hidden, thus facilitating capture.

Indications for hunting based on bone material

Archaeologically preserved bone material can provide indirect indications for hunting tools employed and seasonality of hunting. Specific deep cut marks on bones can, for example, be related to the use of spears; shallow cut marks are evidence of the skinning of animals. Skinning of animals for their fur also indirectly implies the use of passive hunting (*e.g.* certain traps), since this practice does not damage the pelt, whereas most active hunting strategies pierce the skin in order to kill the animal.
Seasonal indications for hunting based on bone material, besides the presence of bones from migratory animals, can also include the presence of young animals, which are only present during a certain time of year. In addition, the presence of specific anatomical parts can also provide seasonal indications, for example the presence of skulls of deer with or without antlers still attached, or the special egg-laying bone structures of birds (Gál 2005, 53; Groot 2010b, 70).

4.3.3 Processing

Processing of hunted animals can involve actions performed for short-term use (*e.g.* for cooking) and long-term use (*i.e.* for preserving), which are both discussed in this section per animal group. Subsequently, indications for processing based on archaeological bone material are examined.

Processing for short-term use

Fish

Short-term processing can include several different actions, depending on the culinary use of the animal. If fish is cooked directly after capture, one or more

parts of the fish are usually removed first. The minimal processing of the fish would include removing the guts, which are most susceptible to rotting. Alternatively, the head and tail could also be removed. When only meat is desired, fish can be filleted, removing all the bones from the animal. Regardless of the processing method applied, the desired part(s) of the fish can be used in further processing for consumption, which may include multiple techniques, such as grilling, smoking, or making a stew or soup.

Birds

Processing a bird for consumption purposes can occur during or right after capture, or at a later time at the settlement. After killing the bird, it should be plucked or skinned. Further processing can include removing the head, feet, wings, tail, and (optionally) the intestines, leaving only the bones, meat, and skin. When only meat is desired, most bones from the wing and leg parts, as well as the skull is discarded, removing them from the subsequent cooking processes. When bird meat is not consumed immediately, after dressing the carcass it can be kept for 4-7 days at 2-4 °C, its shelf life increasing with lower temperatures (Maas-van Berkel *et al.* 2004, 13).

Mammals

The steps for short-term processing of mammals are taken from the US Army Survival Guide (United States 2009), because it is assumed that this reflects the most basic steps required.

Slaughtering and skinning are the first steps in processing a mammal. The animal needs to be bled and cleaned after killing and the intestines need to be removed quickly to prevent spoilage of the meat (Maas-van Berkel *et al.* 2004; United States 2009).
Skinning is achieved by cutting the hide at certain locations and subsequently pulling it away from these cuts. The head and feet of the killed animal are usually removed, although the brain can be used for consumption or tanning of hides (Michaud n.d.). Large game is usually hung for several days (depending on the outside temperature) to increase the tenderness of the meat, which can be cut into manageable pieces by cutting along the leg joints. For smaller mammals, such as hare, this is not necessary. When the meat is processed for consumption, it can be cooked, grilled, roasted, boiled, or made into a stew, especially in combination with bones and their marrow (United States 2009, 97) to increase the flavour and nutrient content. Similar to bird meat, game meat can be kept for 4-7 days at 2-4 °C, its shelf life increasing with lower temperatures (Maas-van Berkel *et al.* 2004, 13).

Processing for long-term use

Fish

Preserving fish for later use (*e.g.* for during winter) means that contamination by micro-organisms from the surroundings needs to be prevented. There are several preservation techniques for the preservation of fish with varying storage lives, or the time the fish remains preserved well enough for consumption. These techniques include drying, salting, smoke-drying, and fermentation.

Drying can be achieved by hanging or placing gutted fish on racks, and exposing them to an air-flow (*e.g.* wind). Drying fish should be kept out of direct sunlight (Maas-van Berkel *et al.* 2004, 40), since high temperatures speed up spoilage. For adequate drying, it is important that the surface area of the fish meat is as large as possible, and that weather conditions are favourable (*i.e.* dry and windy) for a prolonged period of time. Fish which are usually dried include low-fat fish such as flatfish (Beerenhout 2010, 118), and small fish (Maas-van Berkel *et al.* 2004, 37). Most large fish will rot from the inside out before wind-drying can be completed successfully. Therefore, these fish need to be salted first to extract as much water content as possible before additional drying can be attempted (Maas-van Berkel *et al.* 2004, 37). Fatty fish, such as eel and herring (*Clupea harengus*), can be dried by smoking. During smoking, fish is hung on lines or poles and is placed in relatively close proximity to a smoking fire. However, it must be kept in mind that the storage life of fish is not considerably prolonged by smoking alone. Therefore, it should subsequently be dried to be suitable for long-term storage (Maas-van Berkel *et al.* 2004, 15, 46-47).

Fermentation is another method of preservation, which requires anaerobic conditions and large amounts of salt. Entire fish are mixed with salt/brine

and poured into a container. This container is then stored underground and dug out several months later. Depending on the product of fermentation (*e.g.* sauce or whole fish), the storage life can be several years (Maas-van Berkel *et al.* 2004, 60).

A final form of long-term fish preservation is keeping the caught fish alive in a pond or similar water body nearby, until they are further processed and consumed.

Birds
Preserving bird meat for longer periods of time can be achieved by similar techniques as discussed for fish, such as by salting, smoking, and drying. When properly dried, meat can be kept for months (Maas-van Berkel *et al.* 2004, 43). This means that with the availability of appropriate techniques, bird meat can even be preserved in summer in order to prevent possible food shortages in winter. Alternatively, birds could have been kept alive at the settlement until needed for further processing, for example by clipping their wings; these birds are technically not domesticated, but can still be considered as a form of poultry.

Mammals
Preserving game meat for a longer period of time can be performed similarly to the other animal groups mentioned above. Smoked thin strips of meat will, depending on the duration and temperature of the smoking process, preserve for 1-4 weeks (United States 2009, 97). When this process is combined with subsequent drying, game meat will also keep for several months (Maas-van Berkel *et al.* 2004, 53). Other methods of preservation include freezing and salting.

Indications for processing based on bone material

Fish
Fish bones from an archaeological assemblage can display traces of processing procedures. Chop and cut marks are sometimes identifiable on bones, which can give an indication for short-term processing, such as filleting. Burning or charring of bones are also usually considered to be indications for fish consumption. Unfortunately however, in most assemblages, bones showing burn or cut marks are rare, which is related to the fact that these particular marks increase the susceptibility of bones to taphonomical processes in comparison with bones in an undamaged state.

Birds
Marks on bird bones can also indicate slaughter and subsequent processing activities. Cut and chop marks can be visible on bones as well as burning or charring (Serjeantson 2009, Ch. 6). Besides showing marks, the underrepresentation of certain bone elements present in an assemblage is sometimes considered an indication for slaughter practices (Serjeantson 2009, Ch. 6). However, identification to the species level is difficult for certain types of bird bone (*e.g.* wing bones or vertebrae), possibly creating a bias in bone ratios and thus in subsequent interpretation for consumption.

Mammals
Marks that indicate slaughter of mammals also include cut and chop marks on bones. Indications of subsequent processing for consumption purposes include burning and charring of bones. Furthermore, the underrepresentation of certain bones is sometimes also seen as an indication for slaughter and consumption practices, although again, the possible identification problems and resulting biases mentioned in the previous section should be kept in mind.

4.3.4 Storage and long-distance travelling

The final two aspects related to hunting which are discussed in this section are assumed to be optional activities, since they are not essential for the immediate capture and consumption of animals. However, it must be noted that the term optional is not necessarily related to the relatively importance of these activities for subsistence.

Storage
Fish or meat can be stored for long periods of time, depending on the preservation method applied and the existing storage conditions. Dry storage locations require good ventilation, relatively constant temperature, and low humidity, and are preferably elevated from the ground, also to prevent accessibility by pests (FAO 1990). Dried fish or meat could have been stored at similar locations to other

food stuffs requiring dry storage conditions, such as grain (cf. Chapter 6, section 6.4.4).

Long-distance travel
Long-distance travel for hunting could theoretically have occurred, although it is not assumed that this happened in a farming community (cf. Chapter 3). Appropriate hunting grounds may not be available in the immediate surroundings of the settlements (cf. Kent 1989), and this would mean that people would have to travel further away. Time spent on other activities would have to compensate for this phenomenon accordingly. However, long-distance travel is hard to establish, since the presence of non-local animal species might also be the result of trade with hunters from elsewhere. At the very least, however, such observations can provide direct or indirect indications of the interactions between people and their (further) surroundings.

4.3.5 Summary and additional main components

The analysis of the activities related to hunting with the use of multiple disciplines has yielded several interesting notions on the possibilities and role of hunting in farming communities in the Bronze Age. Hunting in general seems to remain an integral subsistence strategy for all researched small-scale farming communities. Preparatory stages for hunting, mainly the locating of appropriate hunting locations, are very important steps in the hunting process. Specific knowledge of the environment, seasonality, and animal behaviour needs to be extensive in order to prepare for the capture of each animal species. The actual type of strategy employed by the hunter also depends on several factors, and can be more active or more passive depending on the time available for hunting, the particular preferences and (seasonal) presence of animals, and the material and techniques available to the hunter to create tools and equipment. Hunting tools and equipment dating to the Bronze Age include fish traps, fish weirs, a bow, arrowheads, and a wooden tread trap, all indicate that hunting still occurred during this time period, both in an active and passive manner. The actual extent of available hunting tools and equipment in the Bronze Age will have been even larger: taphonomical processes will have severely reduced the visibility of hunting gear such as nets and snares, which are expected to have been widely employed for the capture of many different animals. Besides the direct indications for hunting based on the actual presence of hunting gear, specific marks on archaeological bone material can provide information on the hunting technique applied and the seasonality of hunting. Young animal bones or the presence of specific marks on bones can shed light on certain hunting practices such as skinning or spearing. Other marks on bones, such as cut, chop or burn marks, can give insight into how animals were processed after capture for short-term use (*e.g.* consumption). Long-term processing, or preserving wild animal meat until further use, may include techniques such as (smoke-)drying, salting, fermentation, or keeping captured animals alive at the settlement. Storage of such preserved meat and fish requires well-ventilated, elevated locations with relatively constant temperature and humidity. The presence of non-local animals might, finally, reveal indications for the interactions between farmers and people and locations further away from the settlement.

All researched stages of hunting have thus emphasized the elaborate knowledge, skill, and time investment required for hunting and, therefore, the practice of hunting as a whole should not be underestimated. Also, the visibility of some of the tools and practices of hunting is probably very low and might be missed when dealing with an archaeological assemblage.

Finally, based on the ethnographical examples by Murdock (1981) and Kent (1989), an additional main component related to the role of hunting in subsistence was identified. This main component is added to the main components of the current model, and is challenged in section 4.5:

(5) Hunting did not aid Bronze Age subsistence in terms of consumption, but may have been practiced for other reasons which were equally important.

4.4 WEST FRISIAN DATA ANALYSIS

In this section, the data of West Frisia is analysed based on the same basic aspects of hunting identified in section 4.2 and 4.3, including preparation, hunting,

processing, and storage and long-distance travelling. Each aspect is analysed separately below for each of the animal groups through a careful examination of the sources of evidence present for hunting in the West Frisian archaeological assemblage. The investigation of fishing, fowling, and hunting game will show to what extent each of these forms of hunting was still practiced in the Bronze Age. In this investigation, the absence of evidence for certain activities is not directly linked to the actual absence of these activities. First, it is thoroughly evaluated whether factors such as taphonomy or archaeological methodology may have affected the assemblage to result in this absence. When the potential effect of these processes is clear, it is obvious that past human practice cannot be connected directly to only what is uncovered at archaeological excavations. By including several disciplines in the analysis of practice in this chapter, other indications for hunting are identified, which are missed by applying only single proxy approaches such as excavation data. Thus, a more detailed view of past practices becomes available.

This, and other aspects of (the analysis of) hunting are discussed in section 4.4.5.4 after the separate analyses of hunting fish, bird and game.

4.4.1 Fish

Fish remains have been uncovered at six locations in West Frisia. These sites can roughly be divided into western sites and eastern sites (cf. Chapter 2). The western sites include Schagen and Hoogwoud, whereas the eastern sites comprise Medemblik, Westwoud, Enkhuizen, and Bovenkarspel (*e.g.* Figure 4.1).

Preparation: location, seasonality, and bait

Location

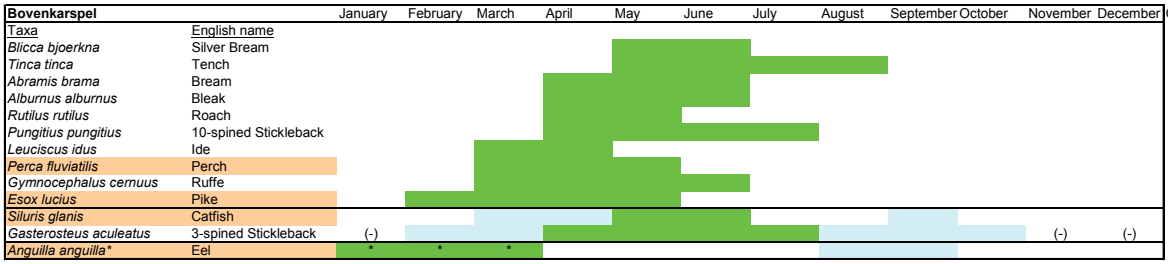
The locations selected for fishing were analysed based on the water type preferences of the uncovered fish species on each of the sites of West Frisia, as previously presented in Chapter 2 (Figure 2.9, Figure 2.11, and Figure 2.14). The water types preferred by the fish species included stagnant to slow flowing water, open water, fast-flowing water (river), a connection to the sea, and open sea. A preference for stagnant to slow flowing water was most prevalent at all the eastern sites of West Frisia, followed by open water at Enkhuizen and Bovenkarspel, specifically (*e.g.* Figure 2.9). Other habitat preferences of fish found at the eastern sites include a connection to the sea, and, although scarce, for fast-flowing water. This variety of habitat type preferences from the fish present at the eastern sites indicates that people were fishing at various locations in the surroundings of the settlement. In the western part of West Frisia, at Schagen and Hoogwoud, most species display a preference for a connection to the sea or the open sea. Other water type preferences of fish from western West Frisian sites include stagnant to slow-flowing water, open water, and fast-flowing water. Although the ratios of the preferences for certain habitats of fish in western West Frisia differ from the east, also here, the diversity of exploited fishing locations is evident.

Seasonality

The investigation of the seasonality of fishing is primarily based on the periods of the year in which fish are readily available, such as during spawning and migration. During these periods, large fish, such as pike, perch, bream, and eel, can be caught with higher success rates, because they swim close to the banks to spawn or are available in abundance due to mass migration. The results of the seasonality analysis, which include fish from the entire Bronze Age, are summarized in Table 4.4. However, due to the difference in habitat types reflected in fish as well as the difference in time period of the sites, the eastern and western sites are discussed separately.

At the sites in the western part of West Frisia, Hoogwoud and Schagen, the months of April, May, August, and September are represented by the highest frequencies of fish displaying seasonal behaviour. In the first two months, fish could be caught during spawning and/or migration, whereas in the latter two months, solely the period of migration could be exploited. Besides these two periods, another period of the year can be employed for fishing near the coast. During summer, deep-sea

On the right: Table 4.4. Schematic representation of the seasonal behaviour of the fish found at each site. Different groups are denoted by codes based on the availability of several fish species throughout the year. Data used derives from Marine Fish Map 2016 and Vissengids 2016.



Bovenkarspel		January	February	March	April	May	June	July	August	September	October	November	December	Code
Taxa	English name													
Blicca bjoerkna	Silver Bream													
Tinca tinca	Tench													
Abramis brama	Bream													
Alburnus alburnus	Bleak													
Rutilus rutilus	Roach													1
Pungitius pungitius	10-spined Stickleback													
Leuciscus idus	Ide													
Perca fluviatilis	Perch													
Gymnocephalus cernuus	Ruffe													
Esox lucius	Pike													
Siluris glanis	Catfish													2
Gasterosteus aculeatus	3-spined Stickleback	(-)										(-)	(-)	
*Anguilla anguilla**	Eel	*	*	*										3

Enkhuizen		January	February	March	April	May	June	July	August	September	October	November	December	Code
Taxa	English name													
Blicca bjoerkna	Silver Bream													
Scardinius erythrophthalmus	Common Rudd													
Rutilus rutilus	Roach													1
Abramis brama	Bream													
Alburnus alburnus	Bleak													
Perca fluviatilis	Perch													
Esox lucius	Pike													
Siluris glanis	Catfish													2
*Anguilla anguilla**	Eel	*	*	*										3
*Eutrigla gurnardus**	Grey Gurnard	-	-	-	-	-	-	-	-	-	-	-	-	8

Westwoud		January	February	March	April	May	June	July	August	September	October	November	December	Code
Taxa	English name													
Abramis brama	Bream													
Pungitius pungitius	10-spined Stickleback													1
Perca fluviatilis	Perch													
Esox lucius	Pike													
Gasterosteus aculeatus	3-spined Stickleback	(-)										(-)	(-)	2
*Anguilla anguilla**	Eel	*	*	*										3

Medemblik		January	February	March	April	May	June	July	August	September	October	November	December	Code
Taxa	English name													
Blicca bjoerkna	Silver Bream													
Scardinius erythrophthalmus	Common Rudd													
Rutilus rutilus	Roach													1
Abramis brama	Bream													
Perca fluviatilis	Perch													
Esox lucius	Pike													
*Anguilla anguilla**	Eel	*	*	*										3
Salmonidae indet.	Salmon	-	-	-	-	-								5

Hoogwoud		January	February	March	April	May	June	July	August	September	October	November	December	Code
Taxa	English name													
Abramis brama	Bream													1
Esox lucius	Pike													
*Platichthys flesus**	Flounder		*	*	*	*								3
*Anguilla anguilla**	Eel	*	*	*										
*Liza ramada**	Thinlip Mullet	-	-								-	-	-	6
*Dicentrarchus labrax**	Sea Bass	-	-	-	-	-	-	-	-	-	-	-	-	
*Gadus morhua**	Atlantic Cod	-	-	-	-	-	-	-	-	-	-	-	-	7
*Pleuronectus platessa**	Plaice	-	-	-	-	-	-	-	-	-	-	-	-	
*Raja clavata**	Thornback Ray	-	-	-	-	-	-	-	-	-	-	-	-	

Schagen		January	February	March	April	May	June	July	August	September	October	November	December	Code
Taxa	English name													
Perca fluviatilis	Perch													1
Esox lucius	Pike													
Gasterosteus aculeatus	3-spined Stickleback	(-)										(-)	(-)	2
*Anguilla anguilla**	Eel	*	*	*										3
Acipenser sturio	Sturgeon	-	-	-							-	-	-	
Alosa alosa	Allis Shad	-	-								-	-	-	4
Alosa fallax	Twaite Shad	-	-	-							-	-	-	
Osmerus eperlanus	Smelt	-						-	-	-	-	-	-	
Coregonus sp	Whitefishes		-	-	-	-	-	-						5
Salmonidae indet.	Salmon-family	-	-	-	-	-								
*Liza aurata**	Golden Grey Mullet	-	-								-	-	-	6
*Liza ramada**	Thinlip Mullet	-	-								-	-	-	
*Clupea harengus**	Atlantic Herring	-	-	-	-	-	-	-	-	-	-	-	-	
*Dasyatis pastinaca**	Stingray	-	-	-	-	-	-	-	-	-	-	-	-	
*Dicentrarchus labrax**	Sea Bass	-	-	-	-	-	-	-	-	-	-	-	-	
*Gadus morhua**	Atlantic Cod	-	-	-	-	-	-	-	-	-	-	-	-	7
*Platichthys flesus**	Flounder	-	-	-	-	-	-	-	-	-	-	-	-	
*Raja clavata**	Thornback ray	-	-	-	-	-	-	-	-	-	-	-	-	
*Solea solea**	Sole	-	-	-	-	-	-	-	-	-	-	-	-	
*Sprattus sprattus**	Sprat	-	-	-	-	-	-	-	-	-	-	-	-	

behaviour
- spawning
- migration

food consumption
- carnivore

* spawning in deep sea
\- not in/near fresh water

code: presence:

code:	presence:
1	available all year + during spawning
2	available all year + during spawning and migration
3	available all year + during migration
4	available during spawning and migration (summer)
5	available during spawning and migration (winter)
6	available during summer and migration
7	available during summer
8	unavailable near the coast

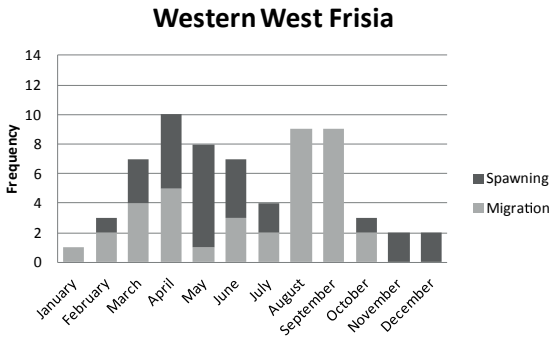


Figure 4.4. Seasonality summary of fish from western West Frisia.

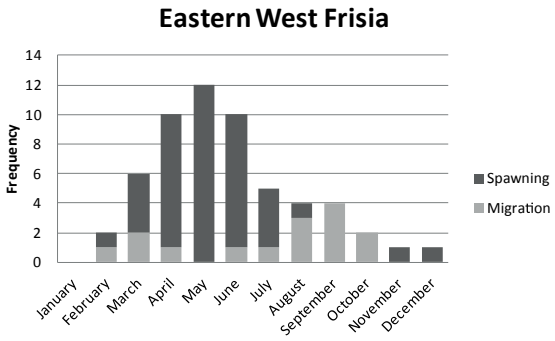


Figure 4.5. Seasonality summary of fish from eastern West Frisia.

fish, such as herring, Atlantic cod (*Gadus morhua*), and sea bass (*Dicentrarchus labrax*), appear closer to the shore (Beerenhout 2005, 44; Zeiler *et al.* 2007: 12, 16), making them more available for capture. Overall, fishing in western West Frisia can occur during the entire year, but during some periods there seems to be a higher abundance and availability of fish than during other periods.

Most of the fish deriving from the eastern sites include freshwater fish that are available all year (Table 4.4, category 1-3). In addition, fish such as catfish (*Siluris glanis*) and eel could be caught during migration, as well as salmon. One species that stands out in the general pattern of the eastern West Frisian sites however, is grey gurnard (*Eutrigla gurnardus*). Grey gurnard normally lives on the seabed, and rarely approaches the water surface, making it a very difficult fish to catch. The combination of its find location (Enkhuizen) and habitat preferences (open sea only) was already shown to be incompatible with the other results found in Enkhuizen and surrounding sites (Chapter 2, 2.4.1.2). It seems that based on its low catching probability, here too, grey gurnard can be considered an outlier.

When the east and west are compared (Figure 4.10, 4.11), it becomes clear that the exploitation of the migratory period of fish is more pronounced in the west, whereas in the east, the focus seems to lie more on the spawning season. Both regions show that fishing could have been practiced during multiple periods of the year, with a broad focus on fishing from spring to autumn in the west, and a focus on spring and early summer in the east.

Bait

Finally, the potential for using bait can be discerned in Table 4.4. Almost half of all the fish species found at every site of eastern West Frisia is predatory. These fish would therefore respond well to the use of animal bait in for example fykes. In Hoogwoud and Schagen, almost all fish are hunters. Therefore, animal bait could have been used to attract and catch these fish. However, it must be kept in mind that some migratory fish do not feed during migration, so alternative hunting techniques must have been employed for these fish (section 4.3.1).

Fishing: tools, equipment, and strategy

Tools and equipment

Archaeological indications for fishing can be direct and indirect. Direct indications for fishing can be the presence of fishing gear on excavated sites. For West Frisia, such a direct indication is represented by the presence of a fyke trap found at Enkhuizen (Roessingh & Lohof 2011, 241-9) (Figure 4.6).

The fyke, measuring around 130 cm, was constructed from wooden twigs bound together by rope. It was presumably used to capture eel, as demonstrated by the dimensions of the original opening of the fyke. Although this fyke is only one direct indication for fishing in the entire area of West Frisia, the craftsmanship reflected in this fyke shows that people were very well able to construct these types of fishing gear. The knowledge and skill required to construct such fishing gear must clearly still have been imbedded in society, no doubt also allowing

for the construction of fishing weirs, nets, and baskets. No such examples have been uncovered in West Frisia, but this may be due to the absence of excavations at locations where such gear may be found. It must therefore be a matter of time and context before more of these examples of fishing equipment are found in West Frisia.

Other methods for capturing fish can be reconstructed indirectly via the specific behavioural aspects of the fish species found. The fish species which are most frequently present at the eastern West Frisian sites are eel, pike (*Esox lucius*), perch (*Perca fluviatilis*), bream (*Abramis brama*), and cyprinids (indeterminable) (Table 4.4). Cyprinids can include the species bream, silver bream (*Blicca bjoerkna*), roach (*Rutilus rutilus*), bleak (*Alburnus alburnus*), common rudd (*Scardinius erythropthalmus*), ruffe (*Gymnocephalus cernuus*), ide (*Leusiscus idus*), and tench (*Tinca tinca*). Most of these species can be caught passively using fykes, weirs or nets. Pike, perch, and eel, being hunters, can also be caught actively using baited hooked lines. In addition, pike and perch can be speared or hit in spawning season or caught with a throwing net. The technique used for each species will have depended mostly on the time available to the fisherman and the selectiveness with which he wants to catch a certain size or species of fish (see below).

In the western sites of West Frisia, Schagen and Hoogwoud, fishing is focused more on a saltwater environment. In both sites, the majority of species found belong to the flatfish-family, which includes, amongst others, flounder (*Platichthys flesus*), plaice (*Pleuronectus platessa*), and sole (*Solea solea*). These fish can be relatively easily caught by spearing when they travel to warmer, shallower coastal waters and neighbouring estuaries during summer. Although fewer in number, true saltwater fish have also been caught in western West Frisia, which most likely also occurred during the summer months when these fish, especially the juveniles, seek warmer, shallower coastal waters. For fishing, the location of Schagen seems to have been optimal, because it was situated at the transitional stage between sea and inland waters and could benefit from fish species from both environments. By using (marine) weirs, (marine) fykes, nets, and spears, many of the species found could have been caught during the migration season.

Figure 4.6. Fyke trap from the Enkhuizen Kadijken excavation (From: Roessingh & Lohof 2011, 245, fig. 11.8).

Another rare indirect indication for a specific catching technique was found on a fish bone from Hoogwoud. Here, a cut mark was found on a vertebra of a plaice (Beerenhout 2011). The cut mark was situated on the bone at such an angle that the only plausible cause would be from piercing it from above. A fishing technique which would match this spearing practice is related to capturing flat-fish. It involves wading through shallow water during ebb tide until a flatfish is located by standing on it. The fish is then kept down with the feet and pierced from above. This catching technique, also known as "bottrappen" or "botprikken" in Dutch, was practiced until very recently in The Netherlands (Brandt 1984) (Figure 4.7), and could have been practiced in Bronze Age West Frisia as well.

Strategy

The size of the fish captured can furthermore provide information on whether the fishing strategy employed was active or passive. It seems that at Hoogwoud and Schagen, different practices for capturing saltwater fish were applied, albeit in similar environments. The fish from Hoogwoud were all of rather limited size, indicating that these juvenile fish most likely derived from the nearby estuary, and could have been caught in fykes, weirs, or nets. In Schagen, a broad range of fish species was exploited, including very large specimens such as an Atlantic cod measuring over 70 cm (Zeiler *et al.* 2007). Saltwater fish of these dimensions must have been caught off-shore using boats. So, both active and passive fishing could have been practiced in western West Frisia.

In the east of West Frisia, two sites, Medemblik and Enkhuizen, also show variation in fishing practices. In Medemblik, sieving mesh sizes of 1 mm and 4 mm were used, whereas in Enkhuizen, only 4 mm

Figure 4.7. Examples of "bottrappen"/"botprikken", or the trapping and spearing of flatfish at low tide (Botvisserij Waddengebied 2016 and Vanger 2016).

sieves were used (Table 4.1; Figure 4.8, step 1). It was therefore expected that both small and large fish remains would be found in Medemblik, but that in Enkhuizen only large fish remains would be recovered (Figure 4.8, step 2).

As predicted, the excavation at Medemblik yielded a variation in fish species size. However, no large eel remains were found, indicating the capture of juvenile fish only. These small eel could have been caught using baited fykes (passively) or with (eel) spears (actively).

In Enkhuizen, large fish were found, including pike and catfish, that were most likely caught actively during the spawning season. The perch from Enkhuizen also seems to have been relatively large, indicating that it was probably selectively caught using bait. The bulk of the eel remains found in Enkhuizen were also large and were therefore remains of adult fish. These would have been caught during migration (cf. section 4.3.2).

In summary, large and small fish species but no large eel were recovered from Medemblik. In contrast, primarily large fish species but no small eel were recovered in Enkhuizen (Figure 4.8, step 3). In Enkhuizen, small eel must have been caught as well however, evidenced by the ability to capture eel with the fyke trap uncovered at this site (Figure 4.6). The absence of smaller eel in Enkhuizen can therefore be explained by recent sieving practices, for which only a wide mesh size sieve was employed (Figure 4.8, step 4, right). In Medemblik, no large eel were found, although these were expected. This absence can be interpreted as a genuine difference as a result of past practices (Figure 4.8, step 4, left). It seems that people in Medemblik fished for eel in a different manner than in Enkhuizen and might, in general, have employed different and seemingly more passive fishing techniques. The average size of fish caught at both sites does not change from the Middle to the Late Bronze Age and neither does maximum size, indicating that the fishing practices differed locally and that this does not appear to change over time.

It is clear that pre- and post-depositional taphonomical processes can severely impact bone assemblages and their interpretation. Therefore, future research, both in the field and in the lab, should be adapted to equalize the data and facilitate interpretation as much as possible (see Chapter 11).

Processing for short- and long-term use

Fish processing activities and fish consumption could solely be discerned based on the different marks found on bone material. From the western sites, information on fish processing and consumption was present only from Hoogwoud. Here, two bones of plaice showed cut marks. One of the marks was on a bone that is situated behind the gills (*cleithrum*), the other on a vertebra near the tail. The mark near the gill was probably made when beheading or filleting a fish, whereas the mark on the vertebra was most likely the result of piercing the flatfish during capture, as was mentioned in the previous section. In addition, a limited number of fish bones from Hoogwoud, again mainly deriving from flatfish, was burned.

The sites in the west of West Frisia were located near saltwater. If Bronze Age West Frisians were able to

extract salt, the entire array of preservation techniques would have been available to them. However, no salt-works from the Bronze Age are (yet) known. The only manner in which salt may have been obtained therefore, was through long-distance salt trade with for example the Hallstatt area in Switzerland (Kowarik & Reschreiter 2010), although no concrete evidence for this practice was observed. If salt was unavailable to West Frisian people in the Bronze Age, the drying of flatfish and the smoke-drying of fatty fish would still have been possible conservation methods.

In the eastern sites, most of the information on processing and consumption comes from Medemblik and Enkhuizen; no specific information on marks or burning of bones was available from Westwoud and Bovenkarspel. At Medemblik, two cut marks were found on the tail vertebrae of a cyprinid and a pike, which indicate the removal of tails. In addition to the cut mark, the vertebra of the cyprinid was burned, which indicates consumption. Medemblik also yielded the largest amount of burned bones (Beerenhout 2010, 111) from fish including eel, various cyprinids, pike, perch, and even a salmon/trout, which all indicate human use of fish near fire, and therefore consumption. The fish remains from Enkhuizen showed no cut marks, but low percentages of fish bones were burned.

The sites of eastern West Frisia did not have direct access to saltwater in the surroundings, nor were there indications for salt trade found. The most plausible preservation techniques therefore, if they were applied or required, would have been drying and smoke-drying.

From many sites in West Frisia there is evidence for fish processing and consumption, even though bones which could provide such indications are often lost to taphonomy due to their bad preservation characteristics. This means that the actual number of bones resulting from processing and consumption activities would have been higher originally, and that fishing as a practice should not be underestimated. However, based on the available evidence, it remains unclear whether the long-term preservation of fish played a significant role in West Frisian societies; when weather conditions were favourable enough for a longer period of time, drying could definitely have been a practiced preservation technique.

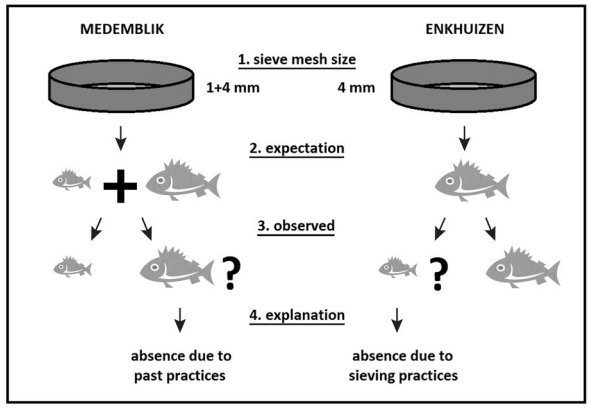


Figure 4.8. Overview of the expectations of fish size finds in Enkhuizen and Medemblik, based on sieving practices employed. Step 4 explains the specific type of absence of certain sized eel in both of the assemblages by linking this absence to either recent sieving or past human practices.

Storage and long-distance travel

Storage locations are unknown in West Frisia in general, so the storage of fish is no exception. However, based on the fact that storage locations need to be well-ventilated and elevated in order to preserve dried foods well, storage in the attic of buildings seems the most plausible location.

Based on the fish species found in West Frisia, there are no clear indications for long-distance travel of people. Rather, the ratios of (the preferences of) the different fish species found at each site seem to indicate very local fishing practices. This observations was further supported by the difference in fishing strategies applied at different sites in similar environments, such as for example between Enkhuizen and Medemblik.

Although evidence for long-distance travel, or trade of non-local species is not clear from the bone assemblage, the recent find of a paddle at Westwoud (Ons West-Friesland 2015; Figure 4.9) does indicate that West Frisian people would have had the ability to travel to other locations by boat for fishing. This paddle, which has a relatively long blade, is often used for travel at sea (pers. comm. R. van de Noort), since it can withstand high waves much more efficiently than a short blade. The additional presence of adult Atlantic cod at the Early Bronze Age site Schagen,

Figure 4.9. Wooden paddle uncovered at Westwoud (Ons West-Friesland 2015).

which can only be caught in the open sea with the use of a boat, underlines the potential importance of boats for sea fishing and sea travel in West Frisia.

4.4.2 Birds

Bird remains have been uncovered at five locations in West Frisia, including again the western sites Schagen and Hoogwoud, and the eastern sites Medemblik, Enkhuizen, and Bovenkarspel. Other reasons for the capture of birds are discussed in section 4.4.5.4.

Preparation: location, seasonality, and bait

Location

The habitat preferences of birds, as analysed in Chapter 2 (Figure 2.16) provided indications for the locations visited for fowling. The habitats included mostly wetlands, followed by grassland, shrub land, trees, and, in Schagen, also (sea) coastal and open water. Although at first glance it may seem that people practiced fowling at various locations, it must be kept in mind that birds can travel long distances through the air on a daily basis, visiting multiple habitats. Furthermore, the presence of only aquatic birds at Hoogwoud does not signify that just wetlands were present to be exploited around the settlement, but rather that specific human selection will have played a role (section 4.4.5). Therefore, the interpretation of fowling locations based on bird species is difficult. Local birds, such as for example woodcock, which do not travel long distances, can be indicators for local areas visited for fowling, in this case a forested area. Overall, based on a combination of the landscape reconstruction (Chapter 2) and the uncovered bird species (Table 4.5), it can be assumed that a variety of habitats was exploited for fowling, possibly with a tendency towards wetlands in the landscape.

Seasonality

Birds can be excellent seasonal indicators due to their long-distance migration behaviour. Similar to analysis of fish, the seasonal periods in which birds are assumed to have been most available or accessible to people were summarized in Table 4.5. The periods indicated in the table, include breeding and migration periods, and, for birds that undergo a flightless moult, the moulting period. Also shown in the table are species which breed and moult simultaneously. Some birds could only be identified to genus level, and in that case, the expected species within that genus (*i.e.* two in the cases discussed here) were included in Table 4.5, so that potential differences in catching methods for these species could be determined. Furthermore, groups were made based on the time of year a bird is available for capture, also based on migratory behaviour. Finally, birds of prey were highlighted in order to identify possible appropriate types of bait.

Table 4.5 shows that on all sites researched, about half the species found are migratory, indicating fowling during specific times of the year (*i.e.* spring and autumn). Other periods of capture most likely exploited were the breeding and moulting season, which can occur from February to November, depending on the species. So, including birds available for capture during winter, overall, birds could have been caught year-round (Table 4.5, category 1-3).

The western sites of West Frisia, especially Schagen, show a different picture from the eastern sites. Although many birds found in Schagen can be caught throughout the year, more than half of the

Table 4.5. Schematic representation of the seasonal behaviour of the birds found at each site.

Bovenkarspel		January	February	March	April	May	June	July	August	September	October	November	December	Code
Taxa	English name													
Bubo bubo	Eagle owl													1
Corvus corone	Carrion crow													
Anas platyrhynchos	Mallard													2
Anas crecca	Common Teal													3
Anser anser	Greylag goose	-										-	-	4
Cygnus cygnus	Whooper swan				-	-	-	-	-	-				5
Cygnus olor	Mute swan				-	-	-	-	-	-				
Grus grus	Crane	-	-								-	-	-	6

Enkhuizen		January	February	March	April	May	June	July	August	September	October	November	December	
Taxa	English name													
Scolopax rusticola	Eurasian Woodcock													1
Accipiter gentilis	Northern Goshawk													
Rallus aquaticus	Water rail													2
Anser anser	Greylag goose	-										-	-	4
Anas penelope	Widgeon				-	-	-	-	-	-				5
Philomachus pugnax	Ruff	-	-	-			-	-	-		-	-	-	6

Medemblik		January	February	March	April	May	June	July	August	September	October	November	December	
Taxa	English name													
Bubo bubo	Eagle Owl													1
Corvus corone/	Carrion Crow/													
Corvus frugilegus	Rook													
Anas crecca	Common Teal													3
Anas querquedula	Garganey	-	-							-	-	-	-	4
Cygnus cygnus	Whooper swan				-	-	-	-	-	-				5

Hoogwoud		January	February	March	April	May	June	July	August	September	October	November	December	
Taxa	English name													
Anas platyrhynchos	Mallard													2
Anas crecca	Common Teal													3
Anas querquedula	Garganey	-	-							-	-	-	-	4
Anas penelope	Widgeon				-	-	-	-	-	-				5

Schagen		January	February	March	April	May	June	July	August	September	October	November	December	
Taxa	English name													
Scolopax rusticola	Eurasian woodcock													1
Rallus aquaticus	Water rail													
Anas platyrhynchos	Mallard													2
Alauda arvensis	Skylark													
Anas crecca	Common Teal													3
Calidris alpina	Dunlin													
Anas querquedula	Garganey	-	-							-	-	-	-	4
Coturnix coturnix	Quail	-	-	-						-	-	-	-	
Branta bernicla	Brent goose				-	-	-	-	-	-				5
Branta leucopsis	Barnicle goose			-	-	-	-	-	-	-				
Gavia arctica	Black-throated loon				-	-	-	-	-	-	-			
Gavia stellata	Red-throated loon					-	-	-	-	-	-	-	-	7

behaviour		code:	presence:
	in molt	1	available all year + during breeding
	breeding	2	available all year + during breeding and moulting
	molt and breeding	3	available all year + during breeding, moulting, and migration (partial migrant)
	migration	4	available during breeding, moulting and migration (summer)
food consumption		5	available during breeding, moulting and migration (winter)
	carnivore	6	available during migration
- not present		7	usually unavailable

Different groups are denoted by codes based on the availability of several bird species throughout the year. Data used derives from Europese Vogelgids Online 2012 and Nederlands Soortenregister 2015. Partial migrant denotes that birds do not migrate annually, but only when necessary due to very harsh weather conditions in winter.

species are migratory or partially migratory, which means they are present for a limited time only (*e.g.* only during summer or winter or resting periods during migration).

In eastern West Frisia, the sites yielded a variety of bird groups. Almost all birds could have been caught during summer. All sites seem to furthermore possess one or more species of bird which are only here during migration.
When the east and west are compared (Figure 4.10, Figure 4.11), it is clear that differences exist in the exploitation of birds. Overall, the periods in which birds can be caught at the western sites are more compressed into fewer months, whereas in the east, all three types of specific behaviour of the birds captured (*i.e.* breeding, migration, and moulting) seem to occur, and also during longer periods.

Still, both regions indicate that fowling could have been practiced at multiple times during the year. Migration seasons could be exploited in early spring and late autumn, whereas breeding and moulting seasons could be the focus for capturing birds in

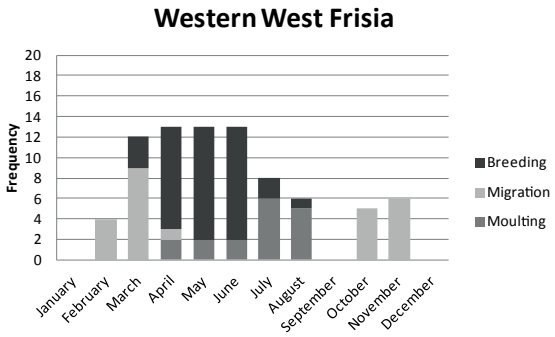


Figure 4.10. Seasonality summary of birds from western West Frisia.

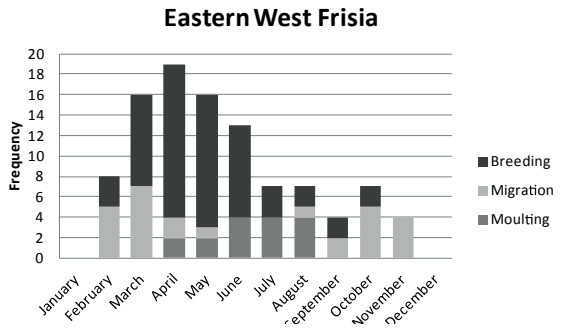


Figure 4.11. Seasonality summary of birds from eastern West Frisia.

between these periods. Winter fowling could have been an option as well, although no specific bird behaviour is linked to this period of the year. The absence of foliage during this time does however increases their visibility and could have facilitated capture.

Indirect indications for the seasonality of fowling, based on bird bones, were also present in West Frisia, although they are scarce. Egg-laying bones were absent from the assemblages, but in Medemblik, a bone of a young bird was found in a ditch, signifying capture in summer. Even though the young bird could not be identified to species level, it was observed that the bird possessed long legs. This could include birds such as cranes, storks, egrets, etc. (pers. comm. M. Groot), which are all possible targets for fowling in summer.

Bait

The two identified large birds of prey, Northern goshawk (*Accipiter gentilis*) and eagle owl (*Bubo bubo*), both hunt small mammals and birds on sight from their perches in trees, but goshawk can also fly along forest edges or waterways in the search of prey (Bijlsma 1993). This means that these birds may be captured with bait at these locations, although during a different times of the day (*i.e.* goshawk hunts during the day, eagle owl is active during dusk).

Fowling: tools, equipment, and strategy

Tools and equipment

Potential archaeological evidence for using a bow and arrow was uncovered in West Frisia in the form of flint arrow heads (Figure 4.12), which could have been used for fowling. Although fowling with bow and arrow will not have been the only form of hunting present in West Frisia, the absence of other hunting tools and equipment may very well be related to the transient nature of such fowling gear, which includes mostly nets, snares, and traps. Nonetheless, witness the fishing fyke present in Enkhuizen (section 4.4.1), people were familiar with the use of rope (also see Chapter 7, section 7.4.6.4), so the construction of nets and snares should have been no problem either.

The most frequently found bird species at the sites of West Frisia are mallard (*Anas platyrhynchos*), common teal/garganey (), widgeon (*Anas penelope*), greylag goose (*Anser anser*), eagle owl (*Bubo bubo*), whooper swan (*Cygnus cygnus*), water rail (*Rallus aquaticus*), Eurasian woodcock (*Scolopax rusticola*), and thrushes (Table 4.5). Most of these species are anatids (*i.e.* ducks, geese), and these can be caught, as said before, during moulting season using the hands, nets, clubs, or dogs, possibly in combination with lures or decoys. Snares, and other traps are also a possibility, when passive fowling is practiced. Widgeon is an exception, since it only present during the winter period and cannot be caught during moulting season. Outside moulting season, anatids can be caught using snares and traps at fields, or by other methods of active fowling, such as nets, spears, arrows, etc.

Two birds which require some more attention include loon (*Gavia arctica/stellata*)(found at Schagen) and crane (*Grus grus*) (found at Bovenkarspel). The loon is a bird that hunts at the open sea and seeks the refuge of coastal waters or inland lakes in the breeding season. It is a difficult bird to catch but

Figure 4.12. West Frisian flint arrowheads.

possible techniques include using nets or practicing night fowling (Kenow 2009). Alternatively, it could be caught as a by-catch when using fish fykes (Studer 1992). Crane is a large bird that is only present in the Netherlands when it is resting during migration further north or south. It uses wetlands for shelter and feeding, and it forages on (agricultural) fields in the autumn. Apart from both the swan species, crane forms the largest bird found in West Frisia, reaching up to 120 cm in height. Catching one of these birds would not have been a simple task, although their size would allow for hunting with bow and arrow.

Another interesting aspect of the birds in West Frisia is that almost all sites in the east of West Frisia (Enkhuizen, Medemblik, Bovenkarspel), no matter how few the finds, have remains of birds of prey, both of which might have been caught by employing a lure in combination with a net. Eurasian woodcock, a resident local bird which inhabits the undergrowth of forests, is very hard to locate, so snares might have been used to catch such a bird, or perhaps it was hunted with the aid of dogs.

Three birds so far not mentioned are dunlin (*Calidris alpina*), and ruff (*Philomachus pugnax*). These birds all forage near water and could also be caught using nets or traps. Quail (*Coturnix coturnix*), rook (*Corvus frugilegus*) and carrion crow (*Corvus corone*) finally, might also have been caught using again nets or traps, but are located more in grassland and shrub land environments.

Strategy

A combination of active and passive hunting strategies will have existed in West Frisia. Although no clear indications for each hunting strategy could be obtained based on the birds themselves, the flint arrow heads uncovered at many sites in West Frisia at least provide indications for the occurrence of active hunting practices. Passive hunting strategies were not represented in the archaeological record in general, but are expected to have been practiced nonetheless, especially considering their combinability with farming practices. Passive hunting strategies usually employ nets, snares, and traps made from organic materials, so their absence is most likely due to taphonomical processes.

Processing

In the West Frisian bird assemblage, no apparent marks were found on bird bones. Although this may be interpreted as an absence of evidence for processing and consumption, the range of bird species present within each settlement makes it very implausible that birds became part of the archaeological assemblage of their own accord. An alternative explanation for the absence of marks on bird bones can be related to the hollow and fragile nature of these bones. These characteristics make them very susceptible to degradation via taphonomical processes. When these already fragile bones are additionally affected by cut or burn marks, their chance at preservation becomes even more reduced. Considering both these bird bone characteristics and the non-specific, wide-mesh sieving practices applied during many excavations, it is surprising that bird bones are uncovered at all.
Even though the bones themselves could not provide information on processing and consumption, potential processing practices performed in West Frisia could still be postulated. Since the Bronze Age climate was largely comparable to the present climate (Zagwijn 1991), low temperatures would have been unavailable in West Frisia during summer. When birds were indeed caught for consumption purposes, it is likely that in summer birds were processed and eaten within hours after capture (Maas-van Berkel *et al.* 2004, 22). In winter time however, temperatures might have constantly been sufficiently low to preserve the meat for longer periods of time. This means that during winter, an additional preservation method was available. Bird meat could also have been preserved using smoking and drying methods, but whether salt for salting procedures was available to the West Frisian farmers remains unknown.

Alternatively, birds could have been made flightless after capture and kept as a form of poultry within the settlement.

Storage and long-distance travel

Storage of processed bird meat could, comparable to processed fish, have been stored on attics within buildings. Due to the highly mobile nature of most birds, it is impossible to assess whether long-distance travel was performed by Bronze Age people; no outliers of bird habitats were uncovered to confirm or contradict this aspect of fowling.

4.4.3 Mammals

Mammal remains have been uncovered at nine locations in West Frisia. Small mammal remains were found at Schagen, Hoogwoud, Westwoud, Hoogkarspel, Enkhuizen, and Bovenkarspel. Large mammal remains were uncovered at Schagen, Hoogwoud, Medemblik, Zwaagdijk, Andijk, Hoogkarspel, Enkhuizen, and Bovenkarspel. Schagen and Hoogwoud are again considered to be the western West Frisian sites. Other reasons for the capture of small and large mammals is discussed in section 4.4.5.4.

Preparation: location, seasonality, and bait

Location
Locations for hunting mammals were reconstructed based on the habitat preferences of the animals (Chapter 2, Figure 2.17, 2.18, and 2.19). Habitat types, and therefore hunting locations for all sites include equal preferences for wetlands, grassland, shrub land, presence of trees, and, in the case of Schagen, the coast. Small mammals indicate mostly open areas, whereas large mammals prefer the cover of trees or shrubs; this difference in cover preference is related to the size of the animal. This variety in habitat types indicates that people fully exploited their surroundings, and targeted many different animal species.

Seasonality
The seasonality of game hunting was first analysed by attempting to identify certain periods of the year based on seasonal behaviour of large mammals (Table 4.6), since it is assumed they were the main targets for hunting; small mammals were not researched here. Two types of seasonal behaviour of mammals included in the table consist of mating and raising young. In both periods, animals are busy with procreation and feeding offspring, making them less focused on threats in the surroundings. Another seasonal aspect of mammal behaviour is migration. Migration for the species found in West Frisia is characterized mainly by short periods of relatively short movements (up to 50 km), mostly undertaken by young individuals that are banned from the population when they reach maturity (Twisk *et al.* 2010). The only exceptions to this are harbour seal (*Phoca vitulina*), wild cat (*Felis sylvestris*), and fox, species of which young individuals might travel up to 100 km in search of their own territory (Twisk *et al.* 2010: 291, 299, 315). However, it must be mentioned that for most animals, the distance of travel is related to the environment in which they reside. For example, the distances travelled in search of food in mountainous areas can differ considerably from distances in lowland areas, where there is more food available per square kilometre. It is therefore not assumed that large mammals migrated over large distances, and if migration did occur, the distance travelled would not take them out of West Frisia.

A final type of mammal behaviour is the formation of groups during winter by some species, which was also included in Table 4.6. In contrast with the seasonality tables related to fishing and fowling, no distinction was made between presence or absence of mammals, since all species could have been present in or near West Frisia throughout the year.

Interestingly, Table 4.6 has made clear that most of the seasonal behaviour of mammals is too general to identify specific periods of the year most suitable for hunting purposes, since each period can be favourable for hunting in one way or another. What is also apparent is that most of the mammals found in West Frisia do not exhibit specific seasonal behaviour during July and August; at two sites, Enkhuizen and Medemblik, none of the uncovered animals show specific behaviour during this time. Also interesting to note is that here, Hoogwoud reflects the eastern

sites of West Frisia based on its mammal assemblage, whereas for fish and birds, it was more similar to the western site Schagen.

Some additional and more specific seasonal information for hunting was obtained from archaeological bone material. In Zwaagdijk, a bone of a young beaver was uncovered, which indicates capture in summer or autumn. At the same site, the skull of an elk with remains of antlers still attached was found, indicating that it was also caught between summer and autumn (Halici & Buitenhuis 2003, 166). Another skull of an elk was identified in Medemblik, with evidence of shed antlers (Groot 2010a, 94). Since antlers are shed between December and March, after which they regrow (Twisk *et al.* 2010), this indicates capture between winter and early spring. Based on these few examples, it seems that large mammals were at least caught from late summer to early spring, during various seasonal behavioural periods.

Bait

The predatory mammals indicated in Table 4.6 could have been lured with animal bait, such as fox, brown bear, weasel, wild cat, otter (*Lutra lutra*), polecat, and harbour seal. Other mammals could also have reacted to the use of bait, but this will have included the use of vegetative material. Bait in combination with traps or snares could have been effective for both type of mammal.

Game hunting

Tools and equipment

As stated previously (section 4.4.2), direct indications for hunting mammals were uncovered in the form of flint arrowheads at many locations in West Frisia (Figure 4.12). Other weapons besides bow and arrow were not identified, but the inherent characteristics of these types of hunting gear (section 4.3.2) can provide indications for possible causes of this absence.

The two main reasons for the absence of weapons in West Frisia can be related to both the shape and the material of the weapons. Rabbit sticks and spears, although very effective hunting weapons, are basically pointed sticks, which might not be recognised by excavators as weapons. Slings, clubs, and arrow shafts are equally hard to identify. Traps, nets and snares are often used off-site and are only found when excavations occur at those locations. All these types of hunting gear furthermore, are perishable, being constructed out of organic materials. Only under very specific circumstances are these materials preserved. The possible presence of flint arrowheads or sling stones, which are made from inorganic materials and are thus better preserved, may indicate the use of bow and arrow or sling, respectively. Still, the direct visibility of game hunting equipment remains very limited. However, the wide range of mammals species found in West Frisia, as well as the uncovered eel fyke from Enkhuizen (section 4.4.1), does provide indications that other types of gear, which may have been used for hunting mammals, must have originally been present here as well.

Indirect indications for hunting tools and equipment were found based on the uncovered mammal species. First of all, the wide range of mammal species found in West Frisia (Table 4.6; Chapter 2), indicates that people indeed had elaborate knowledge of the wild animals in their surroundings, because no “catchall” method exists to ensure the capture of all these species. This observation alone already indicates that multiple hunting techniques must have been known and applied.

From the large mammals species found, the most frequent are roe deer, beaver, red deer, fox, elk, and wild boar (Table 4.6). Roe deer could have been caught using snares or traps, or by using clubs, when young are encountered. Red deer and beaver can be hunted, apart from the use of bow and arrow, by being chased into traps by dogs or men. Fox might be snared, or captured by dogs. Wild boar respond very well to baiting, and can subsequently be hunted in several different ways, for example by trapping. Elk finally, were (pre)historically hunted in Sweden by using pitfalls (Ericsson 2011). People in West Frisia must have been using at least a combination of snaring and trapping, and either hunting with bow and arrow or using dogs and/or pitfalls to catch the range of species

Table 4.6. Schematic representation of the seasonal behaviour of the large mammals found at each site.

Different groups are denoted by codes based on the availability of several mammal species throughout the year. Data used derives from Twisk, van Diepenbeek and Bekker 2010.

observed. Small mammals finally, when targeted for capture, might have been caught using traps or nets.

Strategy

Similar indications for (the absence of) hunting strategies which were discussed in section 4.4.2, were present for mammals. Based on the animal species uncovered, it can be assumed that both active and passive hunting techniques would have been part of the hunting repertoire of Bronze Age farmers, even though actual traps have not (yet) been found.

Processing

Marks on wild animal bones, indicative of processing and consumption, were found at several sites in West Frisia. In Medemblik for example, marks on the remains of a skull of fox, a scapula of wild boar, and a tibia of beaver were found which all indicate slaughter (Groot, unpubl. results). In Enkhuizen, only the femur of brown bear showed slaughter marks (Roessingh & Lohof 2011, 212). No charred or burnt bones of mammals were found.

Potential processing practices could further be explored based on the characteristics of mammal meat. When large game is killed, it is important to hang the meat at a temperature that does not reach above 7 °C, in order to tenderize the meat (cf. section 4.3.3). Inherently, this means that adequate immediate processing of meat from large mammals is only favourable during certain times of the year. Since it is assumed that the climate in the Bronze Age was largely the same as at present in the Netherlands, the months in which the temperature allowed for hanging of meat include October to April/ May (Klimaatatlas n.d.) or roughly from autumn to spring. This time period is largely concurrent with the observed seasonal indications for game capture based on bone material mentioned above, which occurred from late summer to early spring.

Processing with the aim of preserving the meat for a longer period of time may have included methods such as drying or smoke-drying, or refrigeration during winter months. It remains unknown whether salt for salting procedures was available to the West Frisian farmers, but these other preservation methods would have been adequate to ensure the availability of meat in winter.

Storage and long-distance travel

Possible storage locations for game meat are similar to those mentioned for fish and bird meat. The mammal species uncovered in West Frisia do not allow for a clear interpretation of long-distance travel for hunting. However, it is clear from the varying ratios of habitat preferences of the animals found at each site that people must have hunted relatively locally; each site shows a slight local variation in animal composition, and no clear preferences for the exploitation of a specific habitat type could be observed. The exact distance people travelled for hunting game is not known, but is assumed to lie between five and seven-and-a-half kilometres from the settlement (Chapter 3, section 3.3.5). The presence of large mammals such as brown bear and elk suggest that forest locations were present at relatively close proximity to the settlement. More detailed information on the potential location of these forest with respect to the settlements is further explored by an analysis of the home ranges (*i.e.* living areas) of large mammals found at each site in Chapter 8: Bronze Age farming in West Frisia (Cronau 2016).

4.4.4 Summary

The range of habitats, seasons, and animal species exploited in West Frisia indicates that knowledge and skill of (how to prepare for) hunting were still an integral part of Bronze Age society.

The employed hunting techniques could often not be confirmed directly by the presence of hunting gear, which is most likely due to the poor preservation characteristics of the organic materials of which they are often constructed. Some techniques however, could be indirectly reconstructed based on the uncovered animal species, as well as based on marks on bones. The resulting wide range of hunting techniques required to capture all the animals found in West Frisia also underlines the vast knowledge and skill which must have been present amongst Bronze Age people in order to create hunting tools and equipment. Hunting was mostly practiced locally, which was

established for both western and eastern West Frisian sites, although boats may have been employed for particular hunting practices such as fishing. It has furthermore become clear that similar habitats were exploited differently at different sites, and that this remained a constant phenomenon throughout the Bronze Age. In addition, many sites in West Frisia also yielded evidence for wild animal processing and consumption indicating that wild animal meat may have aided Bronze Age subsistence during periods of the year when domestic resources were scarce.

Thus, for every main activity related to hunting, either direct or indirect indications were identified. Hunting therefore seems to have been an imbedded practice in West Frisian farming communities, and its role in subsistence should not be underestimated. Clearly, hunting wild animals was not an occasional occupation, but a careful consideration of environmental exploitation.

Instead of summarizing a list of bones and species present, the analysis of hunting in West Frisia performed here has shown that a detailed comparison between an expectation of practice and the observed data can provide clear evidence of hunting practices, even when the data available for such an analysis is of limited quantity and derives from excavations with differently applied methodologies.

4.4.5 Discussion

As shortly introduced at the beginning of section, several effects of (past and present) methodology and taphonomy can exist in the archaeozoological record. These factors are summarized and reflected upon here for every animal group. By becoming aware of potential influences of processes such as taphonomy (cf. Figure 4.8), and where possible, eliminating these effects, more insight can be gained into actual past human practice. For example, this awareness allows for a more accurate comparison of which species were and were not uncovered, showing possible selections for consumption of wild animals by past humans. Finally, other possible reasons for hunting are investigated in this section, exploring its importance to subsistence besides providing food.

4.4.5.1 Methodology

Sampling and sieving are the most important excavation methods which will have affected the archaeozoological record. Sampling often occurs in a random manner at excavations, and is usually performed when the chance of uncovering remains from a feature is already high. Often, samples for remains of fish, birds, or small mammals are only taken from contexts when they have already been observed with the naked eye. This means that other contexts, which may be equally or more informative, are not sampled, resulting in a possible loss of (additional) information. A more structured plan of sampling before excavation would greatly benefit the research on all the practices related to fishing and fowling, even if contexts do not seem promising at first glance.

Inadequate sieving practices also affect the composition of species uncovered from an excavated site to a large extent. When mesh sizes are too large, many fish, bird, and small mammal species are missed (Huisman 2009, 52), which may result in an interpretation based on biased data that may not reflect actual past practices. According to both Neer & Ervynck (1993) and Meadow (1988, 69), adequate sieving mesh sizes for the different animal groups are 1 mm-2 mm for fish remains, and 2 mm-4 mm for bird and small mammal remains (Chapter 2, section 2.4.5.1, Figure 2.20). Large mammal remains are best uncovered at sieving mesh sizes of 4 mm combined with hand collecting. Sieving for these animal groups at similar mesh sizes at every site can provide a firm platform for comparison of hunting practices between sites and even areas. Since in West Frisia, sieving was performed with different mesh sizes at every site, the detailed interpretation of practices was only limited to two sites with comparable practices. However, based on these two sites new insights into the local praxis of fishing were obtained, which underlines the importance of applying consistent and comparable excavation methodologies. For further elaboration on excavation methodology, see Chapter 11.

4.4.5.2 Taphonomy

Taphonomical processes can have a considerable impact on bone assemblages. Even though West Frisia

has excellent preservation conditions with regard to bones due to its calcareous clayey soils, even here, taphonomy has had an effect. Working of the soil has resulted in high fragmentation of remains, resulting in an underrepresentation of certain find categories. Bones of small animals, including fish, birds, and small mammals, are prone to degradation in general due to their size and fragility. When these bones are further affected by processing such as by cut, chop, and burn marks, they are even more susceptible to degradation and subsequent loss via taphonomical processes. The chance of finding these bones, which are indicative of processing and consumption practices, is therefore small. When bones with marks are found however they provide rare insight into such hunting practices. The fact that these remains were present at all in West Frisia simultaneously means that the original number of bones indicating processing and consumption will have been even higher, and also that their presence is only possible under exceptional preservation conditions.

Similar considerations and reservations should be kept in mind when interpreting hunting methods based on the presence or absence of tools and equipment, since taphonomical processes will have also affected other organic materials. Hunting tools and equipment, often being made from exactly these (perishable) materials, are very prone to degradation, except under waterlogged conditions. The fish fyke found in Enkhuizen is a rare example of the preservation of hunting equipment under waterlogged conditions. Although it is only one example, it already signifies the skill and knowledge of constructing such hunting gear present in Bronze Age West Frisia. The presence of flint arrowheads furthermore, which are not very susceptible to degradation, provides another rare indication of hunting in this area at this time. All other types of weapons are most likely not preserved due to taphonomy, but this does not necessarily mean they were not originally present.

Thus, when interpreting fishing, fowling, and hunting in the past, the effects of methodology and taphonomy should be kept in mind before concluding on the importance of these practices for subsistence. The absence of wild animal remains or hunting equipment does not necessarily suggest the absence of such practices, but could purely be the result of both methodological and taphonomical processes affecting their visibility in the archaeological record. Comparison of expected practices with the (limited) evidence that is available at a site can (still) provide a clear idea of practices, even if not all remains directly indicative of hunting have stood the test of time.

4.4.5.3 Possible selection criteria for consumption

Since this thesis mainly focuses on food procurement, possible reasons for selecting wild animals for consumption are explored here. They include: edibility and flavour, addition to the diet, and availability and abundance.

Edibility and flavour

The flavour of a certain species of animal can be a reason for preferring that species over other species which might be more nutritious or more abundant. Whereas most animals are edible, some can be considered tastier than others, even if we do not perceive it as such nowadays. If (a combination of) certain animal species have a higher prevalence on a site than others, this could thus be a possible indication for a selection on flavour.

Fish

Fish have been uncovered at many sites, but the species most often present both in terms of bone remains and frequency include eel, pike, bream, perch, and cyprinids in the eastern sites (Table 4.7), and mostly flatfish species in the western sites (Table 4.8). The higher presence of these fish could be related to edibility and flavour, since most of them are still being consumed at present. However, flavour is very subjective, so caution must be exercised before drawing definitive conclusions. Still, three of the fish which were expected based on the available habitats present in West Frisia, including sunbleak (*Leucaspius delineatus*), spined loach (*Cobitis taenia*), and bitterling (*Rhodeus amarus*) (Appendix A1.3) were not found, and are also generally considered to taste bad (Vissengids 2016).

Birds

West Frisian birds may also have been selected based on their edibility and flavour. Furthermore, rather than the birds themselves, the eggs of birds

Table 4.7. Frequency and number of fish remains from the eastern West Frisian sites.

Taxa	English name	Boven-karspel	Westwoud	Medemblik	Enkhuizen	No.	Freq.
Cyprinidae indet.	Carp-family	4,863	36	82	1,075	6,056	4
Anguilla anguilla	Eel	1,037	88	82	843	2,050	4
Perca fluviatilis	Mullet-family	100	3	71	427	601	4
Esox lucius	Pike	149	13	147	223	532	4
Abramis brama	Bream	85	1	44	107	237	4
Rutilus rutilus	Roach	67	0	5	40	112	3
Blicca bjoerkna	Silver bream	31	0	3	3	37	3
Gasterosteus aculeatus/	3-Spined stickleback	606	21	0	0	627	2
Alburnus alburnus	Bleak	54	0	0	1	55	2
Siluris glanis	Catfish	14	0	0	10	24	2
Scardinius erythropthalmus	Common rudd	0	0	2	3	5	2
Mugilidae	Pike	0	0	2	2	4	2
Abramis brama/Blicca bjoerkna	Bream/ Silver bream	0	0	0	35	35	1
Leuciscus idus	Ide	8	0	0	0	8	1
Tinca tinca	Tench	6	0	0	0	6	1
Pleuronectidae	Fatfish-family	0	0	3	0	3	1
Gymnocephalus cernuus	Ruffe	2	0	0	0	2	1
Eutrigla gurnardus	Grey gurnard	0	0	0	1	1	1
Salmonidae indet.	Salmon-family	0	0	1	0	1	1
Pungitius pungitius	10-Spined stickleback	0	0	0	0	0	0
TOTAL		7,022	162	442	2,770	10,396	

Table 4.8. Frequency and number of fish remains from the western West Frisian sites.

Taxa	English name	Hoogwoud	Schagen	No.	Freq.
Pleuronectidae	Flatfish-family	97	1,147	1,244	2
Platichthys flesus	Flounder	3	34	37	2
Anguilla anguilla	Eel	2	24	26	2
Liza ramada	Thin lipped grey mullet	9	10	19	2
Dicentrarchus labrax	Sea bass	1	8	9	2
Raja clavata	Thornback ray	1	6	7	2
Gasterosteus aculeatus	3-Spined stickleback	0	34	34	1
Alosa fallax / alosa	Shad	0	23	23	1
Clupea harengus/Sprattus sprattus	Atlantic herring/sprat	0	17	17	1
Cyprinidae indet.	Carp-family	0	11	11	1
Solea solea	Sole	0	11	11	1
Acipenser sturio	Sturgeon	0	9	9	1
Gadus morhua/Merlangius merlangus	Cod/Whiting	0	9	9	1
Osmerus eperlanus	Smelt	0	7	7	1
Alosa alosa	Allis shad	0	6	6	1
Coregonus spec.	Whitefishes	0	6	6	1
Perca fluviatilis	Perch	0	6	6	1
Esox lucius	Pike	0	5	5	1
Abramis brama	Bream	4	0	4	1
Liza ramada / aurata	Thin lipped-/Golden grey mullet	0	4	4	1
Pleuronectus platessa	Plaice	4	0	4	1
Dasyatis pastinaca	Stingray	0	3	3	1
Mugilidae indet.	Mullet-family	3	0	3	1
Alosa fallax	Twaite shad	0	2	2	1
Chondrichthyes	Rays/Sharks	0	2	2	1
Gadus morhua	Atlantic cod	2	0	2	1
Rajidae	Skates and Rays	0	2	2	1
Salmo salar / trutta	Atlantic salmon/trout	0	2	2	1
Clupea harengus	Atlantic herring	0	1	1	1
TOTAL		126	1,389	1,515	

may have been collected as an additional food source in the Bronze Age which was not available at the settlement.

The edibility and flavour of the bird species found in West Frisia, as well their eggs, was evaluated in order to identify possible selection of birds on edibility and flavour. As stated previously, flavour is very subjective, but global trends in the edibility and taste of different birds and eggs has been researched in the past (Cott 1947; Cott 1954). Cott performed taste experiments with wild birds and eggs right after World War II in order to avoid possible food shortages in such situations in the future. He tested the taste, texture and edibility of wild birds and eggs on people from all over the world. Since most birds were tasted by people from different countries, it is assumed that a potential bias due to cultural preference is less probable. Therefore, the information provided by Cott is applied to the West Frisian data. The edibility aspects of the birds and their eggs found in West Frisia are summarized in Table 4.9. Only where it is specifically stated that the bird flesh or egg is inedible, a '-' mark is given.

What Table 4.9 clarifies is that almost all birds found as well as their eggs are considered to be edible to a certain extent. Thus it seems that based on the uncovered bird species, edibility may have been a reason for catching these birds (and eggs) by West Frisian people, except for swallows and loons.

Besides edibility, flavour might also have been an important consideration for selecting certain birds. Interestingly, bird meat absorbs the flavour from the feed a bird consumes (Cott 1947, 484). So, generally speaking, birds feeding on fish are (at present) considered (in the western hemisphere) as less palatable than birds feeding on fruit or nuts. This is a very variable factor, which can differ between species, within species depending on foraging location, and even per time of day or season. Certain species might therefore only be preferred during a certain time of the year, independent of the ease with which they can be caught. Crane for example, is only considered to be palatable when it has consumed crops, and thrushes only in autumn, after having consumed berries. An example of a possible preference for flavour might be observed in Schagen. Schagen was located relatively close to the sea and several saltwater fish were found there, yet only one seabird was found (loon), compared to multiple species of freshwater aquatic bird. Loon hunts on fish, which makes their flesh taste rank and this is not considered to be edible by most (Cott 1947, 478). Other birds expected near saltwater-influenced sites such as Schagen or Hoogwoud would include several species of gull and tern (Birdlife International n.d.). These birds also feed on fish and were therefore perhaps not held in high esteem with regard to their taste. Birds found which are considered to be edible and also appear near the coast are dunlin, brent goose (*Branta bernicla*), and barnacle goose (*Branta leucopsis*). The absence of (other) inedible bird species at Schagen, and the presence of these edible birds from the same habitat type may be the result of human selection on flavour.

Another indication for the possible selection based on flavour in West Frisia is more indirect and is related to the edibility and taste of birds based on plumage colour. Cott examined the relationship between the visibility of birds in the wild (bright plumage vs. cryptic colouration) and their taste (Cott 1947, 436-447). A general trend that is observed is that birds of which both male and female are well camouflaged (and are normally more vulnerable to attack) are usually considered to taste better than their brightly coloured counterparts. Ironically, this also means that the best catches with respect to taste are the hardest to see/find and perhaps catch. Many of the birds found in West Frisia however, are of exactly this camouflaged type. Their presence shows that flavour might indeed have been one of the major considerations when catching a bird.

Eggs

In order to assess the edibility of wild bird eggs, Cott consulted an actual Egg Tasting Panel (Cott 1954). Eggs were rated in a single-blind research fashion based on their colour, texture, flavour, and overall edibility. Of course, a bias exists since the Egg Tasting Panel was already operational for testing "normal" eggs on their quality in Great Britain. Therefore, the range of opinions of people from the article on edibility of wild birds (Cott, 1947) was not

Table 4.9. Overview of the edibility characteristics of birds found in West Frisia as well as their eggs.

Taxa	English name	Bird edibility	Page	Egg edibility	Page
Accipiter gentilis	Northern Goshawk	+	475	?	n/a
Alauda arvensis	Skylark	+	473	+/-	439-440
Anas crecca/querquedula	Common teal	+	n/a	+	370
Anas querquedula	Common teal/ Garganey	+	n/a	+	370
Anas penelope	Widgeon	+	n/a	no eggs	n/a
Anas platyrhynchos	Mallard	+	469	+	368/369
Anser anser	Greylag goose	+	n/a	+	365/366
Branta bernicla	Brent goose	+	475	no eggs	366
Branta leucopsis	Barnacle goose	+	475	no eggs	366
Bubo bubo	Eagle owl	+	461/462	-	425
Calidris alpina	Dunlin	+	471	?	n/a
Corvus corone	Carrion crow	+	n/a	+	430
Corvus frugilegus	Carrion crow/Rook	+	476	+/-	430
Coturnix coturnix	Quail	+	470	+	384
Cygnus cygnus	Whooper swan	+	-	no eggs	364
Cygnus olor	Mute swan	+ (young)	475	+	365
Gavia stellata	Red-throated loon	-	478	no eggs	348
Gavia arctica	Black-throated loon	+/-	478	no eggs	n/a
Grus grus	Crane	+/-	475	no eggs	n/a
Hirundinidae	Swallows	-	463	+/-	451
Philomachus pugnax	Ruff	+	471	+	399
Rallus aquaticus	Water rail	+	n/a	+	389
Scolopax rusticola	Eurasian woodcock	+	471	+	397/398
Sylvia spec.	Warbler spec.	+	462	-	455
Turdus spec.	Thrush spec.	+ (autumn)	485	+/-	454

Page numbers beside the edibility of birds refer to the article by Cott from 1947, the page numbers beside the edibility of eggs refer to the article by Cott from 1954. Symbols related to bird edibility: +=edible, +/-=edibility rating differs between tasters, -=inedible, ?=unknown. Symbols related to egg edibility: +=edible, rating higher than 6.5, +/-=edibility rating between 5.0 and 6.5, -=inedible, rating lower than 5.0, ?=unknown, no eggs=bird is not present in West Frisia during egg laying season, so eggs could not have been collected.

available for the edibility of wild bird eggs. However, it is the only elaborate article on the consumption characteristics of wild bird eggs made before the collection of such eggs was prohibited, and is therefore considered to be a general guideline to flavour.

Even though there is no evidence for the consumption of eggs in West Frisia (*e.g.* in the form of eggshells), the presence of the birds that lay them means they would have been available to people. Table 4.9 shows that the edibility of the eggs might reveal indications for why certain bird species were found and others were not. First of all, eggs of birds of prey are either inedible (*i.e.* eagle owl), or of unknown taste (*i.e.* Northern goshawk). Both birds build nests high up in trees and are very protective, so perhaps it would not have been easy to collect these eggs, even if the taste was good. Secondly, there is a group of birds of which the eggs are of average taste, including skylark (*Alauda arvensis*), rook, and swallows. Thirdly, there is a large group of birds of which both the meat and the eggs are considered to be tasty. These are teal, garganey, mallard, goose, crow, quail, mute swan (Cygnus olor), ruff, water rail, and woodcock. Apart from crow, all these birds build nests on the ground, so eggs could have been collected relatively easily when the nesting location was known.
The last group of birds seen in Table 4.9 is the group of migratory birds. Regardless of the taste of their eggs, which is excellent in the case of brent goose, barnacle goose, and whooper swan (data not shown), these birds are not present in West Frisia in egg-laying season. Therefore, their eggs would have been unavailable to the West Frisians and are therefore not discussed any further.

Eggs can only be gathered during a limited time. After the eggs are lain, the chick will start to develop inside the egg, provided the parent is brooding. Depending on the species, incubation time from egg-laying to hatching will on average take about 20-30 days (Broedseizoen 2016), depending on the size of the bird. Within this short period, eggs need to be gathered; the longer one waits with collecting, the further the chick will have developed. However, when a bird has not completed laying the full clutch of eggs, and eggs are carefully removed from the nest during this time, the bird will continue to lay fresh eggs to try and complete the clutch. This results in a larger time frame for humans in which to collect eggs (United States 2009, 78). Alternatively, a preference could have existed for consuming the underdeveloped chick. Underdeveloped or hatched chicks could potentially also have been collected, which is possible for a longer period of time. Juvenile birds are often easier to collect than adults since they cannot yet fly. In the West Frisian bird bone assemblage, one example of a juvenile bird was found in Medemblik, indicating that this practice probably did occur.

In summary, at the eastern sites of West Frisia, almost all species found either have tasteful meat, or eggs, or both. As mentioned above, in Schagen, several species of gull were expected but missing from the bird assemblage. The eggs of some of the possibly present gulls in western West Frisia, *e.g.* lesser black-backed gull (*Larus fiscus*), kittiwake (*Rissa* spec.), and common tern (*Sterna hirundo*) are all very tasty. The eggs of the lesser black-backed gull even had one of the highest scores of the 212 species of bird eggs tested (Cott 1954, 452-3). This example indicates that the presence or absence of bird species at a settlement does not (necessarily) reflect the total range of bird species exploited (for their eggs); the number of species of which only the eggs were collected will not have entered the archaeological record of settlement sites. Regardless of whether all species which have been exploited were also found however, this study has made clear that most ground-nesting birds have both tasteful meat and/or eggs, and could have been targeted for that reason.

Mammals
All mammals are edible, and every mammal has its own specific flavour. Bronze Age people may have had a preference for a different flavour meat than the meat of their own livestock. Such a selection might have been based specifically on the flavour of the animal regardless of size. Alternatively, elk, wild boar, roe deer, red deer, beaver, and hare could have been selected based on a combination of flavour and amount of meat.

Addition to the diet

Animals may also have been specifically selected for their nutritive properties. One large specimen of fish,

bird, or mammal, or many smaller specimens could have provided people directly with a considerable amount of meat or fat. Furthermore, it would be possible to preserve meat for periods of the year when food was scarce.

Where a selection based on nutritive properties would indeed have been important to Bronze Age people, it would certainly have meant that certain periods of the year were more favourable for capturing animals than other.

Fish

Fish grow throughout their lives, but some species in particular grow larger than others. Eel, pike, catfish, and sturgeon are able to grow to a substantial size and would have been available to people during spawning and migratory seasons. Other species might instead have had a more favourable meat yield than others. Bykowski & Dutkiewicz (1996) propose that cyprinids only have a meat yield of around 50% because they possess relatively many small bones in comparison to meat, but most other fish have a yield percentage of 50-60%. Salmonids can even reach a meat yield percentage of 75%, which can create a possible target for nutritive properties in its own right. Moreover, in general, saltwater and migratory fish are usually more nutritious than freshwater fish, which may have been another possible selection criterium.

In western West Frisia, mostly saltwater and anadromous fish were found. Most species belonged to the flatfish family (Table 4.7), which could be preserved for longer periods of time, providing nutrients for periods in which food is scarce. At the eastern sites, members of the cyprinid family were most abundant (Table 4.8), differing in size from very large to average. Both single large individuals and/or many small individuals together could thus have provided high amounts of nutrients to people throughout West Frisia.

Birds

The selection of birds based on nutritive properties may have been focused on large birds, such as swans. However, many smaller birds have been uncovered in West Frisia as well, which together may also have provided a potentially high meat yield. Furthermore, the nutritive properties of a bird depend on the time of year in which a bird is caught. Obviously, when a bird has used a lot of energy, it will have suffered weight loss, which mainly occurs during moulting and during/after migration. Birds are expected to be most nutritious just before migration, or at the start of breeding and moulting seasons. These periods are therefore interesting to hunt for birds to enrich the diet. In addition, when bird meat was required to sustain people during times of scarcity, the nutritive properties may not have needed to be optimal for a bird to be hunted for consumption. Indeed, birds found in West Frisia, including whooper swan, widgeon, brent goose, and barnacle goose (Table 4.5), are only present from late autumn to early spring, which may indicate the selection of birds to complement the winter diet.

Mammals

Meat of wild mammals generally possesses a lower nutritive content in comparison to domesticated animals (Mann 2000, 74). Hunting mammals will therefore not necessarily have increased the nutrients in the diet of people in comparison with domestic meat. Smaller mammals such as mice or voles could not have added much to the diet on their own, but could have been caught in larger numbers to aid subsistence. Large wild animals, such as elk and especially brown bear, may have possessed more meat than for example domestic Bronze Age cattle, which in this manner may have compensated for the lower nutritive content of their meat.

Similar to birds, mammals differ in their meat yield throughout the year; during winter, their fat reserves become depleted, decreasing their nutritive value even further. Still, the availability of wild animal meat during winter, no matter the nutritive levels, may have aided the winter diet of people during the unavailability of domestic meat (Chapter 8, section 8.3.1). The indication for *e.g.* winter hunting of elk found in Medemblik (section 4.4.3) could be evidence for such a selection.

Availability and abundance

Selection based on taste and nutritional value of animals were not the only possible considerations of people for hunting. Certain species are not (always)

present in the surroundings of the settlement, so availability is an important factor related to the selection of animals. Furthermore, periods of abundance of certain species may have formed specific targets for hunting: when certain species are abundant, this fact may outweigh or even nullify the selection on individual flavour and nutrient properties of a species.

Fish
Possible selections based on both availability and abundance of fish species in West Frisia were observed. Shads, herring/sprat, mullet, and eel all live in schools, which means that they are naturally in abundance. Migratory fish, such as salmon, eel, whitefishes, and mullets might have been caught because of both their seasonal availability and abundance. Other fish, which are not migratory but are abundant, are flatfish, which may also have been selected for this reason.

Birds
Bird species could also have been selected by West Frisian people based on their abundance and availability. Many of the bird species found in West Frisia are available all year, but many migratory birds are only available in spring and autumn. Furthermore, migratory periods also host many bird species which are highly abundant at the same time. This period of the year is therefore a potential target for hunting selections based on both availability and abundance. During moulting season, aquatic birds also become more widely available; due to the decreased mobility of these birds when moulting, the accessibility to these birds increases for a hunter.

Mammals
Mammals are available throughout the year, since migration distance is restricted. Their relative abundance however, can differ depending on the season. During winter, roe deer and elk form groups, which results in a condensed availability of these species. The resulting relatively higher abundance of mammal species in certain areas may therefore have been a specific reason for selection.

4.4.5.4 Other reasons for hunting

Reasons for hunting can also be different than for human consumption purposes. Although it is assumed that animals were consumed after being hunted, their meat may not have been the initial reason for hunting: wild animals have more possible uses.

Fish
Fish may have been caught as food for the consumption by domestic animals or as bait for the capture of other wild animals. Another use may have been for the creation of fish bone tools or ornaments. Tougher elements of the fish skeleton, such as the spikes of a perch, could potentially have been used as needles, or punching tools. The possession of special skeletal elements, such as the dorsal fin of the grey gurnard found in Enkhuizen, may have for example functioned as a form of skill portrayal, since this fish is so hard to catch (section 4.4.1).

Birds
Bird bones and feathers can have multiple uses. Bird bones can be used to make awls or needles (Gál 2005, 56). Furthermore they can be made into flutes or whistles, which, perhaps ironically, can be used to attract other birds when fowling (Mannermaa 2003, 21). The possession of a specific bird bone might also have had ornamental reasons, or even a religious or ritual meaning if certain birds were considered to have a special status.

In West Frisia, certain pottery decorations were created by pressing hollow bird bones into the clay (Bakker & Brandt 1966: Fig. 17; Figure 4.13).

Feathers could be also have been an important reason for hunting birds. The preference for a specific colour of feathers for use as decoration or as ornaments can furthermore be one of the reasons to capture birds in a certain season, for example when males display their bright breeding plumage during courtship (section 4.3.1), such as ruff (found in Enkhuizen). Bird species such as cranes and swans have conspicuous feathers all year-round.
Another, perhaps more practical reason to collect feathers from a bird, would be for insulation. Down can be used for bedding, lining of (winter) clothes, shoes, etc. Especially aquatic birds and birds living in cold environments produce more down in autumn to prevent heat loss in winter (Ginn and Melville 1983; Bird body temperatures 2016). The capture of

Figure 4.13. West Frisian pottery with decoration made with bird bones (from: Bakker & Brandt 1966: Fig. 17).

barnacle goose and brent goose in Schagen, which are only present from late autumn to early spring, may indeed have been carried out to obtain their thick layer of down.

Ritual, religious, or symbolic uses for bird bones and feathers might also have existed, although clear evidence for this is rare and hard to interpret. However, in some prehistoric burial rituals, bird bones or bird bone artefacts have been found. At the Neolithic site Vaateranta in Finland for example, wild bird remains are only found in graves (Mannermaa 2003, 20-1). Symbolic properties of bird wings have also been assigned to a Late Neolithic burial site in Tamula, Estonia, where parts of crane wings have been found in the hands of a deceased child (Mannermaa 2003, 23). Although the region and time period are different from West Frisia, these examples show the potential importance of birds in the lives of people.

A final other reason for hunting which does not include a use of the animal, is killing birds because they are considered pests. Examples of pests are carrion crow and rook, which are both species that are known to eat meat from dead animals. When hunted fish or meat is hanging in a settlement, for example when drying, it may form a source of food for these birds as well. Other birds may have been killed for feeding on grain and seed(ling) s, potentially endangering the harvest yields, or preying on young domestic animals (*e.g.* eagle owl). Killing these birds will mainly have occurred to protect food sources at and around the settlement rather than that they themselves were a source of food themselves.

Mammals

Wild mammals could have been hunted for several reasons, but the main reasons discussed here are for obtaining wild animal parts and exercising pest control. Hunting for portrayal of skill or status are also possible reasons for hunting mammals, but these are not further elaborated upon here.

Wild animals can have certain physical attributes that domesticated animals do not, or no longer possess, such as large(r) long bones, antlers, and hides/pelts. People may have hunted these wild animals because they could not produce these sources of raw material themselves. Depending on the desired animal part, hunters will have needed to employ different hunting techniques. Antlers and bone can be made into tools, and these raw materials can be obtained by capturing the animal regardless of technique. Hides and pelts however, are presumably used for clothing and should not be damaged by for example being pierced by hunting gear. Therefore, if wild animals were caught for their pelt or hide, they are most likely to have been caught using traps or snares, which do not damage the skin (section 4.3.2).

In fact, all the large mammals found in West Frisia, besides being ultimately used for consumption, may have initially been caught for their fur. Species such as beaver, otter, hare, polecat, fox, and wild cat possess well-insulating fur coats. Indications for skinning of fur animals can include specific markings on skulls and pelvic bones of mammals (Trolle-Lassen 1986;

Trolle-Lassen 1987). In the Medemblik assemblage, cut marks on the skull and mandible of a fox indeed indicate skinning and use of the entire pelt (Groot 2010a, 86), and in the assemblage of Schagen, fine cutmarks on the phalanges of otter also indicate skinning of the animal (Zeiler *et al.* 2007, 9). Schagen and Medemblik are situated approximately 20 km apart, and range in habitation time from the Early to Late Bronze Age. Therefore, these examples provide few but clear indications that wild animals were exploited for their pelts throughout the Bronze Age, and throughout West Frisia. It follows then that if people were specifically hunting animals for their fur, they may also have selected a particular type of fur. In winter, most mammals possess a winter coat which consists of thicker fur, which might be preferred by people for winter clothing.

Other wild mammals, such as roe deer, red deer, and elk possess a hide that can also function as a source of clothing material. Indeed, a Bronze Age bog body from the province of Drenthe, the Netherlands was wearing deerskin shoes, indicating the persistent use of wild animal skins during this time (Sanden 1990). Deer can also provide antlers, which have specific properties for the creation of tools, which are not present in other types of raw material. Antlers may be collected after being shed, therefore finding them does not necessarily indicate hunting. However, the presence of a skull of elk with attached antlers, which were removed after death (Groot 2010a, 94) indicates that hunting for this source of raw material may still have played a role in subsistence for creating specific tools. Indeed, several tools made from wild animal bone and antler have been identified in West Frisia. These include a possible hammer made from red deer antler (found in Enkhuizen: Roessingh & Lohof 2011, 214), a possible hoe tool and an axe socket also made from red deer antler (found in Bovenkarspel: IJzereef 1981, 141), and an awl made from elk bone (found in Medemblik: Schurmans 2010, 96-7).

Another reason why wild animals might have been hunted by the people of West Frisia might be because they were posing a threat to the safety or well-being of the farming community. Animals can be dangerous when people or livestock are attacked, or be a nuisance or pest when they are consuming food stores in houses or crops and domestic animals in fields. Many of the animals found in West Frisia can be considered pests in one way or another. Small mammals which could have been pests include wood mouse (*Apodemus sylvaticus*), harvest mouse (*Micromys minutus*), common vole (*Microtus arvalis*), and house mouse (*Mus musculus*), since they may have eaten seeds and grains from storage locations. Therefore, these animals might have been selectively killed by humans for this reason. Roe deer, red deer, wild boar, elk, and hare form a threat to modern-day harvests by feeding on cultivated crops (Twisk *et al.* 2010, 336-7), and could have done so in the past as well. Brown bear, wild cat, polecat, fox, otter, and weasel, being carnivores, might have been attracted to (smoke-)drying fish or meat, if indeed this preservation method was practised in West Frisia. Brown bear and wild boar might in addition have posed a threat to humans if threatened when with young (Twisk *et al.* 2010, 337). Livestock and their young finally, may also have been threatened by brown bear, fox, and wild cat (Twisk *et al.* 2010, 279). So, pest control could also have been an important (additional) reason to kill wild animals.

Overall, there are clear indications from all over West Frisia, throughout the Bronze Age, that hunting for raw material or pest control may have formed a very important additional part of subsistence. In concurrence with Kent (1989, 45), hunting formed a complementary subsistence strategy to animal husbandry, providing people with meat and raw materials not (always) available from domestic animals. Killing wild animals could provide people with tools, clothing, and safety, besides having a final use as a source of food. The reflection of such practices will have resulted in a lower visibility in the archaeozoological record than when wild animals still formed the main food resource: hunting for raw material is necessary on a much less regular basis than for daily year-round consumption purposes. Within a Bronze Age farming community, where domestic animals will have formed the major source of consumable animal products, the presence of such regular consumption waste (*i.e.* domestic animal bones) will have greatly overshadowed the presence

of waste from, raw material processing, pest control, or seasonal consumption (*i.e.* wild animal bones). Furthermore, the selection of only a few individuals from a wild animal population, versus the presence of every domestic animal present within a breeding herd population increasingly exacerbates the ratios between wild and domestic animal bone reflections at a settlement.

The above examples are the results of the new manner in which data is approached in this chapter. They have clearly indicated that the presence of low numbers of remains of certain wild animal groups within a settlement should not be directly interpreted as being of minor importance to subsistence without first considering the methodological, taphonomical, and selection processes which may have resulted in the final observed wild animal bone assemblage.

4.5 RECONSTRUCTION OF HUNTING

The current view on hunting, with its inherent main components, was challenged in this chapter by applying several disciplines to the analysis of the subject. The summary provided below (4.5.1) shows the contribution of each of these proxies as well as the applied approach in this chapter. Results obtained from this new manner of analysis are compared to the main components of the current model as well as the new main component presented in section 4.3.5. It is subsequently evaluated whether these current components remain valid (section 4.5.2), and the new main components are combined to form a new model for hunting in Bronze Age West Frisia (section 4.5.3).

4.5.1 Contributions of proxies and approach to the reconstruction of hunting

The use of ethnographical studies for the creation of an expectation of hunting has provided a means to identify its general and persisting importance within modern-day small-scale mixed subsistence farming communities. Furthermore it provided examples of specific methods related to hunting.

Ecological information of animal species has allowed for an analysis of the ratios of possible hunting locations based on animal habitat preferences (cf. Chapter 2), as well as the seasonality of hunting based on animal migration studies. By applying ecology to the West Frisian data, more information on location and locality of practice related to hunting was obtained, also in relation to the settlement (cf. Chapter 3).

Biology has mainly provided information on the behaviour of animals. This behavioural information, including food preference, reproduction, and migration, has enabled the reconstruction of human practice including the use of possible appropriate types of bait, seasonality, availability, and abundance. Furthermore it gave indirect indications for the use of different hunting strategies and equipment. Biological and ecological information combined are both vital to understanding the complexity of skill and knowledge required to capture animals.

Archaeology finally, has provided direct and indirect indications for hunting as a practice in the Bronze Age. Direct indications for capture include the actual finds of hunting gear, whereas indirect indications for capture and seasonality could be obtained from the specific presence and marks on bone material.

The approach in this chapter was to view hunting from different perspectives by using multiple proxies. Combining and integrating these sources of information has enabled the analysis of West Frisian data to produce more detailed results as well as create an understanding of why certain activities or tools may rarely become visible in the archaeological record. Through this approach it has become clear that the absence of evidence for tools and activity should not directly be linked to their relative importance to subsistence. Rather, through the evaluation of other processes affecting the assemblage, the importance of hunting in a farming community could be postulated as an additional but integral part of life in the Bronze Age.

4.5.2 Assessing previous main components

From the previous section, it is clear that the approach of this chapter has yielded new results with regard to the role and praxis of hunting in Bronze Age West Frisia. In this section the validity of the

main components of the current model are evaluated by comparing them to the new results.

Main component 1 was formulated as follows:

(1) Bronze Age people are self-sufficient full-time farmers with no apparent need for wild resource exploitation.

Based on all available proxies, the presence of wild animal resource exploitation in the Bronze Age in West Frisia was established. Clearly, people continued to hunt wild animals to aid them in their subsistence, either for obtaining an additional source of food, raw material or protection of the settlement. Since the new results do not match main component 1, a new main component 1 is formulated:

(N1) Bronze Age people were farmers producing crops and livestock, but continued to exploit the surroundings of the settlement for wild animals to aid them in their subsistence.

Main component 2 was formulated as follows:

(2) Frequency of wild animal remains can be linked directly to relative (economic) importance of hunting in aiding subsistence in Bronze Age farming communities.

A careful analysis of the potential effects of excavation methodology, pre- and post-depositional taphonomical processes, and past human selections, has revealed that the frequency of wild animal bones should not be directly linked to relative (economic) importance of hunting for subsistence, since a shift in use of wild animals may have occurred during the Bronze Age. It is postulated in this chapter that animals may no longer have been hunted for daily consumption purposes, since livestock is available for this purpose. Reasons for hunting in this period may include procuring raw material not available from own production, obtaining additional food sources, or eliminating pests that threaten people, crops, and livestock. A subsequent reflection of wild animals in the archaeozoological record will thus have also been different. Again, the current main component and the new results are not compatible and main component 2 is therefore newly formulated:

(N2) Frequency of wild animal remains cannot be linked directly to relative (economic) importance in aiding subsistence in Bronze Age farming communities without careful consideration of the effects of methodology, taphonomy and past selection processes on the final bone assemblage.

Main component 3 was formulated as follows:

(3) Hunting of mammals and birds was not practised in the Middle and Late Bronze Age, but fishing remained of some importance.

Based on all available proxies combined with the analysis of the potential effects of methodology, taphonomy, and past human selections, it is clear that hunting of all animal groups (including fish, birds and mammals) was still occurring in the Bronze Age. Their relative importance to subsistence should not be identified purely based on numbers of remains (see new main component N2), but rather on the potential individual contribution of each animal group, also for reasons other than for consumption. The results suggest that also main component 3 should be reformulated:

(N3) Hunting of fish, birds, and mammals was practiced in both the Middle and Late Bronze Age in West Frisia; their individual importance should not be measured by amounts of remains but by their potential individual contribution to subsistence, encompassing only consumption purposes.

Main component 4 was formulated as follows:

(4) Large game was only hunted on a very opportunistic basis, without specialisation or concentration on a particular species or the surrounding available richness in the area.

Based on analyses with the aid of ecology, biology, and ethnography, it has become clear that West Frisian people were able to acquire a wide range of animal species of each animal group. Each animal

group in turn contains species from varying habitats, which all display varying behaviour. Extensive knowledge about these different types of animals and their behaviour, as well as the skill involved in order to catch them in different habitats must have been present amongst Bronze Age people, signifying a strong connection with the available richness in the surroundings of the settlement. At first glance hunting may appear opportunistic, because no single species was preferred, but when the other uses of animals are analysed, a single use may tie different species together. Hunting to acquire antlers may include targeting several species of deer, whereas the procurement of skins, pelts or hides may include many different targeted mammal species as well. Furthermore, hunting animals for food during times of scarcity (*e.g.* winter) may also be based on a single goal (meat) without a clear preference for the obtained animals species. The above results show that main component 4 should also be reformulated:

(N4) Large game was hunted for specific uses such as raw material or meat during periods of the year when domestic meat was scarce; specialisation occurred not based on a species, but rather on a use, and the surrounding available richness in the area was exploited accordingly.

Main component 5 was formulated as follows:

(5) Hunting did not aid Bronze Age subsistence in terms of consumption, but may have been practiced for other reasons which were equally important.

Based on the comparison of the West Frisian data and subsistence situation to the ethnographical examples, it was concluded that hunting in the Bronze Age could have aided subsistence both for reasons of consumption as well as other reasons. Hunting animals during times of scarcity or preserving animal meat for such times may have been important additions to the Bronze Age diet during the winter, when available food sources were scarcer. Furthermore, additional uses of animals such as for raw material for the construction of tools and clothing may have aided subsistence in a comparably important manner. In fact, since in the Bronze Age, tools and clothing could only be constructed from limited types of material, the need for hunting for these types of raw materials may have been more pronounced in Bronze Age subsistence in comparison to modern-day parallels where presumably only hunting for food is considered. Therefore, main component number 5 should therefore be reformulated as follows:

(N5) Hunting aided Bronze Age subsistence both in terms of consumption and as a source of raw material, increasing its relatively importance to subsistence in comparison to when only dietary contribution is considered.

Since none of the main components of the current model were able to describe the role and praxis of hunting in West Frisia in concurrence with the new results, the new main components are combined and integrated to form a new model.

4.5.3 New model for hunting

The role of hunting in the Bronze Age in West Frisia is postulated to have been different from preceding periods. Where wild animals previously would have formed a large part of the daily diet, farming communities would have produced their own meat by practicing animal husbandry. In order to aid Bronze Age subsistence, hunting must have added something to subsistence which farming life alone could not provide. Additions to subsistence in the Bronze Age made by hunting may have included different types of food that were unavailable at the settlement, such as fish and eggs, or ensuring the availability of consumable animal products in general during times of food scarcity. The latter example could be achieved by hunting animals during these times of scarcity, or by hunting during preceding periods of wild animal abundance with the aim of preserving fish and meat for the long term. Periods of availability and abundance included (depending on the animal group) reproduction, moulting, and migration periods. Other reasons for hunting animals during the Bronze Age may have included acquiring raw material not available at the settlement, such as feathers, antlers, or furs. A final reason for hunting postulated in this research is that some animals may have been hunted because they posed a threat to the people, crops, and livestock on the settlement.

Although the zoological remains from West Frisia contained relatively few bones of wild animals, the broad range of wild animal species found reflects the intricate knowledge of a wide variety of animals that still existed throughout the Bronze Age.

The organisation of hunting would have required careful preparation and planning, especially because it was practiced next to farming with its inherent multitude of related activities. First of all, since hunting mostly requires more than one person, it would have needed a combined effort from several inhabitants of a settlement. Hunting needed to be combined with farming, meaning that only certain times of the day or year would have allowed enough people to hunt. Hunting would therefore have included both active and passive hunting strategies. Since during active hunting the presence of the hunter is required throughout the entire hunting process, active hunting would have mainly occurred during quiet times within the farming calendar. Passive hunting techniques however, could have been practiced throughout the year, during both quiet, and busy periods, when it could have been practiced during quiet times of the day (*i.e.* dawn and dusk). This means that passive hunting is overall most easily combined with farming life. The required combination with farming practices would furthermore have resulted in a relatively local nature of hunting in general. Visited locations for hunting would have been varied and available in the settlement surroundings, and these habitat types would have differed between the western and eastern part of West Frisia. In the west of West Frisia, the intertidal habitat was exploited with a focus on migratory fish and birds. Other habitats, including grassland, shrub land, forests, and wetlands were also exploited, resulting in a variety of mammals being caught as well. Eastern West Frisian sites divided their attention between hunting in wetlands, grassland, shrub land, and forests to obtain a range of fish, birds, and mammals. Here, mainly the breeding and moulting seasons were exploited, with an additional focus on migration periods.

Processing of hunted animals depended on the species and its final use, but may have included skinning for obtaining fur, processing for immediate consumption, and preservation techniques for long-term storage of fish and meat.

Thus, considering both the wide range of uncovered animal species with their different behaviour and habitat preferences, and the inherent skill and knowledge required for the preparation of hunting and processing these animals, hunting as a practice must still have formed an integral part of the lives of Bronze Age people.

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,

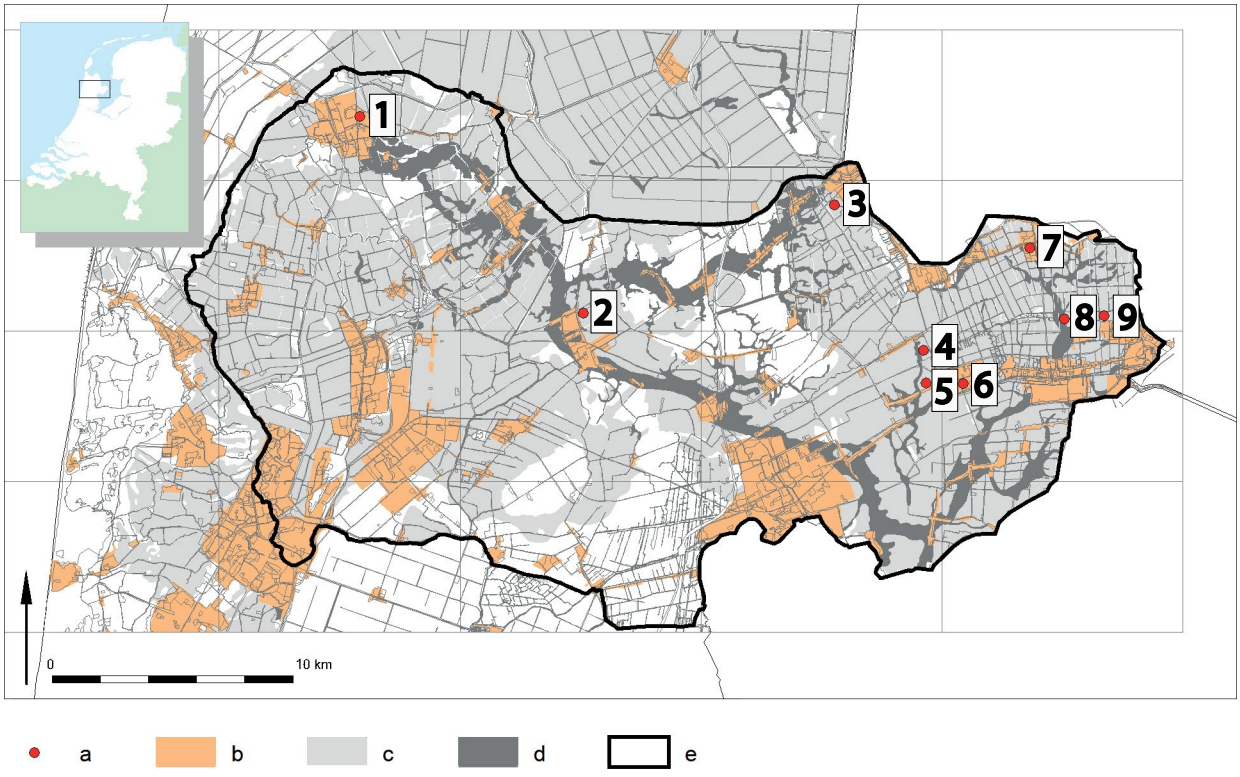


Figure 5.1. Overview of the sites of West Frisia that yielded domestic animal remains. 1: Schagen de Hoep-Noord; 2: Hoogwoud Opmeer; 3: Medemblik Schepenwijk II; 4: Zwaagdijk 1961 and Zwaagdijk Oost; 5: Westwoud; 6: Hoogkarspel Tolhuis and Hoogkarspel Watertoren; 7: Andijk Zuid and Noord; 8: Bovenkarspel 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 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.

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

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.

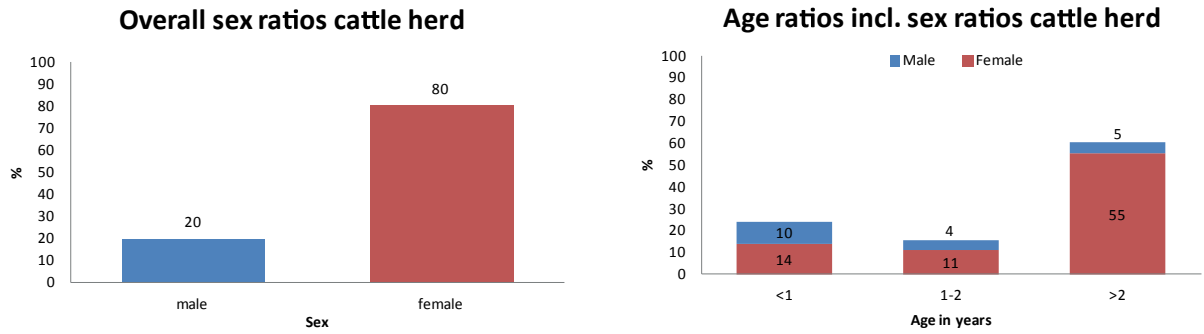


Figure 5.2. Example of the general composition of a small-scale living cattle herd in South Africa in terms of age and sex (after: Lehloenya *et al*. 2007, 220-1). This study forms one of the very few examples wherein this type of detailed quantitative information on small-scale herds in mixed farming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

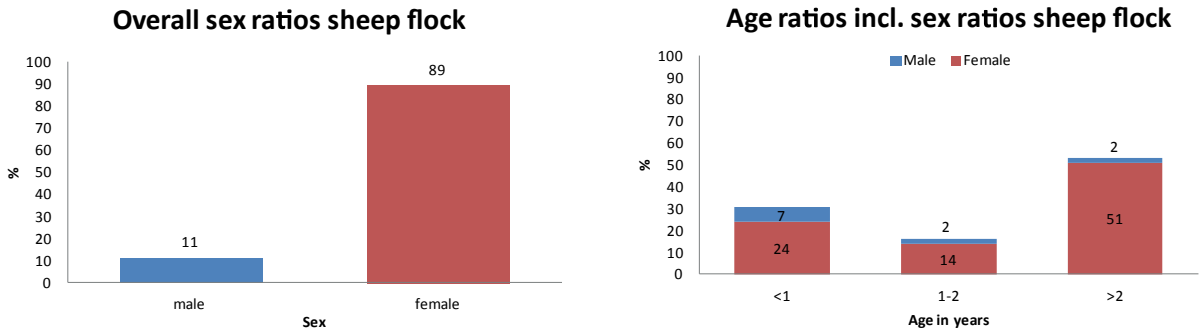


Figure 5.3. Example of the general composition of a small-scale living sheep flock in South Africa in terms of age and sex (after: Lehloenya *et al.* 2007, 220-1). This study forms one of the very few examples wherein this type of detailed quantitative information on small-scale herds in mixed farming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

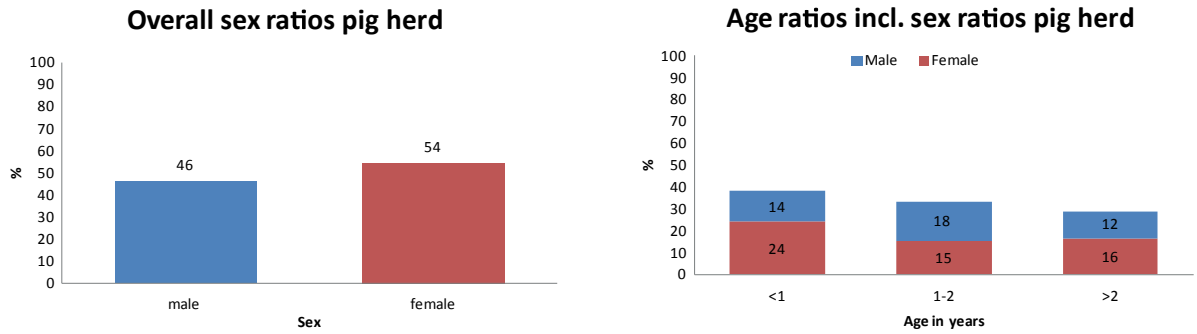


Figure 5.4. Example of the general composition of a small-scale living pig herd in terms of age and sex (after: Karimuribo *et al.* 2011, 3-4). This study forms another one of the very few examples wherein this type of detailed quantative information on small-scale herds in mixed farming communities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

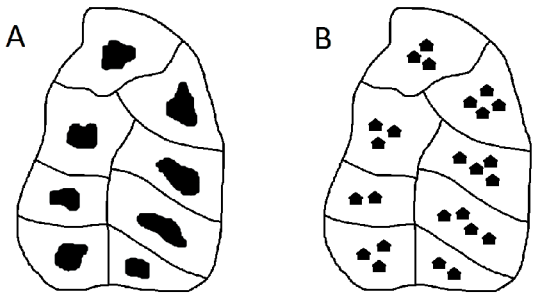


Figure 5.5. Theoretical model for the occurrence of inbreeding in a natural, and a man-made situation; a: The core population method (wild populations) (after: Lehmkuhl 1984, 174, fig 2); b: The settlement population method (domestic animal populations). Here, each core from Figure 5.5a is replaced by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

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

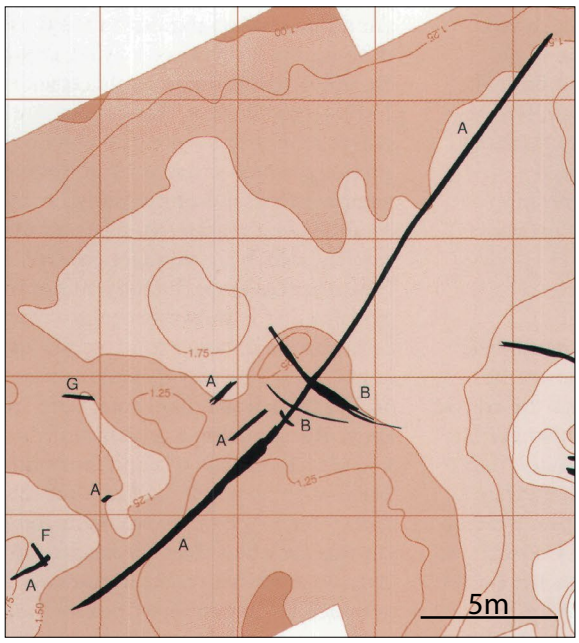


Figure 5.6. Overview of the Bronze Age track ways observed on the island of Texel, the Netherlands (from: Woltering 2006, 110). Trackway A represents a cart trackway that was possibly already in use at the end of the Middle Bronze Age and in the Late Bronze Age (Woltering 2001, 109-114).

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

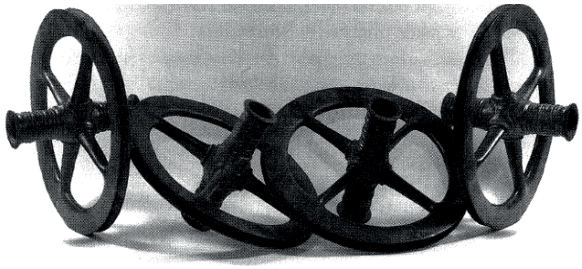


Figure 5.7. Wooden solid wheels and spoked bronze wheels dating to the Bronze Age (from: Uckelmann 2013, 404).

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

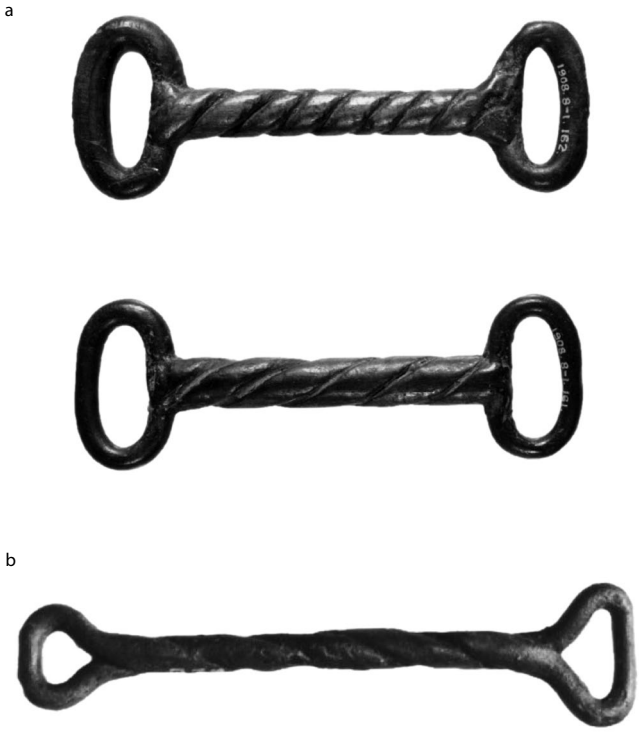


Figure 5.8. Examples of Bronze Age horse gear; a: Middle Bronze Age (1300-1050 BC) horse bridle-bit from Sigmaringen, Badem-Württemberg, Germany (British Museum 2016a); b: Late Bronze Age (1000-750 BC) horse bridle bit from Auvernier, Neuchâtel, Switzerland (British Museum 2016b).

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.

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

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.

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.

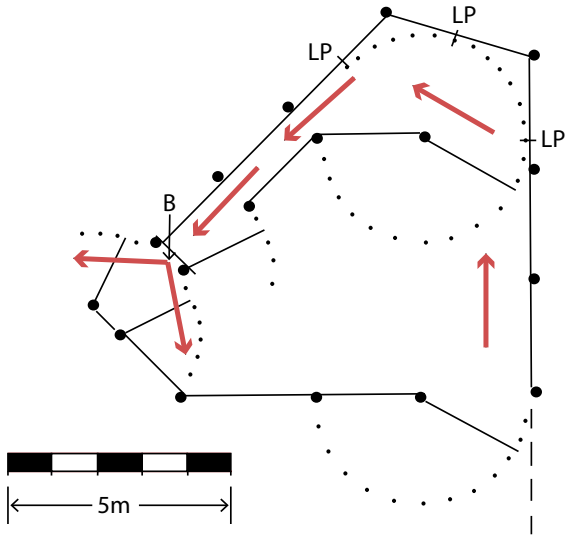


Figure 5.9. Example of a minimal handling system for small cattle herds, in this case 20 animals (adapted from: Hayes 2008, 41). B: head bail; LP: locking point; arrows indicate movement direction of cattle.

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

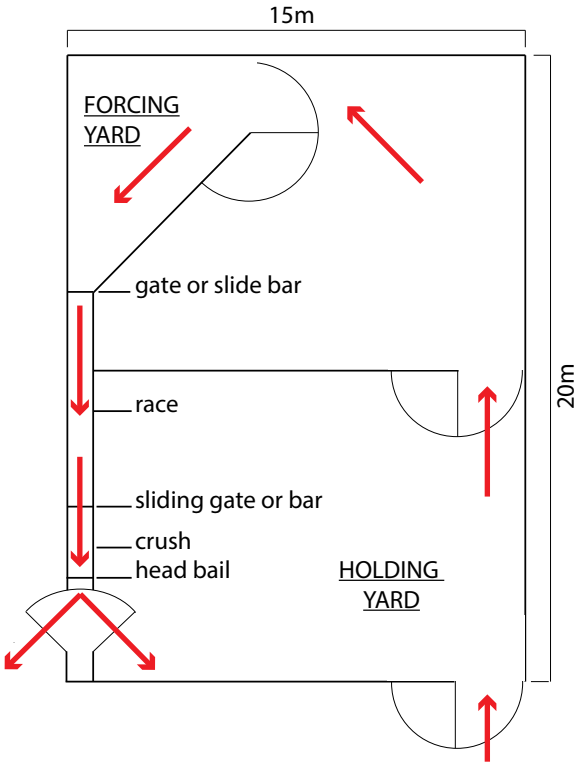


Figure 5.10. Example of a minimal handling system for small cattle herds (adapted from: Bengtsson & Whitaker 1988). Arrows indicate movement direction of cattle.

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).

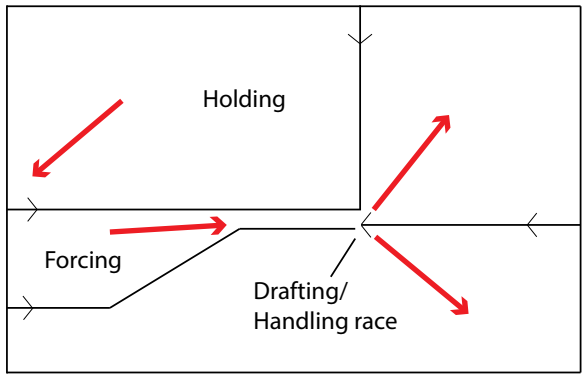


Figure 5.11. Example of a handling structure for small sheep herds (adapted from: Hinton 2006, 39, fig. 7.3). Arrows indicate movement direction of sheep.

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.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cattle: breeding												
Cattle: birthing												
Sheep: breeding												
Sheep: birthing												
Goat: breeding												
Goat: birthing												
Pig: breeding												
Pig: birthing												

	birthing occurs, but less frequent
	birthing is frequent
	breeding occurs, but less frequent
	breeding is frequent

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.

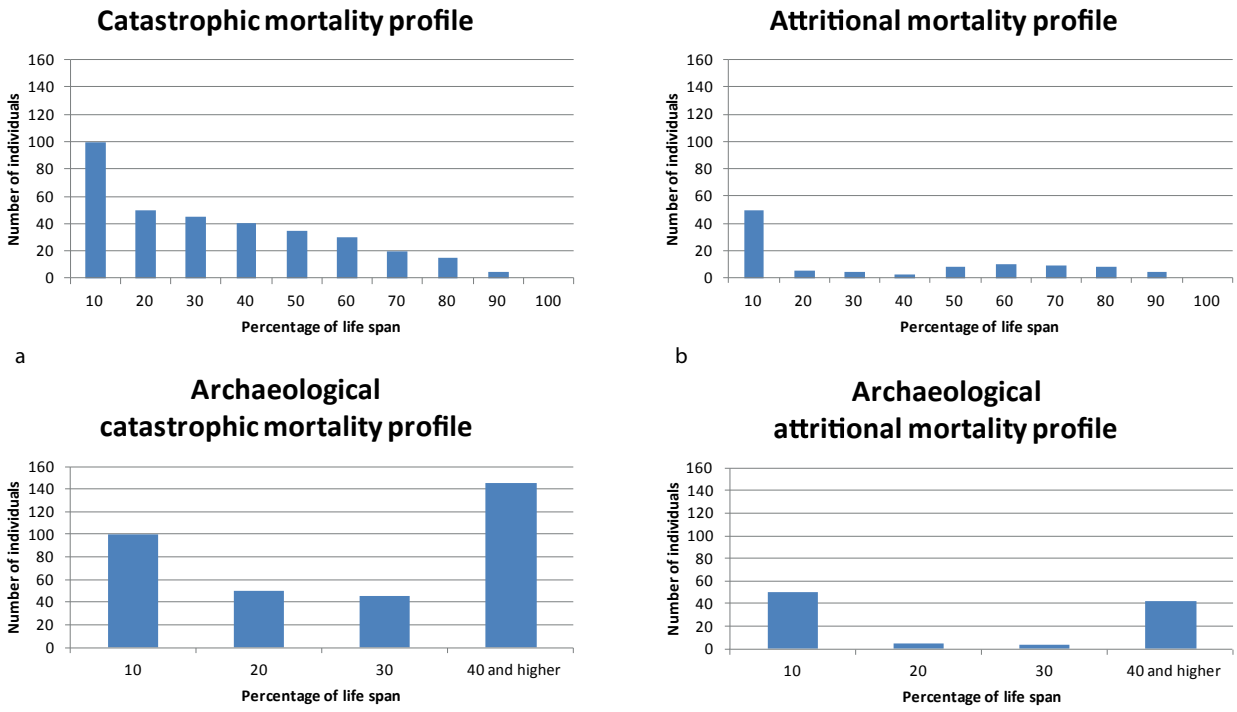


Figure 5.13. Comparison of the two different types of mortality profiles; a: catastrophic mortality profile, representative of the original living herd; b: non-catastrophic or attritional mortality profile, representative of selections of animals from a herd when meat production is not the main focus (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*),

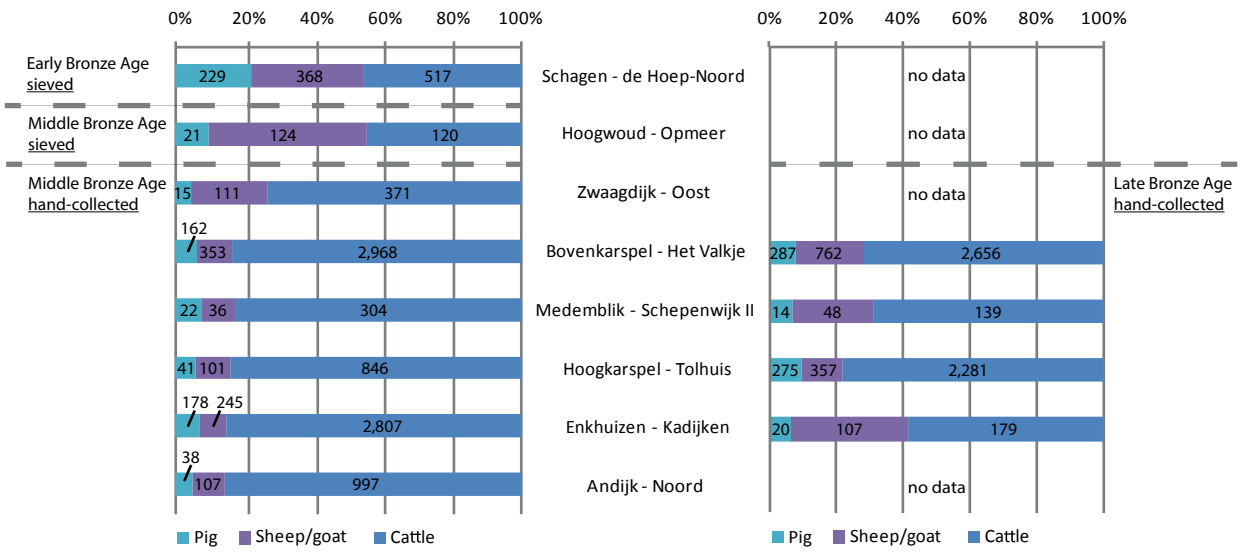


Figure 5.14. Overview of the ratios of numbers of bones from different livestock species present at each site in West Frisia, including cattle, sheep/goat, and pig. Both the Middle and Late Bronze Age material is presented. At the sites Schagen and Hoogwoud, sieving was performed systematically during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

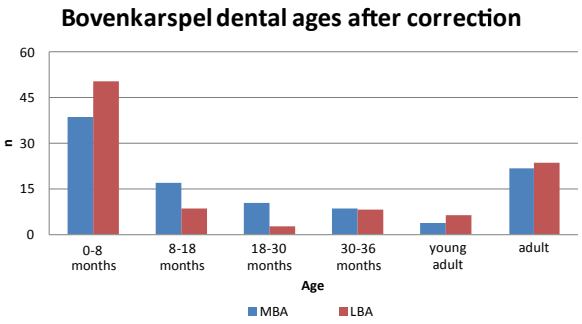


Figure 5.15. Corrected age data of Bovenkarspel cattle based on dental remains for both the Middle and Late Bronze Age. Original data before correction is for the MBA: n=212, and for the LBA: n=146.

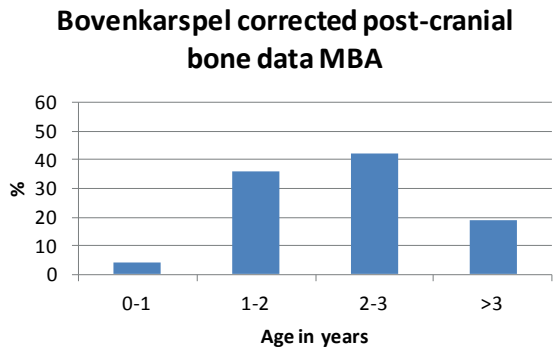


Figure 5.16. Middle Bronze Age mortality profile of cattle from Bovenkarspel based on post-cranial bones. Original data before correction is: n=619.

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

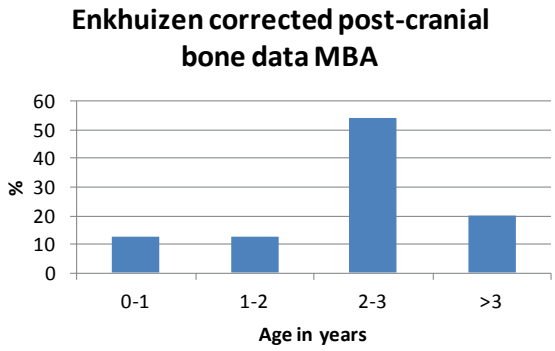


Figure 5.17. Middle Bronze Age mortality profile of cattle from Enkhuizen based on post-cranial bones. Original data before correction is: n=479.

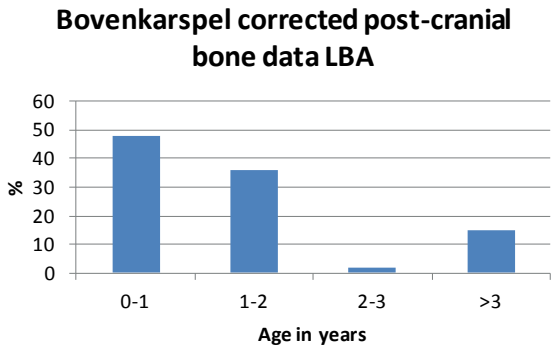


Figure 5.18. Late Bronze Age mortality profile of cattle from Bovenkarspel based on post-cranial bones. Original data before correction is: n=288.

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

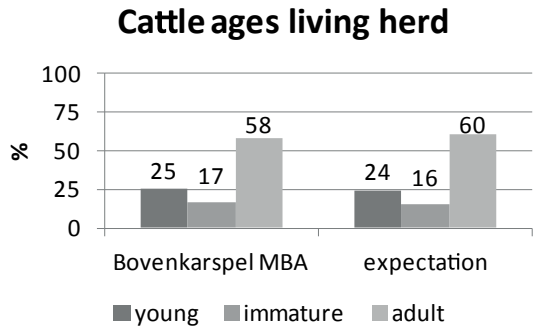


Figure 5.19. Living cattle herd composition comparison between reconstructed Middle Bronze Age data from Bovenkarspel (left) and ethnographic parallels (right). Young: 0-1 year; immature: 1-2 years; adult: > 2 years.

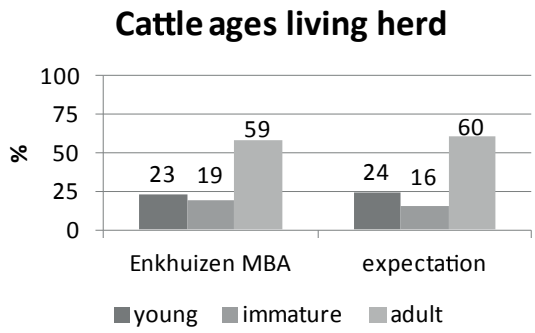


Figure 5.20. Living cattle herd composition comparison between reconstructed Middle Bronze Age data from Enkhuizen (left) and ethnographic parallels (right). Young: 0-1 year; immature: 1-2 years; adult: > 2 years.

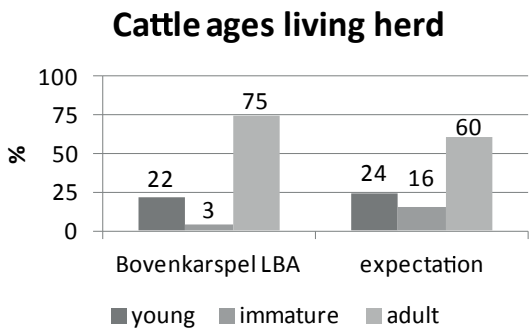


Figure 5.21. Living cattle herd composition comparison between reconstructed Late Bronze Age data from Bovenkarspel (left) and ethnographic parallels (right). Young: 0-1 year; immature: 1-2 years; adult: > 2 years.

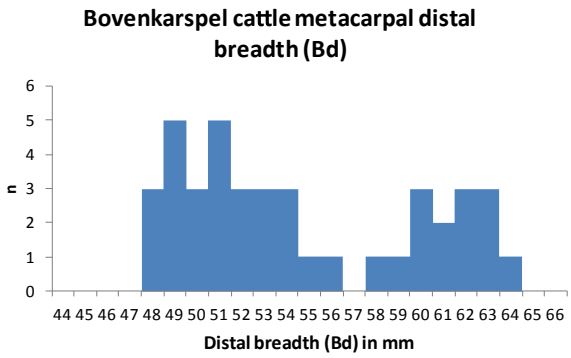


Figure 5.22. Metacarpal widths of cattle from Bovenkarspel from the entire Bronze Age. A clear difference in size groups can be observed ranging from 48-56 cm and 58-64 cm, which are interpreted as evidence for female and male cattle, respectively.

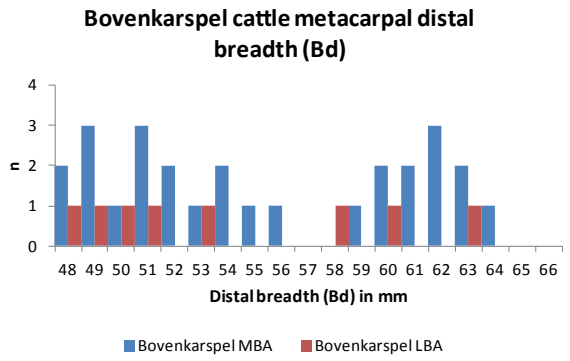


Figure 5.23. Metacarpal widths of cattle from Bovenkarspel divided into metacarpals from the Middle (blue bars) and Late Bronze Age (red bars). Divisions of widths within each time period presumably reflect the differentiation in female (small) and male (large) animals. No clear size difference of cattle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

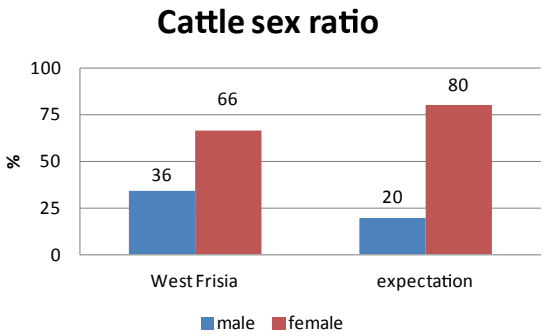


Figure 5.24. Cattle herd sex composition comparison between reconstructed West Frisian data (left) and expected values based on ethnographic parallels (right).

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

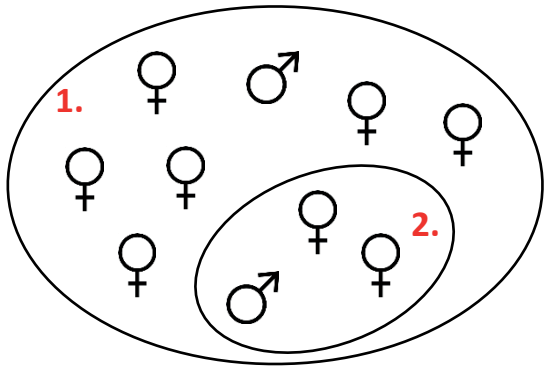


Figure 5.25. Representation of the reflection of an entire population (catastrophic mortality, number 1) versus a selection from that population (attritional mortality, number 2). The first type of mortality would approach the sex ratios observed in the living herds of ethnographic parallels, whereas 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

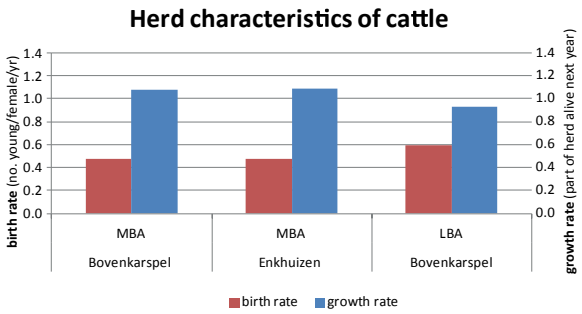


Figure 5.26. Cattle birth and growth rate data from Bovenkarspel and Enkhuizen. Birth rate indicates the number of young born per female per year and growth rate indicates the annual growth of the herd. Growth rate values higher than one indicate an increase of the herd, whereas a value lower than one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

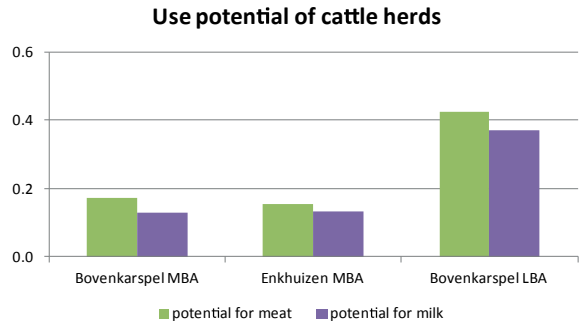


Figure 5.27. Potential of West Frisian cattle herds for meat or milk production. Use potential is a relative value to evaluate the production potential of a herd for different uses (cf. Cribb 1985). The higher the value, the higher the potential.

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

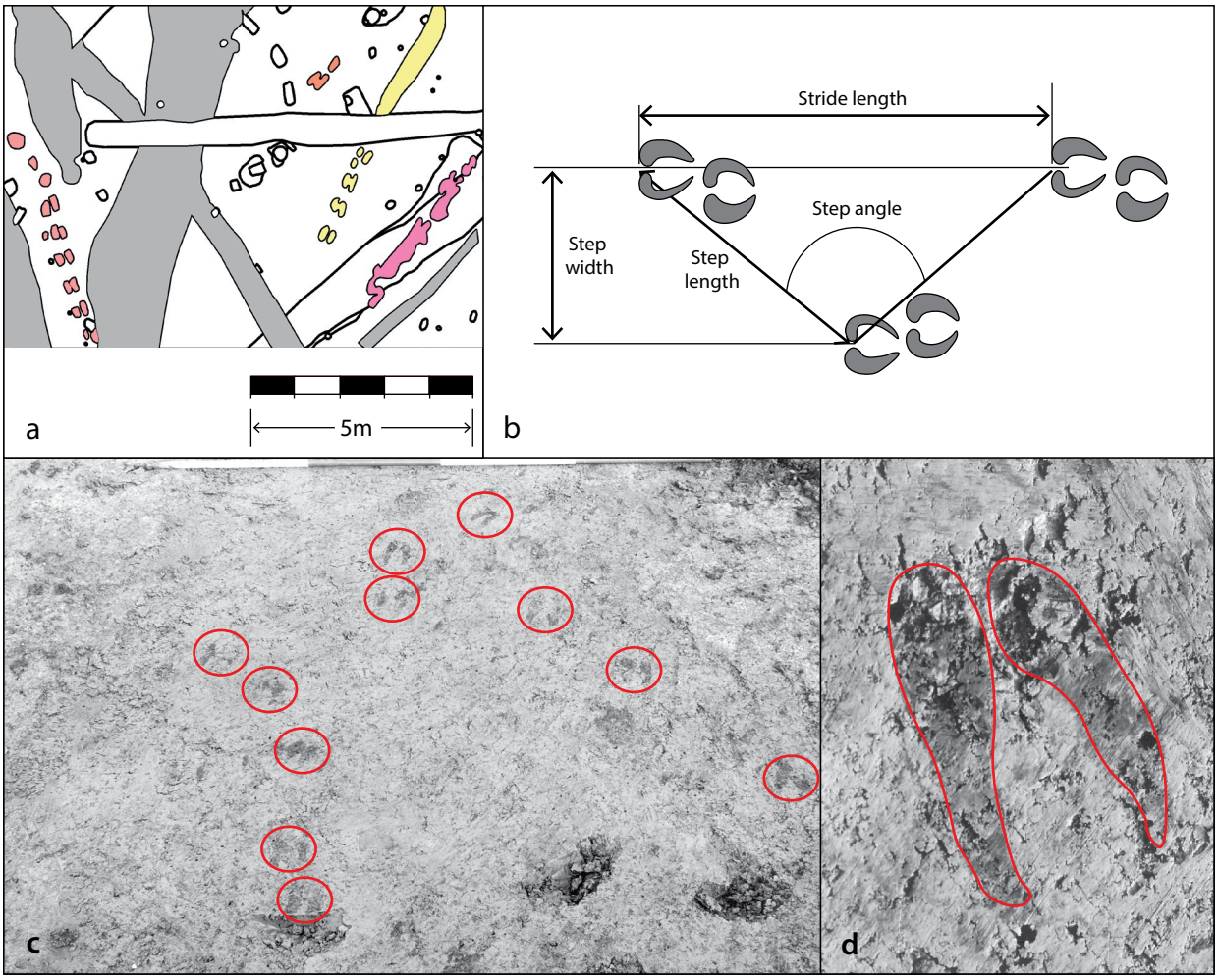
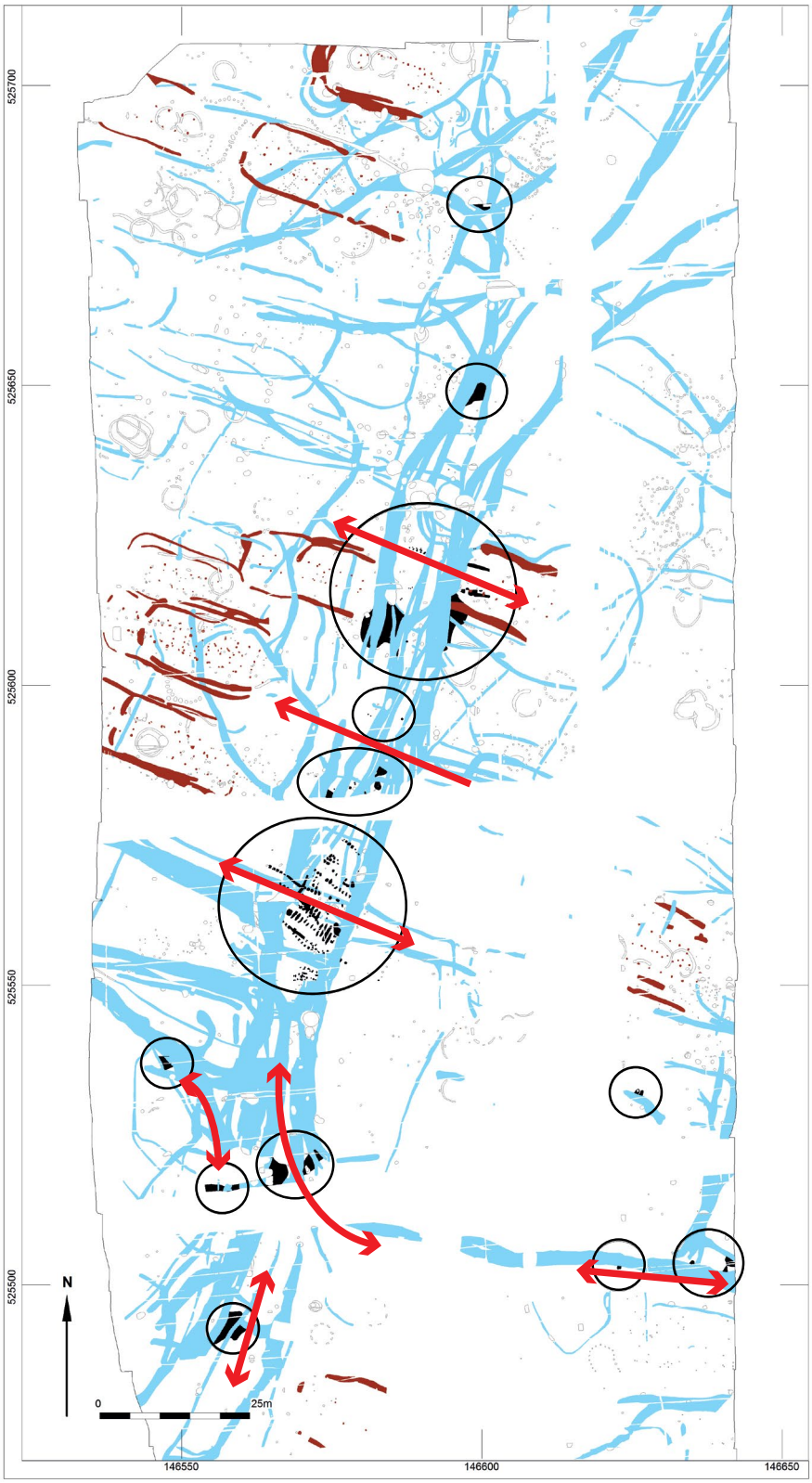


Figure 5.29. Examples of possible and actual track ways of cattle. a. Example of a postulated track way of cattle hoof prints in Medemblik Schepenwijk II; b. Zigzag pattern of an actual cattle gait (after: Telezhenko 2009); c. Overview of a track way of cattle hoof prints (red circles) preserved in the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

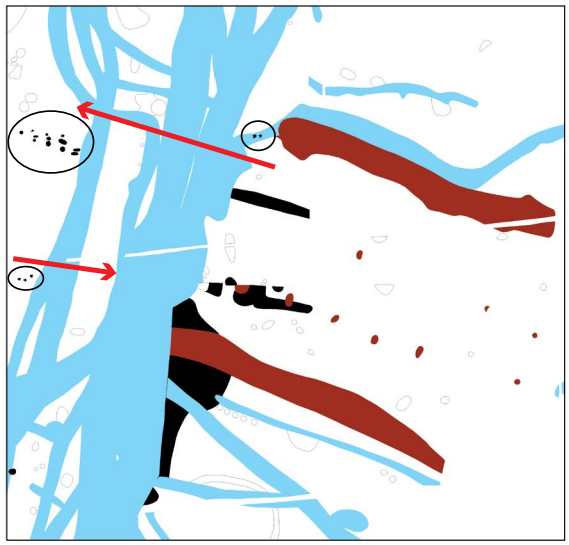
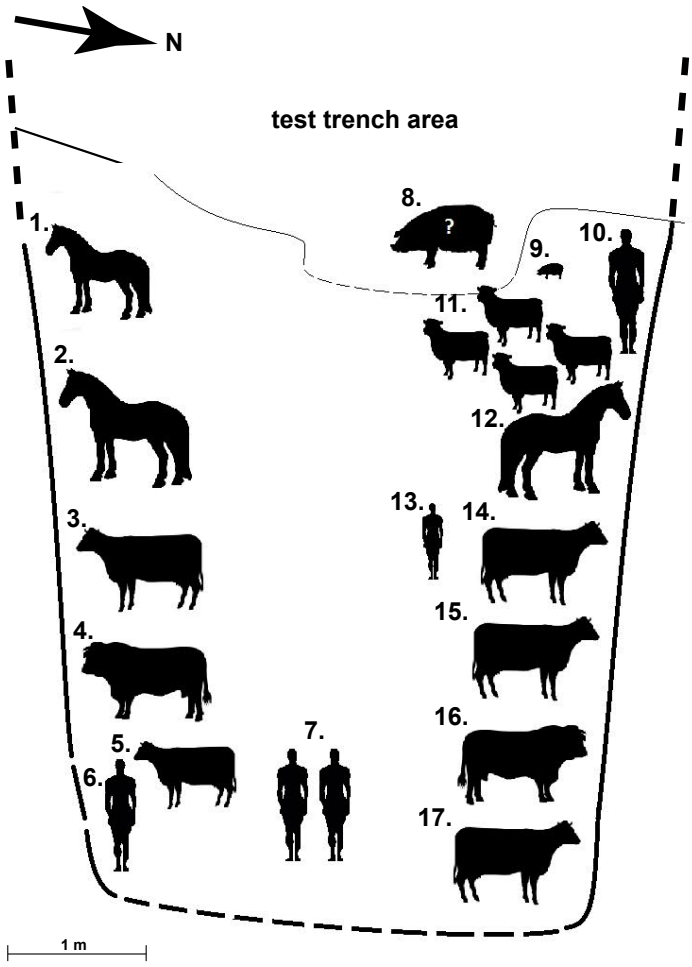


Figure 5.31. Detail of the excavated site of Enkhuizen Haling. Blue fill: ditches; dark brown fill: house context; black fill: cattle hoof prints; black circle: clear cattle prints with a direction; red arrows: general directions of movement across the settlement based on the orientation of the prints.

(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.



1. sub adult horse of unknown sex
2. senior horse of unknown sex
3. adult cattle of unknown sex
4. adult male cattle, possibly ox
5. sub adult cattle of unknown sex
6. sub adult human of unknown sex
7. two sub adult humans of unknown sex
8. adult female pig, possibly missing due to test trench
9. young pig of unknown sex
10. adult human of unknown sex
11. two adult and two subadult female sheep, pregnant
12. adult horse of unknown sex

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)

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

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.

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

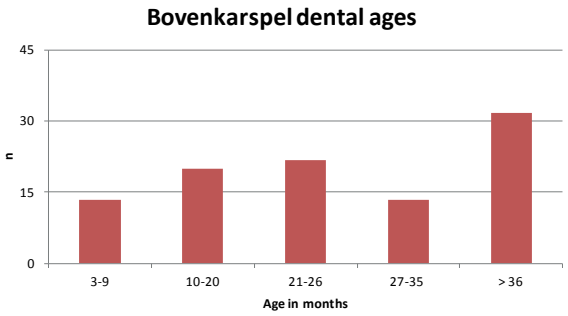


Figure 5.36. Age data of Bovenkarspel sheep/goat based on dental remains from the entire Bronze Age; n=60.

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.

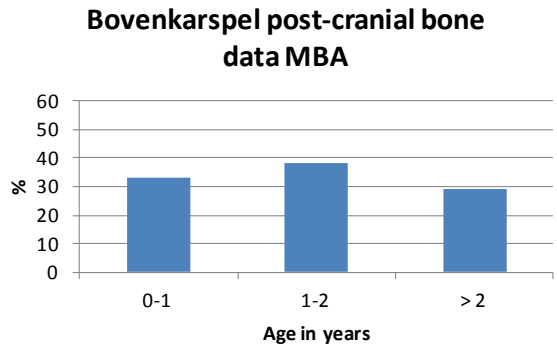


Figure 5.37. Middle Bronze Age mortality profile of sheep/goat from Bovenkarspel; n=108

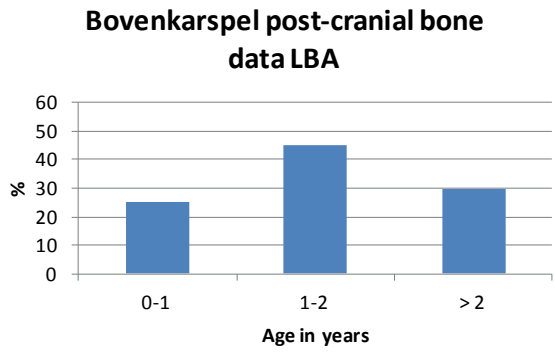


Figure 5.38. Late Bronze Age mortality profile of sheep/goat from Bovenkarspel; n=112.

(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.

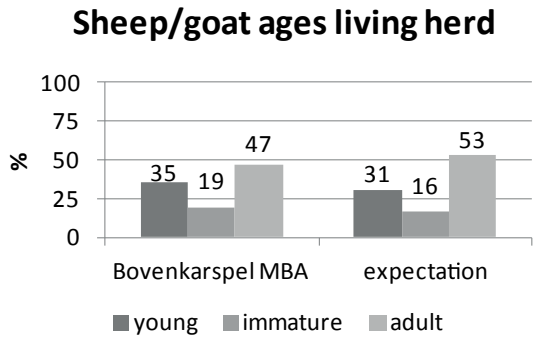


Figure 5.39. Middle Bronze Age living sheep/goat herd composition comparison between reconstructed West Frisian data (left) and ethnographic parallels (right). Young: 0-1 year; immature: 1-2 years; adult: > 2 years.

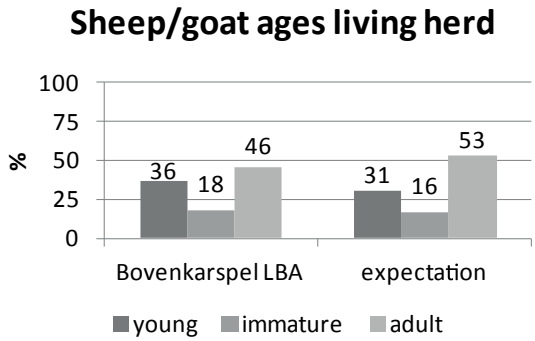


Figure 5.40. Late Bronze Age living sheep/goat herd composition comparison between reconstructed West Frisian data (left) and ethnographic parallels (right). Young: 0-1 year; immature: 1-2 years; adult: > 2 years.

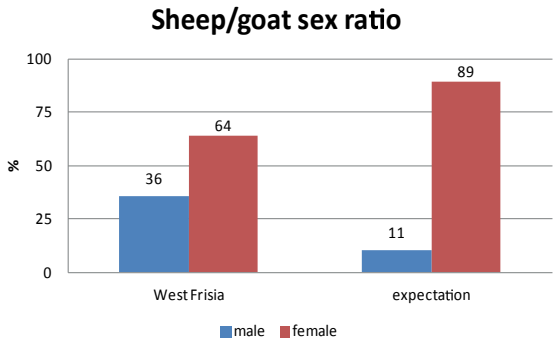


Figure 5.41. Sheep/goat herd sex composition comparison between reconstructed West Frisian data (left) and expected values based on ethnographic parallels (right).

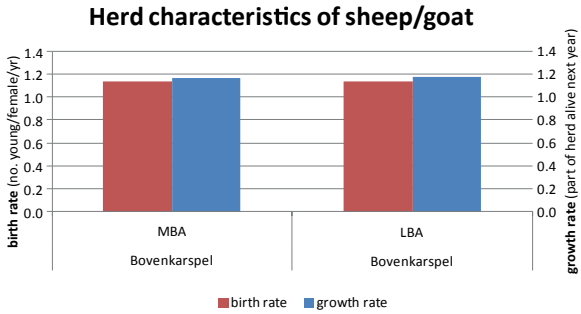


Figure 5.42. Birth and growth rate data of sheep/goat from Bovenkarspel for the Middle and Late Bronze Age. Birth rate indicates the number of young born per female per year and growth rate indicates the annual growth of the herd. Growth rate values higher than one indicate an increase of the herd, whereas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

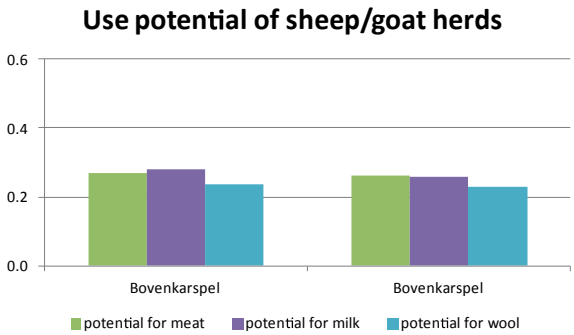


Figure 5.43. Potential of West Frisian sheep/goat flocks for meat, milk, and wool production. Use potential is a relative value to evaluate the production potential of a herd for different uses (cf. Cribb 1985). The higher the value, the higher the potential.

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).

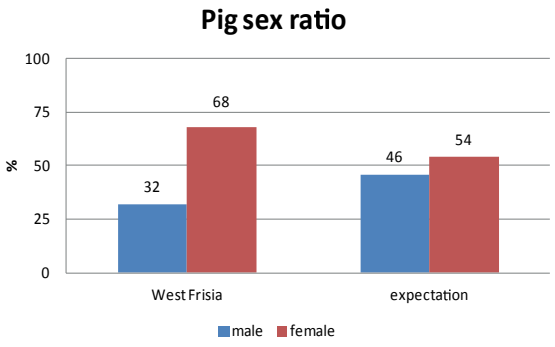


Figure 5.44. Pig herd sex composition comparison between reconstructed West Frisian data (left) and expected values based on ethnographic parallels (right).

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

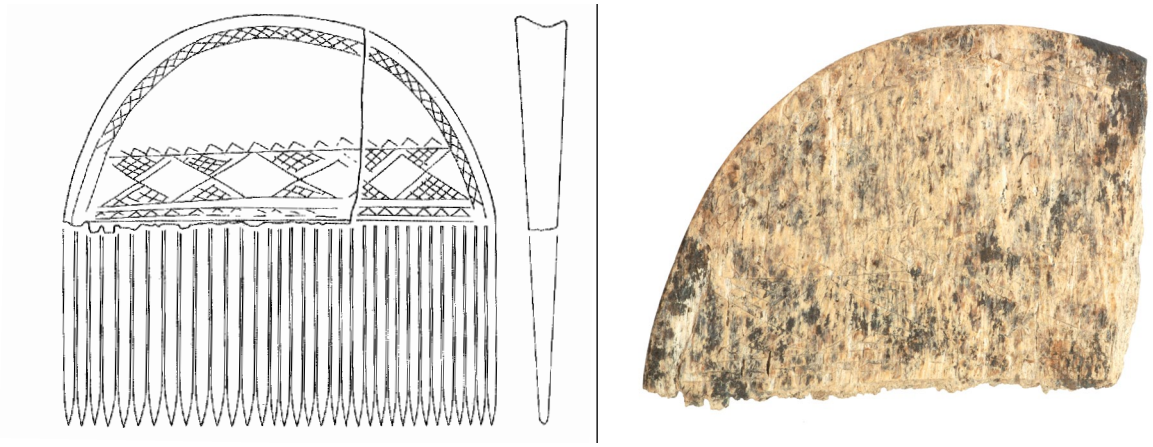


Figure 5.45. Bone comb uncovered at Bovenkarspel. a. drawing of the comb: the top left part of the comb is what is actually found, the rest is a reconstruction (from: IJzereef 1981, 139, fig. 86); b. photo of the comb (courtesy of: Archeologisch Depot Noord-Holland).

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.

6. Crop husbandry

6.1 INTRODUCTION

Crop husbandry in West Frisia is assumed to have been practiced in a small-scale mixed subsistence farming context. The role of crop husbandry in this type of subsistence as well as the practices related to it are researched in this chapter in a similar manner to the previous two chapters: by re-evaluating the old and new available data on the subject. Previous research and the current view towards crop husbandry in Bronze Age West Frisia is represented first, together with its main components. These main components are challenged in this chapter by comparing them with the results of the new analyses performed on the West Frisian data. Further explanation of how these main components are challenged is provided in the methods section (section 6.2).

6.1.1 Previous research

Crop husbandry refers to all activities which are performed regarding planting and harvesting crops, as well as the processing and storing of the harvest. Clearly, many activities are required to ensure that a crop is performing well in the field, so that farmers can obtain a good crop yield in terms of quantity and quality. West Frisian crop husbandry has previously been researched by Buurman (1996), who based her model mainly on the analysis of botanical macro remains from several excavated Bronze Age sites. The charred remains of crops and crop weeds provided valuable information on both the range of crops available in the Bronze Age, as well as the specific crop husbandry practices performed in West Frisia. For example, based on charred wild plant remains of waterside vegetation and charred concentrations of crop remains, Buurman concluded that arable fields in West Frisia were very wet, and only contained one crop species at a time (1) (Buurman 1996: 28, 190). The crops available to West Frisian farmers were mainly emmer wheat and barley, of which the hulled variety was cultivated during most of the Bronze Age (2). In the Middle Bronze Age, emmer wheat and hulled barley were of equal importance (2a) (Buurman 1996, 18), whereas in the Late Bronze Age, hulled barley was the only cultivated crop (2b) (Buurman 1996, 19). Sowing seasonality was reconstructed by Buurman based on the remains of crop weeds: in West Frisia, crops were sown in spring, and can thus be characterised as summer crops (3) (Buurman 1996, 190). Fertilisation of arable fields was achieved by applying a combination of animal dung and household waste (4), evidenced by the remains of small bones and ceramics found in plough layers (Buurman 1996: 25, 190). Harvesting of crops occurred by reaping low on the stalk with a bronze sickle, or, in the Late Bronze Age, by uprooting crops (5) (Buurman 1996: 25, 191). After harvest, the crops were processed in and around the house, and were finally stored as sheaves outside the house until further processing for consumption was necessary (6) (Buurman 1996, 191).

The role of crop husbandry for Bronze Age subsistence in West Frisia was only inexplicitly stated by Buurman by closely linking her results to the animal husbandry results of IJzereef. Buurman postulates that in the Middle Bronze Age, crop husbandry formed the main subsistence strategy together with animal husbandry for meat and traction; in the Late Bronze Age, domestic animals were mainly used for milk production, rather than for pulling the plough (Buurman 1996, 26, Table 4). In combination with the incorporation of the old landscape model and inherent calculations on available land for crop husbandry, Buurman concludes that in the Late Bronze Age, crop husbandry could not be practiced to the extent where people could entirely sustain themselves (7) (Buurman 1996, 31-2).

Clearly, most of Buurman's research towards crop husbandry practices was performed with the previous landscape model for West Frisia in mind. Since this landscape model is inconsistent with new data and analysis (cf. Chapter 2), it is interesting to re-evaluate the old and new botanical data in combination with

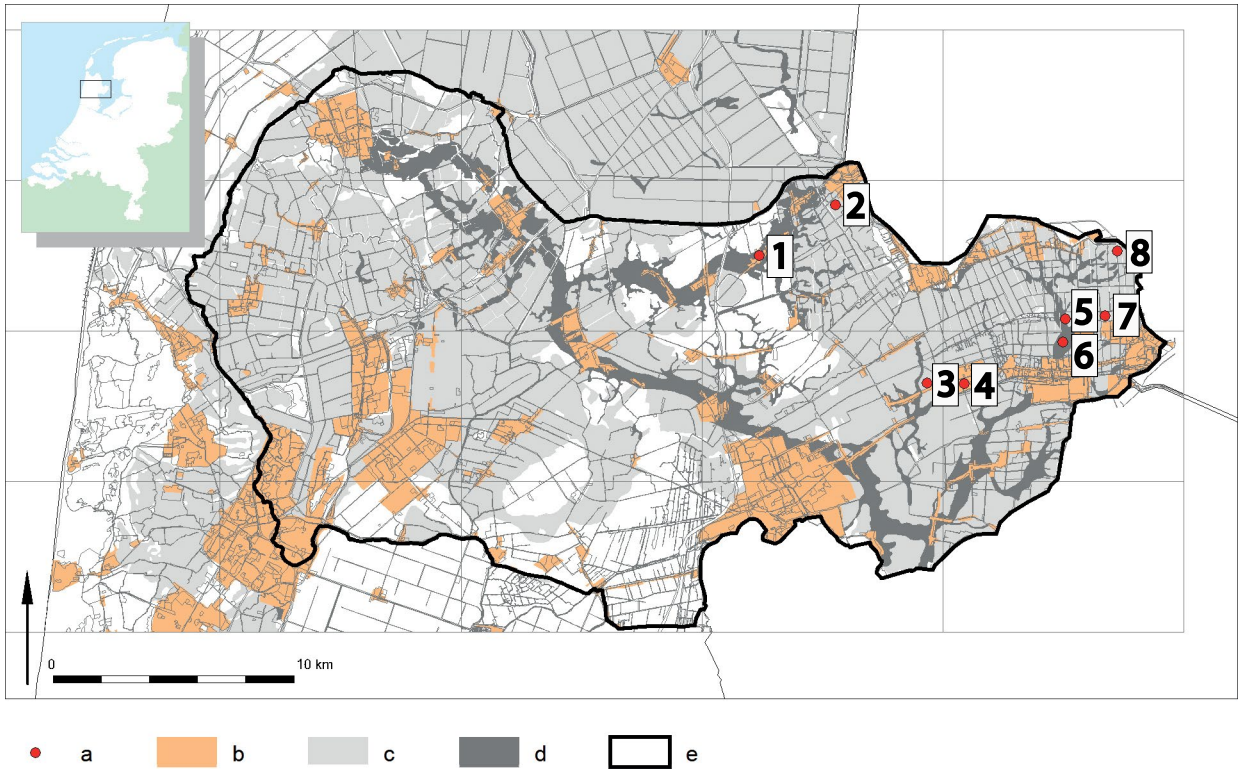


Figure 6.1. Overview of the sites of West-Frisia that yielded (large amounts of) crop remains. 1: Twisk; 2: Medemblik Schepenwijk II; 3: Westwoud; 4: Hoogkarspel Tolhuis and Hoogkarspel Watertoren; 5: Bovenkarspel Het Valkje; 6: Bovenkarspel Het Monument; 7: Enkhuizen Kadijken; 8: Enkhuizen Rikkert; 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.

the new landscape model in order to identify possible differences in conclusions about the role and praxis of crop husbandry in West Frisia.

6.1.2 The proxies and the sites

The proxies used for the re-evaluation and re-analysis of the old and new data on crop husbandry include ethnography, ethnobotany, biology, ecology, archaeobotany, and archaeology (section 6.2). The combination of these different disciplines provided a clear basis for the creation of what basic principles can be expected for small-scale crop husbandry (section 6.3), and the subsequent analysis of these aspects (section 6.4).

Although charred remains of crops and wild plants were uncovered at most of the excavations performed in West Frisia, only some sites possessed large enough quantities of charred botanical remains to allow for a more detailed analysis. Therefore, only two old and two new excavated sites are employed for the re-evaluation of the role and praxis of crop husbandry. Information on these sites is summarized in Figure 6.1 and Table 6.1.

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.

6.1.3 Main current model components

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

(1) Arable fields in West Frisia were sometimes wet and contained only one crop species at a time.
(2) West Frisian crops were mainly emmer wheat

and hulled barley for most of the Bronze Age.
(2a) In the Middle Bronze Age, emmer wheat and hulled barley were of equal importance.
(2b) In the Late Bronze Age, solely hulled barley was cultivated.
(3) Sowing of crops occurred in spring.
(4) Fertilising fields was achieved by applying a combination of household waste and animal dung.
(5) Harvesting ripe crops was performed by reaping low on the stalk with a bronze sickle, and in the Late Bronze Age, by uprooting crops.
(6) Processing of the harvest occurred in and around the house and harvest was stored in sheaves.
(7) In the Late Bronze Age, people were not able to practice crop husbandry to the extent required to complete subsistence.

6.2 METHODS

The different methods applied to investigate the role of crop husbandry in Bronze Age West Frisia are shortly presented here. Similar to the previous two chapters, the main approach in this chapter is to identify multiple activities related to crop husbandry (Table 6.2) and create an expectation of what each component entails (section 6.3). Note that no separate basic aspect of "use" is included in Table 6.2, because it is assumed that crops were primarily grown for human consumption. Other uses for crops and their residues are discussed in section 6.4.8.4.

The individual components outlined in Table 6.2 are first analysed separately in order to create an understanding of every part in the West Frisian subsistence economy (section 6.4). After the analysis of the separate basic principles of crop husbandry, they are re-combined and integrated to view crop husbandry entirely. During this analysis, the available botanical data is used, and the data is also compared to the expectation made in section 6.3. This comparison provides indications for what components should be a part of small-scale crop husbandry practices, but are missing from the West

Table 6.1. Information on the sites of West-Frisia used for the analysis of crop husbandry.

Site location	Typonym	Excavated	Date	Dating method	Sieving mesh size	Reference(s)
Bovenkarspel	Het Monument	1977	1500-800 BC	pottery typology	n/a	Roessingh in prep.
Bovenkarspel	Het Valkje	1974-1978	1500-800 cal BC	14C-dating and pottery typology	0.25-1.0 mm	Buurman 1996, 83-104
Enkhuizen	Kadijken	2007-2009	1500-800 cal BC	14C-dating and pottery typology	0.25-1.0 mm	Moolhuizen & Bos 2011, 259-69
Enkhuizen	Rikkert	2012-2015	1500-800 BC	pottery typology	n/a	unpublished
Hoogkarspel	Tolhuis	1964-1969	1500-800 cal BC	14C-dating and pottery typology	0.25-1.0 mm	van Zeist 1968-1970
Hoogkarspel	Watertoren	1973-1978	1500-800 cal BC	14C-dating	0.25-1.0 mm	Pals 1977, 189-225
Twisk		1980	1300-1100 BC	14C-dating	0.25-1.0 mm	Buurman 1996, 37-68
Westwoud	1988	1988	1400-800 cal BC	AMS-dating	0.25-1.0 mm	Buurman 1996, 107-56
Medemblik	Schepenwijk II	2007	1450-800 cal BC	14C-dating and pottery typology	0.25-1.0 mm	Kooistra 2010, 125-42

Table 6.2. Basic aspects related to crop husbandry.

Crop husbandry	Related to:
a. Arable field size and crop composition	land and crops belonging to the household
b. Soil preparation	tending to arable fields
c. Cultivation	tending to crops
d. Handling and related locations	post-harvest processing and storage
e. Arable field soil conditions and locations	location and improvement of arable fields
f. Seasonality	seasonal activities related to crops

Frisian archaeobotanical assemblage. The absence of such components is further explored in section 6.4.8 where the effects of archaeological methodology and taphonomical processes on the data are assessed. By using multiple proxies and recent research in the analysis of the West Frisia data more detailed information on the praxis of crop husbandry, as well as it social organisation was obtained, which would not have been possible based on the use of only one discipline.

6.2.1 Ethnography

The ethnographic study of Murdock (1981) was used to assess the general role of crop husbandry within small-scale mixed farming communities, similar to the previous chapters 4 and 5, and with the same selections applied as in these Chapters (Appendix A1.4). More detailed ethnographic parallels were chosen for specific aspects related to crop husbandry, including soil preparation, cultivation, and post-harvest practices. Each of these parallels are elaborated upon in the respective sections.

The employed research of Murdock for the general importance of crop husbandry contained examples from different areas of the world, which allowed for the understanding of consistent crop husbandry characteristics regardless of geography, time period or climate. The more detailed examples were chosen to most closely reflect the presumed environmental conditions of Bronze Age West Frisia.

6.2.2 Ethnobotany

An in-depth ethno-botanical study of Romanian and Slovakian small-scale subsistence farming (Hajnalová & Dreslerová 2010) was employed to investigate specific crop husbandry practices.

This parallel was chosen because it is the only example of an ethnobotanical study that incorporates both qualitative as well as quantitative data on all the basic aspects of crop husbandry in a small-scale mixed farming situation. Furthermore, this is the only study of this scope known to the author that researches such a farming situation in a region outside southern Europe (see below). The researched communities still cultivated einkorn and emmer, two of the main cereals from late prehistory, in a traditional manner, without the use of heavy machinery. Even though most farms were located in central Europe in the Carpathian mountains, it is assumed that the practices reflect north-western European land use in a more accurate manner than many of the ethnobotanical studies undertaken in the Mediterranean. Of course, several aspects of crop husbandry in a hilly, central European environment will be different from low-land crop cultivation, and these differences are discussed where appropriate.

6.2.3 Ecology

Ecological information regarding the growth requirements of crop weeds (Ellenberg *et al.* 1991) was employed to research soil characteristics of arable fields.

6.2.4 Biology

The biological information on crop weeds was employed to investigate crop husbandry practices such as sowing time, harvesting height, and fallow periods. For references regarding these crop husbandry practice reconstructions, see sections 6.4.2 and 6.4.3.

6.2.5 Archaeobotany

Archaeological information for this research mainly consisted of an overview of crops available in the Bronze Age in general (Stika & Heiss 2013), in order to assess the potential range of crops present during that time. Differences and similarities in the crop composition between West Frisia and other areas north-western Europe thus became apparent, which allowed for further interpretation of possible crop choices made by Bronze Age farmers in West Frisia.

6.2.6 Archaeology

Archaeology was employed to investigate the different field systems present in the Bronze Age, as well as the range of possible storage locations available at this time.

6.3 CREATING AN EXPECTATION OF CROP HUSBANDRY PRACTICES

The relative role of crop husbandry in small-scale mixed farming communities was first investigated, similar to the previous chapters, by selecting specific cultural parallels from the ethnographical work by Murdock (1981). The analysis has resulted in an average contribution of crop husbandry to subsistence of 59% (Appendix A1.4), although the precise meaning of this value remains unclear based on the statements of Murdock (cf. Chapter 4, section 4.3). However, crop husbandry can be regarded as the main contributor to subsistence by being a source of staple food for farmers, through providing more than half of the required means for subsistence. Furthermore, in every selected mixed farming culture, crop husbandry always aids subsistence more than animal husbandry, regardless of the size of the community.

The manner in which crop husbandry is practiced in small-scale communities was also researched, starting with the size of arable fields. In general, the size of arable land is dependent on several restrictions. First of all, the available land for crop husbandry can be a deciding factor in how large a (set of) field(s) can become. Furthermore, the type of farming system, and its inherent labour force size can be a restriction in the sense of available time and people. Lastly, climate, soil properties, and plant species characteristics decide the yield of a crop at a certain location and therefore the amount of land required.

For small-scale mixed subsistence farms, the size of the arable land is often restricted most by the number of people available for labour: even though the climatic conditions might be favourable and ample arable land might be available, it is often not feasible to cultivate larger field sizes with the given amount of time and size of labour force for sowing and harvest of the crops. The restrictions of arable land size are closely linked to the adopted land use strategy of farmers, which can be intensive, extensive, or a combination of both.

In the Encyclopaedia Brittanica, intensive agriculture [9]is classified as a "system of cultivation using large amounts of labour and capital relative to land area. Large amounts of labour and capital are necessary for the application of fertilizer (...) to growing crops" and "a farm using intensive agriculture will require less land than an extensive agriculture farm to produce a similar profit".

Extensive agriculture is, logically, defined as a "system of crop cultivation using small amounts of labour and capital in relation to area of land being farmed. The crop yield in extensive agriculture depends primarily on the natural fertility of the soil, terrain, climate, and the availability of water."

In practice however, small-scale farmers often adopt a mixture of intensive and extensive farming.

In archaeology, the model of Boserup (1965) is frequently used for the interpretation of crop husbandry. She developed a system of classification to show the dynamic properties of crop husbandry, in which she discerned five main land use types. The types are: forest fallow, bush fallow, short fallow, annual cultivation, and multiple cropping; the latter

9. Although agriculture is applied here to the cultivation of crops, its definition usually includes the practice of cultivating the soil, producing crops, and raising livestock. Therefore, the more specific term crop husbandry is used for the rest of the chapter.

Table 6.3. Comparison of farming operations in different farming systems (adapted from: Pingali *et al.* 1987).

	Farming System				
Operation or situation	**Forest fallow**	**Bush fallow**	**Short fallow**	**Annual cultivation**	**Multiple cropping**
Land clearing	Fire	Fire	None	None	None
Land preparation and planting	No land preparation; use of digging stick to plant roots and sow seeds	Use of hoe and digging stick to loosen the soil	Plough	Animal-drawn plough and tractor	Animal-drawn plough and tractor
Fertilization	Ash; perhaps household refuse for garden plots	Ash; household waste for garden plots	Animal dung or other manure; sometimes composting	Manure; sometimes human waste; composting; cultivation of green manure crops; chemical fertilizers	Manure; sometimes human waste; composting; cultivation of green manure crops; chemical fertilizers
Weeding	Minimal	Required as the length of the fallow decreases	Intensive weeding required	Intensive weeding required	Intensive weeding required
Use of animals	None	Animal-drawn plough begins to appear as length of fallow decreases	Ploughing, transport	Ploughing, transport, postharvest tasks, and irrigation	Ploughing, transport, postharvest tasks, and irrigation
Seasonality of demand for labour	Minimal	Weeding	Land preparation, weeding and harvesting	Land preparation, weeding and harvesting	Acute peak in demand around land preparation, harvest and postharvest tasks
Supply of fodder	None	Emergence of grazing land	Abundant open grazing	Open grazing restricted to marginal lands and stubble grazing	Intensive fodder management and production of fodder crops

two being intensive types of land use (Boserup 1965; Meertens *et al.* 1995: 8, table 1; Table 6.3).

Forest fallow: plots of forest are cleared each year and cultivated for a few years followed by a fallow period of more than 20 years; bush fallow: shorter fallow than forest fallow from around six to ten years with varying lengths of cultivation in between fallow periods; short fallow: fallow lasts only a few years followed by a period of cultivation; annual cultivation: close to no fallow period is observed, if only for the few months between harvest and subsequent sowing; multiple cropping: most intensive system of land use because the same plot is cultivated by two or more successive crops each year, and fallow is (almost) absent (Boserup 1965, 9).

As stated above, farmers can, to a certain extent, be dynamic in their choice of adopting intensive or extensive strategies and indeed many intermediate or mixed land use types exist.

Boserup postulated the hypothesis in her model that an increased population pressure is the main agent

for intensification of practice (Boserup 1965, 16), but others have indicated that economy, technology, ecology, and social restrictions can have an effect on the adoption of either an intensive or extensive land use strategy (Meertens *et al.* 1995,52). First, an example of how these variables can influence farmer's decisions is given based on one of the selected cultures from Murdock, the Sukuma from Tanzania. This example was chosen, because it is the only quantitative study available on crop husbandry practices based on the selected cultures from Murdock. Other cultures in this list (Appendix A1.4) have merely been described on an anthropological basis, rather than an ethnographic basis.

After the description of crop husbandry practices of the Sukuma, the variables from this study are used in combination with Boserup's initial land use types to develop an expectation for the West Frisian situation. The effect of each of the variables has been investigated in Tanzania based on small-scale farming communities (Meertens *et al.* 1995). This study revealed that ecology and social factors can drive farmers to intensive agriculture, such as during land shortages, warfare, or imposed policies by others (Meertens *et al.* 1995, 67). However, under normal circumstances, small-scale subsistence economies with the availability of a plough (*i.e.* economy and technology) show a preference for extensive land use. This is illustrated by the fact that as soon as restrictions such as war and policy were relieved in Tanzania, people immediately reverted back to extensive agriculture. The combination of availability of land and plough allowed them to cultivate larger fields, and letting them lie fallow, actually eliminating the need for manuring to maintain soil fertility (Meertens *et al.* 1995, 68-9). At low population densities, the farmers had land use strategies that were either extensive bush fallow or short fallow systems.

Building on the evidence of the case study in Tanzania and the examples provided by Boserup, two types of land use seem most applicable to small-scale crop husbandry, namely extensive bush fallow and short fallow. However, since only short fallow farming systems are characterized by the presence of a plough, this land use type seems most appropriate for West Frisia. The analysis of the West Frisian data will have to show whether this land use type, or perhaps a different land use type, is indeed most plausible.

Other aspects related to this short fallow land use include: fertilization with animal dung and household refuse/compost; intensive weeding; using animals for ploughing and transport; demand of labour for land preparation, weeding, and harvesting; and open grazing of animals (Boserup 1965; Meertens *et al.* 1995: 8, Table 1; Table 6.3). The use of animals for hard labour such as ploughing and transport has indeed been identified based on cattle bones in West Frisia (Chapter 5, section 5.4.7.4). Furthermore, open grazing of livestock was also postulated based on the vegetation reconstruction (Chapter 2, section 2.3.3), and animal husbandry practices (Chapter 5, section 5.3.5).

The concurrence of the other aspects, related to crop husbandry, is assessed in the following relevant sections.

6.3.1 Arable field size and crop composition

Arable fields

Considering the short fallow land use type as a prerequisite, parallels for field sizes of small-scale mixed farming communities were sought using the ethnographic work performed by Murdock (1981). Note however, that the definition of intensity of crop husbandry employed by Murdock is different than the definition by Boserup: Murdock considers crop husbandry with short fallow to be intensive, whereas in Boserup's model, only annual cultivation and multiple cropping are deemed intensive land use. The selection on Murdock's work therefore uses the prerequisites intensive agriculture1 on permanent fields, use of fertilization, crop rotation, or other techniques to ensure a short to no fallow period. In addition, the cultures selected should be cultivating cereal grains as their main crops.

The outcome of the selection has made it possible to further investigate the characteristics of these farming communities (Appendix A1.4). Narrowing the selection down to only the smallest settlement sizes (*i.e.* neighbourhoods and hamlets), the average size

Figure 6.2. Example of a garden kept near the main house in the Danube delta, Romania.

of arable land owned per household (with on average 6 people) accounts to 1.8 hectares, with a range of 1-3 hectares (Byrnes 1992; United Nations 1996; Shundi 2006; Nyasimi *et al.* 2007; Talensi-Nabdam n.d). Similar trends can be observed in eastern and central Europe (Sarris *et al.* 1999; Mathijs & Noev 2004). This total arable land size can be, and often is, subdivided into several smaller plots. In Sweden, individual field sizes related to small-scale mixed farms up until recent times never reached more than 1 ha in size (Ihse 1995). When rotation of crops is applied due to fallow periods, the arable field size required will increase (section 6.3.3).

In order to further assess the size of arable fields of small-scale mixed farming units, Romanian and Slovakian ethnobotanical research was employed, for reasons described in section 6.2.2. Romanian small-scale farming households (consisting of ca. 5 people) own on average 4.7 ha of land, of which approximately 2.5 ha consists of arable fields

Figure 6.3. Example of a garden kept directly adjacent to the main house in the Danube delta, Romania.

(Hajnalová & Dreslerová 2010, 183, 186). Large strips of arable land are subdivided into smaller plots with an average size of 0.01-0.2 ha in Romania (einkorn) and 0.17-0.4 ha in Slovakia (emmer) (Hajnalová & Dreslerová 2010: 173, 190). Such smaller plots could have been worked and sowed in a day.

Interestingly, none of the fields had clear demarcated boundaries, which, in the abundant presence of deer, wild boar, and bear, leads to ample losses of crops. For this reason, dogs are kept at the borders of the fields to reduce crop losses (Hajnalová & Dreslerová 2010, 173).

The acreage of arable fields in the Romanian Carpathian mountains is somewhat higher than the average value based on the selections of the cultures researched by Murdock, which may be due to the hilly terrain. Therefore, the average value of 1.8 ha is used further, but the subdivision of plots observed in both the selections on Murdock's work and eastern Europe will also be kept in mind.

The postulated arable land size would therefore have been used extensively under a short fallow strategy. However, several of the selected cultures (*e.g.* Sotho, Lepcha) also showed the presence of garden plots near to the house, which were managed more intensively and which mainly contained vegetables etc. (*e.g.* Bhasin 2011; Sotho n.d.). A similar phenomenon was also observed by the author in a rural village in the

Figure 6.4. Example of a garden further away (ca. 100m) from the village.

Danube delta of Romania (Figure 6.2-Figure 6.4), where an extensive crop production was combined with more intensive small-scale horticulture. Garden plots are usually tended to by hand, sometimes with the help of hand tools such as a hoe. Since these types of gardens occur in several small-scale communities around the world, the presence of garden plots cultivated in a more intensive manner is expected.

Bronze Age arable fields

Ethnography has given clear indications for an expectation of arable land size and use. For the Bronze Age of north-western European specifically, indications for these aspects of crop husbandry also exist. Two different major types of field system seem to exist in the Bronze Age: fields of various shape and size, and Celtic fields. The former fields are usually of varying size, which sometimes have borders but usually show no clear boundary demarcations. Examples of such fields are observed in Denmark, as well as in the western area and the river area in the Netherlands (Poldermans 1987; Bech 1993; Tegtmeier 1993, 119; Bech 1997; Jongste & Wijngaarden 2002; Robinson 2003). Fields which do show boundary demarcations were found in Denmark, evidenced by an ending of the criss-cross pattern (Figure 6.5).

Celtic field systems arise only in the later Bronze Age. They are composed of a checkerboard complex of fields of comparable size, possibly bordered by wattle work or hedges (nb. the earthen boundaries

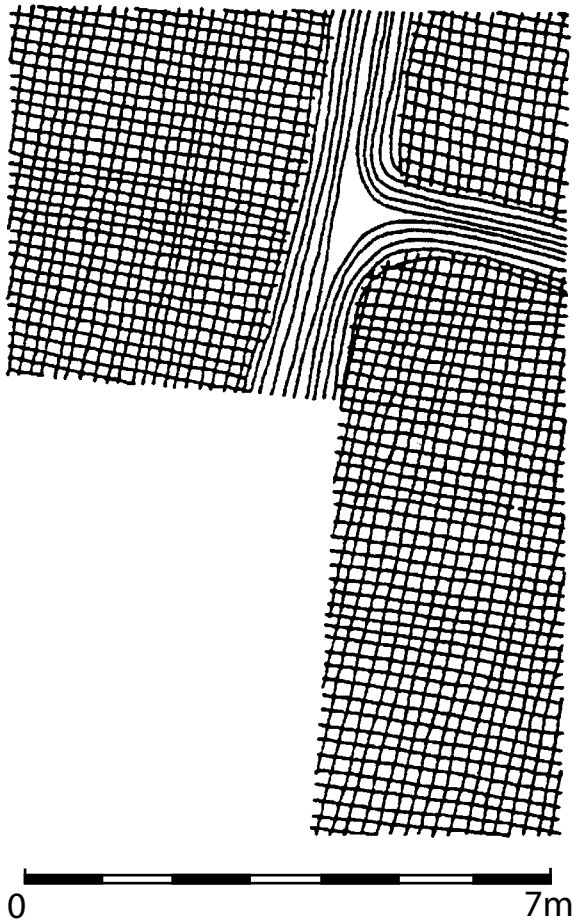


Figure 6.5. Overview of Bronze Age arable fields with boundaries (parallel lines) from Lusehøj, Denmark (from: Thrane 1984).

were only in use from the Middle Iron Age onwards) (Fokkens 1991; Tegtmeier 1993, 76; Fries 1995; Spek *et al.* 2003, 67; Arnoldussen 2012; Arnoldussen & Scheele 2014). The two different field systems seem to appear on different types of soils. Plots of varying shape and size mainly appear on clayey soils, as can be observed in the Dutch river area and Denmark (Tegtmeier 1993, 119). Celtic fields however, seem to appear mostly on sandy soils in north-western mainland Europe (*i.e.* Denmark, Germany, and the Netherlands) (Tegtmeier 1993; Spek 2003; Kooistra & Maas 2008).

In both field systems, plough marks can be identified, which reflect past ploughing practices. These marks are, however, only visible when certain conditions

are met. First of all, plough marks are only visible when the plough perforates too deeply into the soil, thus scratching the layers underneath, producing a linear pattern of contrasting colours of soil (Figure 6.5). It can be imagined that when either perforation does not occur or soils are not of contrasting colour, plough marks will not be apparent. Since perforation into deeper layer is often irregular, sometimes only dependent on local soil conditions or inexperience of the person or animal ploughing, usually, no continuous plough marks can be discerned. The entire original size of arable fields is thus normally not visible during excavation, hindering the reconstruction of past arable field size.

Exceptions to this are for example continued ploughed areas in Noorderboekert, West Frisia (Knippenberg in prep.) and Haarlem, in the western Netherlands (Poldermans 1987), which cover an area of at least 120 x 60 m (pers. comm. S. Knippenberg), allowing for an estimation of minimum arable field size.

Arable field sizes in archaeology have been postulated for the Netherlands based on the amount of calories and inherent arable field sizes required per household. For the Neolithic, Bakels & Zeiler have hypothesized an arable field size of 0.6-2.3 ha for a household of 6 people (Bakels & Zeiler 2005). For the eastern parts of the Netherlands in the Bronze Age, an arable land size ranging from 2.0-3.9 ha was postulated to have been sown by one household practicing 50-100% arable farming on an annual basis (cf. Fokkens 1998, 142). The higher end of this estimation seems to be a on the large side compared with the examples mentioned above. The value of 2.5 ha provided by Brinkkemper (1993), for Iron Age wetland areas in the Netherlands, is more within range of the values above, but is based on protein requirement, not ethnographic parallels.

Based on the examples outlined above, it is expected that arable fields located on clay were of various shape and varying size. A total arable field size of 1-3 ha per household is expected, with an average of 1.8 ha.

Crops

Crops can be cultivated for multiple reasons, but the main reason assumed in this research is for human consumption. Other reasons for the cultivation of crops are discussed in section 6.4.8.4.

The main types of cultivated crops that are used in food production are cereals, pulses, legumes, and cultivated fruit, as well as oil containing plants (Stika & Heiss 2013, 349). Furthermore, the distribution of crops can be influenced by geography, time period, and climate. Therefore, in order to create an adequate expectation of the available crops in West Frisia, the focus will be on the crops that were available to farmers in the Bronze Age of western-central Europe (WCE), southern Scandinavia (SSc), and the North Sea coast (NSC) (Stika & Heiss 2013, 358-9). In Table 6.4, the relative dominance of cereals, pulses and legumes, oil-containing plants, and cultivated fruits is summarized for these three areas of Europe throughout the Bronze Age.

The most prevalent crops throughout the Bronze Age were emmer wheat and barley, which was mostly present in its hulled variety. Secondly, in some areas, spelt wheat, einkorn, and broomcorn millet were present. Less prevalent crops include foxtail-millet, rye, and oat. Non-cereal cultivated crops are less prevalent than cereals, being almost absent in southern Scandinavia and the North Sea coast, except for rare finds of field bean. In western central Europe, the available pulses and legumes include lentil, garden pea, bitter and common vetch, and field bean. Even less species of oil-containing plants were found, including linseed/flax, gold-of-pleasure, and opium poppy. Only one cultivated fruit was found, in the Late Bronze Age in western central Europe, which is grapevine.

In general, it appears that in the Early and Middle Bronze Age, little change in crop plant composition occurs in each area. However, towards the Late Bronze Age, more species are available and they become more frequent, although pulses, legumes, and oil-containing plants remain relatively scarce.

6.3.2 Soil preparation

The different manners of tending to arable fields in small-scale farming communities were mainly researched using the Romanian ethnobotanical example outlined in section 6.2.2.

Table 6.4. Overview of the available crops in the Bronze Age in West-Central Europe (WCE), Southern Scandinavia (SSc), and the North Sea Coast (NSC) (after: Stika & Heiss 2013, 358-9).

		EBA		MBA		LBA	
Taxa	**English name**	**SSc and NSC**	**WCE**	**SSc and NSC**	**WCE**	**SSc and NSC**	**WCE**
cereals							
Hordeum vulgare	Barley	+++	+++	+++	+++	+++	++
var. *vulgare*	Hulled barley	+	+	+	+	+	
var. *nudum*	Naked barley	+	+/-	+	+/-	+	
Triticum dicoccum	Emmer wheat	++	++	++	++	++	++
Triticum spelta	Spelt wheat	+/-	++	+/-	++	+/-	+
Triticum monococcum	Einkorn	+/-	+	+/-	+	+/-	+
Panicum miliaceum	Broomcorn millet	+/-	+	+/-	+	+/-	++
Free-threshing wheat	Free-threshing wheat	+/-	+/-	+/-	+/-	+/-	+/-
Setaria italica	Foxtail millet	-	+/-	-	+/-	-	+/-
Secale cereale	Rye	-	+/-	-	+/-	-	+/-
Avena sativa	Oat	-	-	-	-	+/-	+
pulses and legumes							
Lens culinaris	Lentil	-	+/-	-	+/-	-	+
Pisum sativum	Garden pea	-	+	-	-	-	+
Vicia ervilia	Bitter vetch	-	-	-	+/-	-	+/-
Vicia faba	Field bean	-	+/-	-	+/-	+/-	+
Vicia sativa	Common vetch	-	-	-	-	-	+/-
oil-containing plants							
Linum usitatissimum	Linseed/Flax	+/-	-	+/-	-	+	+/-
Camelina sativa	Gold-of-pleasure	-	+/-	-	+/-	+	+
Papaver somniferum s.l.	Opium poppy	-	-	-	-	-	+/-
cultivated fruit							
Vitis sylvestris ssp. *sylvestris*	Grapevine	-	-	-	-	-	+/-

+++=dominance, ++=subdominance, +=present, +/-=low amounts, -=absent. Adapted from: Stika and Heiss 2013, 358-9)

Tillage

Tillage of fields, or the preparation of arable fields by disturbing the soil, can take several forms, but in small-scale subsistence economies, the means are often limited. Therefore, often only digging sticks, hoes, rakes, and wooden ploughs[10] are used, sometimes in combination with metal parts.

Ploughing

Ploughing is often applied to larger fields directly after harvest in autumn. In this manner, any leftover stubble is worked into the soil in order to retain soil nutrients. When the weather or other factors do not allow for ploughing in autumn, it is postponed until the next spring. When crops are sown in spring rather than in autumn, fields are ploughed for a second time or harrowed directly before sowing. This ploughing only needs to occur in a very shallow manner (max 15 cm deep) (Hajnalová & Dreslerová 2010: 175, 187, 194), since spring crops do not require deep furrows for sowing. After sowing, the seeds are covered manually with earth, or by harrowing or raking (Hajnalová & Dreslerová 2010, 177).

Ploughing speed depends on the cattle pulling the plough. A pair of cattle in Romania plough 0.1 ha/day, but these cattle are larger than Bronze Age cattle and they often plough in hilly terrain (Hajnalová & Dreslerová 2010, 176). Experiments with smaller cattle have been performed in Denmark using Iron Age sized oxen instead, which are actually even smaller than Bronze Age cattle. Such a pair of such oxen can plough 0.35ha/hr (Hansen 1969), which means that in a day, a much larger area could be ploughed. However, these results are from sandy/loamy soils, which are much less resistant than clayey soils, the latter of which are the kind of soils relevant for West Frisia (cf. van Zijverden forthcoming). Therefore, the speed of Bronze Age cattle will probably lie somewhere between the values 0.1-0.35 ha/hr.

Ploughing in prehistory often occurs in a criss-cross fashion. Although not often practiced in present-day farming communities, one example from Ethiopia exists where people still use the ard to plough furrows in a criss-cross fashion (Temesgen *et al.* 2011). Parallel furrows cannot be ploughed in too close proximity, since the plough would slide into the previously made furrows rather than follow its own path. Therefore, perpendicular ploughing is practiced, to ensure the largest area possible of the arable field is worked (Temesgen 2007, 7).

Hoeing and raking

Smaller fields are often tended to by means of hoeing or raking. The stubbles from the previous year are removed by either hoeing or stubble burning, after which the field is raked. Subsequently, the hoe is used to produce furrows for sowing, after which the rake is used to cover the seeds (Hajnalová & Dreslerová 2010,175-6).

No tillage

On very heavy clay soils, sometimes no tillage (*i.e.* ploughing) is applied, under the condition that flooding of the land takes place during winter. Sherratt (1980, 318) states: "*Where soils are subject to winter flooding and summer desiccation, the deep cracking caused by drying-out would provide natural aeration and make them practically self-cultivating*." The winter floods would regenerate the soils with nutrients, making manuring a redundant practice for these soils. This type of crop cultivation would, however, only be combinable with spring sowing. In the USA, the no tillage strategy produced the highest crop yields on the very heavy clayey soils present there (Chen *et al.* 2004). Additionally, Rasmussen (1999) finds similar results for arable fields in Scandinavia.

Burning

A fast and low-cost method with a low labour input is the burning of crop residue (*i.e.* stubble) from the previous crop (Kumar & Goh 1999, 230); burning of arable fields can form an efficient tool for small-scale farmers. Stubble burning is practiced shortly after the harvest has been completed, to remove remaining stubbles from the previous crop stand (Williams *et al.* 2013; Burning residues 2016). This form of

10. Ploughs used in the Bronze Age are called ards (see Appendix A1.9). These types of wooden ploughs only tear the soil, they do not turn it.

crop residue management is much more efficient than incorporating entire and elaborate amounts of crop residues into the soil, especially when high amounts of crop residue are present, which hamper the pre-sowing ploughing and subsequent sowing of the following crop (Williams *et al.* 2013: 6). After burning, the resulting ash after burning is either left on the surface or worked into the soil. Advantages to stubble burning are the removal of crop weed seeds, the facilitation of sowing of subsequent crops, and the improvement of management of pests and diseases (Williams *et al.* 2013: 6, 24; Burning residues 2016). When a field is intended for burning however, it should not be grazed to ensure that there is enough stubble for the burn. Another adverse effect of stubble grazing is that weed seeds are being trampled into the soil, reducing the chance that they are destroyed in the stubble burning process (Burning residues 2016).

Stubble burning is distinctly different from slash-and-burn practices, where forest is burnt to clear fields. Burning of stubble is still practiced in some areas of Europe and the United States today (Hajnalová & Dreslerová 2010, 176; Ascoli & Bovio 2013; Manitoba 2016), but was much more common in the not too distant past (Figure 6.6). Apart from efficiency reasons, stubble burning can also be a necessity, since in areas where the soil consists of very heavy clay, it can prove impractical or even nearly impossible to plough the land. Examples of this can still be seen in Manitoba, USA, were farmers prefer to practice stubble burning rather than ploughing when policies allow it (Chen *et al.* 2005).

In fact, when executed properly, a regime of stubble burning can produce spring barley crop yields that surpass yields of spring barley grown on fields with ploughed under stubble, or manured fields (Badaliková & Hruby 2006).

Figure 6.6. Stubble burning in France (photos courtesy of C. Vermeeren).

Fallow

Both wheat and barley are intolerant of continuous cultivation, so land needs to be left to lie fallow. Alternatively, rotational cropping can be applied, or a combination of fallow and rotational cropping, all with the aim of regenerating the soil. The practice of letting fields lie fallow after the harvest can occur

after one or more years of cultivation. As postulated in section 6.3, the short fallow system is considered the most plausible type of land use for small-scale mixed farmers. In these systems, plants are cultivated for a number of years, after which subsequently one or two years of fallow follow. Fallow fields can for example be used as pastures for livestock, decreasing the extra amount of pasture needed to sustain animals.

6.3.3 Cultivation

Sowing

Sowing practices
Sowing of crops can be performed in several different manners. Two of the main methods include broadcasting and planting in furrows. Planting in furrows requires the farmer to put each individual seed into the soil one by one, or, alternatively, funnel-like instruments can be attached to the plough to facilitate sowing (Steensberg 1971, 245). This is applied for crops with relatively large seeds, such as pulses. Alternatively, a combination is possible, wherein furrows are sown by throwing multiple seeds along the furrow with or without being combined with animal dung (Steensberg 1971, 249-50), which also occurs with several wheat species (Steensberg 1971, 250). However, in general, for cereals crops with small grain kernels such as emmer wheat, it is more applicable to cast multiple seeds in furrows or by broadcasting seeds (*i.e.* or scattering seeds by throwing them over a large surface), since their grains are hard to handle individually over large areas (Steensberg 1971: 250, 253; Lerche & Steensberg 1983, 229; Peña Chocarro 1995, 97, 117; Hajnalová & Dreslerová 2010, 177). After sowing, the seeds are for example covered by harrowing soil over them. The amount of seeds sown by broadcasting is roughly 100-200 kg/ha in Romania (Hajnalová & Dreslerová 2010, 176), and a comparable volume (150-250 kg/ha) is observed in Asturias, Spain (Peña Chocarro 1995, 118). When the expected arable field size of 1.8 ha per household is applied, this means that a family would sow around 180-360 kg of sowing seed per year based on the Romanian example.

Sowing seed
Seeds needed for sowing the next year are retained from the harvest. Only the largest and most well-developed seeds are selected for this purpose, since it ensures a good quality of sowing seed (Hajnalová & Dreslerová 2010, 176). The amount of seeds retained is preferably twice the number of seeds needed for planting: harvests can fail and in this manner, it is ensured that enough seed is left to sow the following year. In Romania, 200-400 kg of seeds are retained per harvest, when possible (Hajnalová & Dreslerová 2010, 184).

Maslin
Crops can be sown as one species per field, or can be combined with another crop on the same field. When two or sometimes three crops are mixed by casting multiple seeds in furrows or during broadcasting, this is called a maslin crop. Maslin crops are used as risk-reducing strategy, since different species have different tolerances for different environmental conditions. Due to this difference in tolerance, and because the farmer cannot predict the conditions of the following year, he ensures some level of success by mixing two crops in one field (van der Veen 1995, 335; Bakels 2012). Although the practice of sowing maslin crops is a known phenomenon from ethnography and history (Slicher van Bath 1963; Bieleman 1992), it is notoriously hard to prove for prehistory, since mixing of remains from both crops can occur at multiple stages of harvest processing (van der Veen 1995, 335). Still, it is possible to identify some aspects based on reasoning.

Cereal crops cultivated solely for human consumption can indeed have been sown as maslin. However, we are considering small-scale mixed farming communities, who will most likely have used or recycled every residue. When straw of cereals has been used as supplementary fodder for animals unable to graze by themselves for whatever reason, a maslin crop will not always be the best option.

The two main types of cereal cultivated in West Frisia are emmer wheat and barley (see section 6.4.1). The straw of emmer wheat is unsuitable as fodder because it is sharp and tough (Hajnalová & Dreslerová 2010, 187), but barley straw is very suitable (Bakx 2011, 64 and references therein). If these two crops were mixed in fields, it would have been very hard to ensure the correct fodder, since wheat and barley

straw would have had to be separated again in the field. Also, straw of different species may not ripen at the same moment, resulting in different or bad quality straw of these two cereals. Therefore, it is more likely that emmer wheat and barley were cultivated in separate fields, and perhaps only became mixed during further harvest processing steps.

Rotation

Rotation of crops involves planting different crops in the same field in subsequent years, often followed once every couple of years by a period of fallow. Wheat, barley, pulses, and especially flax are very intolerant of continuous cropping (Hajnalová & Dreslerová 2010, 195), these crops are usually sown after one another. Pulses are known for their soil regeneration properties, due to their ability to fix nitrogen through their root-systems. They are therefore usually planted after a few years of cereal crops to replenish possible nutrient deficiencies. An alteration of autumn sown plants with spring sown plants is also a rotational strategy which can be applied.

Weeding

Weeding of crops is a practice with varying levels of incorporation into the crop husbandry regime. The level of weeding of a field depends on the distance from the settlement, available time and labour force, and intensity of land use. Based on Boserup's model of short fallow systems, it was expected that weeding would be performed intensively. In Romania however, crop weeds are usually left in the field, even up to the point where the researching ethnobotanists mistook the arable field for a fallow field (Hajnalová & Dreslerová 2010, 193). However, such plots were far away from the settlement, and these crops were used for animal fodder. Romanian farmers believe, in contrast to common opinion, that weeding disrupts the calm life of the crop and that the presence of weeds ensures the moisture of the soil. When weeding is done in the field, it is mostly done one to three times per spring, and only by hand. The only weeds consistently removed are thistles (*Cirsium/Carduus* spec.).

Another interesting observation made by the ethnobotanists in Romania related to weeding, which should actually be considered the first step of harvest processing, was the removal of weeds during and after harvest, especially when the straw is valued. Instead of weeding the field while the plant is growing, weeds are removed by hand during harvesting by "combing" them away using the fingers, from a bundle of reaped crops at a time, when weather conditions are good (Hajnalová & Dreslerová 2010, 177-8). When the weather is forcing the people to make more haste harvesting, bundles of cereals are taken to the village, with weeds still attached. They are then removed after the harvest in a similar manner, and bundles of clean crops are taken into storage. The weeds are used as animal feed (Hajnalová & Dreslerová 2010, 178).

Harvesting

Harvesting practices

Harvesting in small-scale subsistence communities usually occurs by hand, often with the use of tools. In Romania, two types of sickles were in use: a smooth bladed sickle and a sickle with a toothed blade. The preference for either of these sickles was different for each farmer and did not depend upon family or village traditions. However, when farmers who normally use one type of sickle were given the other type, the tendency for uprooting occurred (Hajnalová & Dreslerová 2010, 177). Although uprooting can be the result of an unpractised hand, it can also be a deliberate harvesting technique. The plant is pulled out of the ground entirely by hand, making the most of the stem for possible further uses such as animal fodder, raw material for basketry or thatching, or fibre (Ibanez *et al.* 2008; Hajnalová & Dreslerová 2010: 177, 189). A similar result can be obtained by harvesting low to the ground, which is also the case in Romania and Slovakia, where reaping takes place 10-15 cm above the ground (Hajnalová & Dreslerová 2010, 177). The ears are removed from the stems, after which the culms are dried for animal fodder and the ears are kept for post-harvest processing. Besides uprooting or reaping low on the stem, other harvesting methods include: ear-plucking, thus leaving the stems in the field and reaping high on the stem, when the length of the straw is not important. Other methods can be applied to remove ears from the stem in the absence of (appropriate material for)

Figure 6.7. An alternative harvesting method: the mesorias; a: The harvesting tool called mesorias (Peña Chocarro 2014, 104, Figure 4.22); b: The wooden sticks are connected by a string or leather; the sticks are pinched around crop stems and moved upwards to pinch off crop ears (from: McClatchie 2008).

sickles. One such an example comes from Asturias, Spain. It is called a *mesorias*, or reaping clamp, which is a set of large wooden sticks (approx. 1 m in length) connected by a small string at one end (Figure 6.7a; Peña Chocarro 2014, 104). By pinching these sticks on the stems of the crop and moving in an upward fashion, ears are pinched off and collected in baskets (Figure 6.7b; Ibanez *et al.* 2008, 190-1).

Harvest speed

The speed with which people using sickles are able to harvest averages around 0.02 ha/hour (Hajnalová & Dreslerová 2010, 177). In contrast, people using reaping clamps can harvest around 0.02 ha/day, which is comparable to uprooting (Halstead 2014, 108). When one person needs to harvest an entire field of 1.8 ha, this may take several weeks. Since this takes too long to complete before deterioration of the crop, more people are required to complete this practice. This demand for labour during harvest time supports the expectation of short fallow land use in small-scale farming communities.

Harvest yield

The einkorn harvest in Romania yields approximately 2t/ha. Emmer harvests from Slovakia average around 1.77 t/ha, with a range of 0.73-3.80 t/ha (Tempír 1976), which is in concurrence with the yields of experiments performed in Bohemia, Czech Republic, which average around 1.7 t/ha (Beranová 1987). It is unknown whether these examples entailed spring or autumn varieties, and a modern experiment from eastern Austria shows the possible difference in yield: spring emmer yielded 2.7 t/ha, whereas winter emmer yielded considerably higher at 3.8 t/ha (Grausgruber *et al.* 2004).

Barley grown on unmanured arable fields at the research station at Rothamsted, Britain, yielded on average 1.2 t/ha (Barker 1985, 51). Spring barley on a medium sized organic farm in Sweden has a yield of around 1.0 t/ha (Östman *et al.* 2003). Thus, on average, the yield of barley averages around 1.1 t/ha. For the postulated arable field size per household of 1.8ha (section 6.3.1), this would mean an overall

	Post-harvest processing steps								
	1. threshing	2. raking	3. first winnowing	4. coarse sieving	5. first fine sieving	6. pounding	7. second winnowing	8. second fine sieving	9. sorting
	Steps required for processing after storage for daily consumption								
Storage as sheaves/ears	x	x	x	x	x	x	x	x	x
Storage as spikelet	completed before storage					x	x	x	x
Storage as grain	completed before storage							(x)	x

Figure 6.8. Overview of post-harvest crop processing steps and of which steps need to be conducted before daily consumption, depending on the manner in which the grain is stored (adapted from: Fuller *et al*. 2014, figure 4).

yield of around 3,000 kg of emmer wheat or around 2,000 kg of barley per year.

Harvest losses

Losses of harvest can occur when sown seeds have not germinated, during harvest, because of pests (*i.e.* rodents, birds, mammals, insects), and because of transport and processing. Romanian harvest losses vary from 0-40% (Hajnalová & Dreslerová 2010, 181), and in the Czech Republic it is estimated to be around 17-20% (Rozsypalová 2000, 69-70). When 20% loss is assumed, this means that the remaining yield of harvest would be around 2,400 kg of emmer wheat or 1,600 kg of barley per household per year.

Crop yield factor

The crop yield factor investigates the ratio of input of grains for sowing and the output of grains of subsequent harvest, basically to assess the efficiency of crop husbandry. In archaeological experiments, the crop yield factors may vary from 1:7-1:59 (Reynolds 1987).

In Romania, around 180-360 kg of seed is sown per household (see above: sowing practices). The yield, after losses of 20%, lies around 1,600-2,400 kg depending on the crop species. The crop yield factor would thus be ca. 1:8. This crop yield factor value is slightly lower than the 1:10 factor proposed by Fokkens (1991, 141), and the input of grains is higher (*i.e.* 100-200kg vs. 60 kg). This higher input is probably due to the fact that seeds are broadcast in Romania, which requires relatively high amounts of grains for sowing compared to for example planting in furrows. Nonetheless, the Romanian values are used for further interpretation, because they reflect observed values in small-scale mixed farming communities. Note that this crop yield factor value is much higher than the normally assumed value and applied values based on medieval crops (1:3 – 1:4, from: Slicher van Bath 1962, 18).

6.3.4 Handling and related locations

Post-harvest crop processing

Before the harvest can be employed for consumption or other uses, multiple crop processing steps need to be undertaken, especially when hulled grains are concerned, such as in West Frisia (cf. section 6.4.1). These steps include: drying of the harvested crop (often in the field); threshing to release the grain and chaff from the stem; collecting the threshed grains; and a series of winnowing and sieving of the grain on different mesh sizes to remove unwanted weeds and other cereal plant parts (cf. Hillman 1984; Figure 6.8). Finally, grains are dried (in wet climates sometimes with the use of fire) to avoid spoilage in storage. All of these steps can be recognised in ratios or occurrence of remains in archaeological assemblages, although some steps are more distinct than others (cf. Hillman 1984; Figure 6.8).

Several factors influence how crop processing is practiced as well as the degree to which this occurs. Factors affecting crop processing include, amongst others, climate, available man-power, and cereal type. Climate can influence post-harvest processing in the form of rain. Harvesting needs

to occur in a dry period of the year, since storage and subsequent processing requires a dry crop. Therefore, when bad weather is imminent, farmers may choose to harvest quickly and perform most of the crop processing steps indoors. Conversely, good weather allows farmers to process in the field, returning only the essential parts of the crop to the settlement and leaving the remaining stubble in the field. Of course, this practice also depends on how many people are available to help with the harvest. If the weather is favourable for processing in the field, but not enough people are available to perform this bulk task, the harvest may still become stored in a relatively unclean manner (pers. comm. C. Stevens). The type of cereal grown is also of influence to crop processing. In wet climates, grain is prone to spoilage in storage due fungi infections or germination before further use. Susceptibility to infection can be lowered by cultivating hulled cereals. Hulled cereals are protected against most infections due to their chaff, so they are often stored in bulk in their chaff. This storage can occur whilst still attached to the sheaf, as whole ears, or as individual spikelets (*i.e.* bulk store: Hillman 1984, 8; Figure 8.6). Another method to reduce the chance of spoilt grain is artificial drying with the use of fire before storage (Hajnalová & Dreslerová 2010, 187 and references therein).

As mentioned, the vast majority of crops in West Frisia were hulled (see section 6.4.1). Therefore, only hulled cereals are discussed next. For the preparation of food for one or more days, dried, hulled cereals were removed from the bulk store and processed further (Hillman 1984). The final processing steps from storage to consumption are expected to have occurred on a near-daily basis (Figure 8.6). These processing steps, which will have occurred hundreds of times each year, will thus be far better reflected in charred assemblages on a site than the annual harvest bulk pre-processing steps, which occurred only once, and sometimes not even at the settlement (Peña Chocarro 1995, 102-107).

The social organisation of harvesting can also be recognised in archaeological assemblages through the manner in which cereal is stored. It has recently been postulated that when limited time and man-power are available during harvest, crops are stored

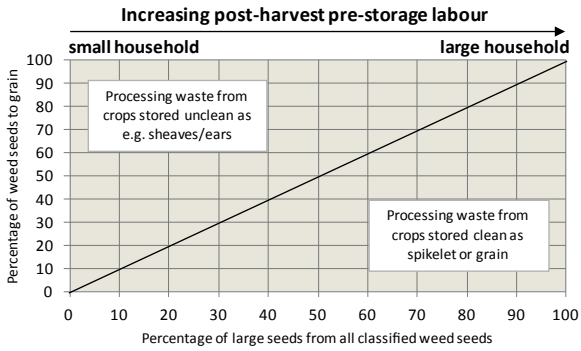


Figure 6.9. Graph depicting the social organisation during harvest based on the ratios of weeds and grains in an assemblage. The ratios of weeds and grains, as well as the size of the weeds inform about the range of processing steps undertaken from storage to consumption. Crops brought unclean to the settlement require more processing at the settlement and this will result in more and different processing waste than relatively clean crops (cf. Figure 6.8). The storage of clean or unclean crops is linked to the availability of time and man-power during harvest, and therefore social organisation. Having clean crops in storage is related to large(r) households, whereas storage of unclean crops is related to small(er) households (after: Stevens 2003, 73, fig. 7).

in a relatively unclean state (*i.e.* in sheaves or ears), and pre-storage processing is then limited (Stevens 2003; Fuller *et al.* 2014). Conversely, a relatively clean crop in storage may reflect the ample time and man-power available during harvest time, allowing for bulk processing of the harvest entirely down to spikelet form. Since daily processing is expected to have been the reason for the majority of charred crop remains at a settlement, the range of processing steps undertaken from storage to consumption can inform about the available time and man-power during harvest. For example, if indeed the crop was stored relatively unclean, the assemblage of charred remains on a settlement should reflect more processing steps and different inherent processing waste than when grain was stored in spikelet form. Limited time and man-power, and therefore social organisation during harvest, might then be reconstructed based on certain ratios of weeds and grains in archaeological samples (Stevens 2003; Fuller *et al.* 2014; Figure 6.9).

What is clear from Figure 6.9 is that smaller households can be recognized in archaeological assemblages by relatively high percentages of

(small) weeds. Weeds, and especially small weeds are removed during the early stages of post-harvest processing (Hillman 1984; Figure 6.8), so they will be most prominent in daily post-storage processing of unclean cereals. By the same reasoning, archaeological assemblages reflecting the processing of clean cereals from storage by larger households will contain relatively many cereal grains, and relatively many large weeds, since these are removed during later stages of harvest processing (Hillman 1984; Figure 6.8). Small households will therefore appear in the upper left region of a graph such as in Figure 6.9, whereas larger households will appear in the lower right region. Small households will thus reflect the possession of limited time and man-power, whereas the opposite might be regarded as the reflection on large(r) households. Although both household sizes cannot be directly translated into family size, they do allow for the identification of relative differences between houses and their (post-) harvest practices.

Storage

Types of storage area

Storage areas for the harvested cereals needs to be dry, well-ventilated, and of a size that is sufficient for maximum possible harvest yields, as these may vary annually. In addition, cereals stored in storage areas should be protected from pests. In Romania and Slovakia, grains are stored in wooden chests, or, in the past, they were stored in wattle-and-daub containers or hollowed-out tree trunks. These were stored in the attic above the living area of the house (Hajnalová & Dreslerová 2010: 184, 190). Cereal grains can be stored in this manner for two to three years. Alternatively, but only sporadically, grains can be kept in textile bags, but this only allows storage for shorter periods of time (Hajnalová & Dreslerová 2010: 185, 190).

Bronze Age examples of storage possibilities for cereals include wooden containers, ceramics or leather sacks hung from the ceiling, such as was observed at several locations in Bronze Age Denmark (Andreasen 2009, 55 and references therein). Often, the living area and also potential storage location of grains in Bronze Age Denmark was thought to be in the western part of the house (Andreasen 2009, 55). Harvests can also be stored without containers in a silo underground, but in areas with a very high water table this practice is not expected.

Other archaeological examples of storage locations mostly include separate outbuildings such as granaries, in which the grain is elevated from the ground.

Size of storage area

When it is assumed that the emmer yield lies around 1.7 t/ha, losses not included, and the harvest is stored in spikelet form (like in Romania and Slovakia), the maximum space necessary for emmer storage would be around 2.2 m^3/ha (using the weight to volume conversion of wheat as a guidance; Weight to volume conversion 2016). Similarly, if the yield of barley is considered to be around 1.2 t/ha, an additional maximum of 2.0 m^3/ha would be required to store barley (using the conversion values of barley grains a guidance; Weight to volume conversion 2016).

Based on the ethnographical parallels, a small farm would cultivate around 1.8 ha, which means that a maximum of 4 m^3 of space would be required per household to store the grain. Storage in ears or sheaves would require a much larger area.

6.3.5 Arable field soil conditions and locations

Environmental conditions

The growth of a plant is dependent on the fertility of the soil as well as other abiotic environmental characteristics. Water availability and adequate temperature are required in order for a seed to germinate, and remain important environmental factors throughout its life: drought and cold are conditions in which only specialized plants can survive. Salinity and acidity are two further environmental factors which can limit plant growth; most plants require fresh, non-acidic water conditions in order to grow. Furthermore, amongst other important nutrients in the soil, nitrogen can affect plant growth positively or negatively, depending on the species. Finally, phosphate is important as an energy provider for the plant. These various abiotic factors all influence the growth of a plant. Generally, the most beneficial growing conditions for most plants are moist

soils, warm temperatures, a pH of 5.5-7.0, and ample available nitrogen and phosphate.

Soil fertility

The fertility of a soil is not only expressed in the amount of nutrients in the soil. Fertility is basically the characteristics of a soil in relation to the accessibility to the abiotic factors mentioned above. Fertile soils are characterized by being able to retain enough moisture for plant growth, but also allow enough water to seep through to deeper levels in order to prevent rotting of roots. Nutrients should also be retained in the topsoil to increase their accessibility to plant roots.

Sandy soils are usually deemed unfertile due to their loose structure and their inability to retain enough water and nutrients for a plant. Manure is often added to sandy soils to improve their water and nutrient retaining properties. Most clayey soils on the other hand, are fertile due to their very fine structure and ability to retain enough water and nutrients. The fertility of clay soils however, depends on the structure. Although rich in nutrients, heavy clay soil can also be classified as unfertile because access to water and nutrients is prevented by its dense structure. Manure is often added to improve/ aerate the structure of clayey soil, but not necessarily for the addition of nutrients.

Manuring

Manuring is a practice which entails the application of (plant or animal) fertilizer to an arable field in order to improve the fertility of the soil. Fertilizing a soil can include adding nutrients to the soil, improving its aeration, its water retention, and its crumbling characteristics, which are all necessary soil characteristics for adequate plant growth (Lynden & Bakker 1990, 215-30).

Manuring is however, not always practiced, since it is dependent on the available time, labour force, condition of the soil, and presence of (enough) domestic animals. In Spain, the quantity of manure produced by domestic animals was insufficient to manure all the fields. Different fields were therefore manured in different manners and emmer wheat fields were not manured at all because this would cause lodging (*i.e.* flattening to the ground due to wind and rain) of the crop (Peña Chocarro 1995: 93-4, 113). In another area of Spain, animal manure was mixed with household waste, plants, and ash during winter (Peña Chocarro 1995, 94). In Tanzania, farmers only applied manure to the fields when forced to intensify their crop husbandry regime, reverting back to no manuring directly after colonial pressure was released. When abundant land is available, letting fields lie fallow is preferred over manuring, since the practice of manuring is very high in labour input (Meertens *et al.* 1995, 77). Farmers would need to apply 7.5-20 t/ha of manure to their fields; an investment in time and labour many could not muster. Even today, people in Tanzania usually do not apply manure to their fields, stating that the clayey soils are fertile enough (Meertens *et al.*1995, 78).

Romanian farmers traditionally used farm-yard manure for garden plots and for spring barley. Manure was transported to the fields and ploughed into the soil as close after the previous harvest as possible. One cow was said to produce just enough manure for 1 ha, and when enough manure was available, it could also be used for meadows. Still, manure was not applied to all arable fields, especially when the crop was not primarily grown for cereal grain but for its straw (Hajnalová & Dreslerová 2010, 176).

In Slovakia, many plots are not manured either. When manure is applied, it is usually for a specific crop and only takes place every four years, depending on the crop rotation strategy. Alternatively, during fallow years, sheep pens could be circulated around the fallow fields to manure the plot in that manner (Hajnalová & Dreslerová 2010, 189). Clearly, the use of animal dung and household waste for manuring expected based on Boserup's model on short fallow systems, is not applied everywhere.

Location of arable fields

Similar to arable field size, the location of arable fields can be dependent on many factors, including available suitable land, population density, technology, and social organisation. In times of social conflict for example, farmers are known to manage

their arable land closer to the settlement than when no immediate threat exists (Meertens *et al.* 1995; section 6.3). Furthermore, a high population density and an inherent decrease of appropriate arable land may force people to cultivate fields closer to the settlement. Finally, choices made by farmers whether or not to incorporate certain technologies, such as manuring, may influence the distance of fields from the settlement due to practicality of labour and transport. In Europe in general, China, and Pakistan, the average distance of arable plots from the farm ranges from 0.3 to 2.0 km (Chisholm 1968, 46). In the Carpathian mountains of Romania, fields of subsistence farmers are located as close to the village as possible and are no more than half an hour walk away (Hajnalová & Dreslerová 2010, 172), which would translate to a maximum distance of 2.5 km from the settlement. This value is concurrent with the observations made by Chisholm, which range from 0.7 to 2.5 km (1968, 46).

6.3.6 Seasonality

Ploughing, burning, stubble grazing, manuring, weeding season

Ploughing occurs either once or twice a year. After the harvest, somewhere in the period from August to October, fields may be grazed by livestock, after which the fields are ploughed relatively deeply in order to remove the remains of the previous crop. Alternatively, stubble is burned. Manuring of fields usually occurs directly after harvest and is ploughed into the soil with the autumn ploughing. Spring sowing requires additional ploughing or harrowing, albeit more shallow than in autumn, which occurs as close to sowing as possible, somewhere from March to April. Weeding might occur one to three times in spring, depending on field location and land use intensity (Hajnalová & Dreslerová 2010, 176-7).

Sowing and harvesting season

Cereal crops can be sown during two periods of the year: in autumn or in spring. Autumn sowing involves sowing the seeds before the winter, in September-November, in which the seed lay dormant (only frost tolerant varieties) until germination in early spring. Cereals sown in autumn are called winter cereals, and experience a longer growing season. Therefore, the advantages of these cereals are that they have a high yield, and they can be harvested early in the year (June-July) (United States 1997).

Summer cereals on the other hand, are sown in early spring (February -March) after the worst wetness and cold of the winter have passed. These cereals have a shorter growing season and often a lower yield than winter cereals, and are also harvested later in the year (late July-early September) (United States 1997).

6.3.7 Summary and additional main components

Crop husbandry practices were researched with the aid of ethnographical and ethnobotanical parallels, which has resulted in general characteristics of such practices in small-scale mixed farming communities. The land use is usually more or less extensive, under a short fallow regime. In addition, farmers have small garden plots which they work more intensively. The size of the arable fields ranges from 1-3 ha per household, with an average of 1.8 ha, and this arable land is often divided into smaller plots. The shape and distribution of such fields is expected to consist of a system of fields of varying shape and size; a Celtic field system, as observed on the Pleistocene deposit areas in the Netherlands, is not presumed. Based on both ethnography and archaeology, it is clear that fields need not necessarily possess clear demarcations.

The crops available during the Bronze Age mostly consist of cereals. Based on comparisons with north-west European areas, an emphasis on hulled barley is expected, followed by emmer wheat. Furthermore, minor additions of spelt wheat, einkorn, broomcorn millet, and free-threshing wheat can be expected. Pulses and legumes are scarce, and it is not expected that many species are present, perhaps only in the Late Bronze Age. From the oil-containing crop plants, linseed/flax and perhaps gold-of-pleasure might be present.

Arable fields are ploughed in autumn, and, in the case of postponed ploughing and/or spring sowing, they can (also) be ploughed in spring. In spring, the ploughing occurs at a more shallow level than in

autumn. Ploughing occurs by using a pair of cattle for traction, which could have been either cows or oxen. Smaller fields or gardens are worked by hand using hoe and rake. Alternative or even complementary methods to ploughing may include no tillage (under the influence of flooding in winter and breaking of the soil in summer) or stubble burning after harvest. Finally, land can be left to lie fallow for a few years, in order for soils to regenerate. In the short fallow system assumed here, fallow periods last one or two years at most.

Sowing of crops is expected to be performed by sowing multiple species in furrows or by broadcasting, due to the fact that their relatively small seeds are hard to handle over large areas. Per household, it is expected that on average 270 kg of grain is sown each year, during spring or autumn. The best grains are retained from the previous harvest to ensure a good quality sowing crop. The presence of maslin crops is an option, because they allow the farmer to spread the risk, which might be helpful in a dynamic environment. However, when it is assumed that farmers used crop residue for other purposes, maslin crops will have prevented the adequate separation of straw for animal fodder (barley) and for raw material (emmer wheat). Weeding is usually performed several times during the growth of the crop, and rotation of crops can occur by alternating cereals with pulses and fallow periods.

Harvesting is often performed by low reaping or uprooting, and will be performed simultaneously by multiple people. Harvest yields are expected to lie around 3,000 kg for emmer wheat, or 2,000 kg for hulled barley. These values are on an annual basis per household. The crop yield factor (*i.e.* input vs. output of sowing) for small-scale farming communities lies around 1:8, after harvest losses. Harvest losses can be severe and amount, on average, to more than 20%, due to transport and processing procedures.

Harvesting processing is mostly dependent on available man-power and time, and these factors influence whether crops are stored as sheaves, ears, or spikelets. The difference in how grains are stored can thus inform about the original harvesting conditions and possible variation in practice between households or settlements.
Storage most often occurs indoors above the living area of the house, since dry, elevated, and well-ventilated storage space is required. Also, the valuable staple crops can be easily guarded and accessed for further processing. The grains of the sowing seed may have been kept in wooden or wattle-and-daub containers or something similar to keep pests out and to ensure longer storage life. Cereals for consumption may have been kept in textile containers or containers made of a more sturdy material. Storage in ceramic containers might also be a possibility. The total storage area for grain in spikelets for one household measures around $4m^3$, with higher demands for grains stored in sheaves or ears.

Many environmental conditions can affect a growing crop, of which water, temperature, salinity, acidity, and nitrogen are amongst the most important factors. Ideal soil characteristics for cereal growth include a moist soil with an average pH value of 5.5-7.0, and high in nutrients (especially nitrogen). Soil fertility is achieved by a combination of soil characteristics and availability to the environmental factors. In clayey soils, manuring may have ensured fertility of the soil, not by adding nutrients, but by aerating the soil and thus increasing the accessibility of nutrients to crops. The location of arable fields is normally relatively close to a settlement and they are rarely situated more than 2.5 km away.

Most of the expected aspects related Boserup's short fallow land use system are consistent with the ethnographical small-scale crop husbandry practices. However, as is clear from the Romanian example, weeding and manuring may not always be applied to a high extent.

The system is very comparable to most practices, so it will be the employed model for comparison with the West Frisian data.

Finally, also in this chapter the detailed investigation of crop husbandry practices has brought forth an additional main component, in this case regarding post-harvest field tending. This main component is added to the list of main components of the current model, and is challenged in section 6.5:

(8) Stubble burning may have been applied to clean arable fields after harvest for the subsequent sowing season.

6.4 WEST FRISIAN DATA ANALYSIS

This section is focused on the analysis of the West Frisian data, keeping in mind the different basic aspects of crop husbandry recognized in section 6.2 and 6.3. The analyses presented here are performed on both old and new data, and include both conventional archaeobotanical analyses such as the assessment of crop composition, seasonality of sowing, harvesting height, and arable field soil conditions, but also some new analyses including the investigation of social organisation with regard to harvesting practices and storage. After these analyses, a thorough assessment is provided of the effect of archaeological methodology, taphonomy, and other factors on an botanical assemblage (section 6.4.8). By elucidating such factors, and keeping this in mind during interpretation, the results of this chapter yielded a clearer image of past human selection and practice.

6.4.1 Arable fields and crops

Arable fields

Throughout West Frisia, evidence for ploughing in the form of *ard* marks were uncovered. Although providing rare and valuable information on the practice of ploughing in the Bronze Age (section 6.4.2), these marks cannot be directly translated into arable field size. The first aspect that makes the interpretation of field size difficult is that ard marks are not always continuous, and usually not present over longer distances. This is due to the fact that ards only pierce the subsoil in certain instances, and the the original length of the ploughed furrow is often lost, only becoming visible during excavation as a discontinuous feature (section 6.3.1). Although discontinuous, these features do show a similar orientation, which means that their continuity may still be postulated based on this observation (see below). The second aspect that encumbers the analysis of field size based on ard marks is that clear boundaries of arable fields are not always found or recognised, or may even have been absent in the past as well. In West Frisia, also no clearly bordered arable fields were uncovered and it was therefore only possible to determine a potential minimum field size based on the ard marks themselves.

West Frisian ard marks

The most meticulously excavated site with regard to ard marks in West Frisia, Hoogkarspel Tolhuis: find spot F, was employed to create a general overview of arable field size, ploughing practices, and length of field use (cf. Roessingh in prep.). Minimal arable field size was estimated by measuring the size of the spread of ard marks with similar orientation. Ard mark orientation was portrayed by assuming perpendicular ploughing and this orientation was used to find matching ard marks throughout the settlement. Each orientation was indicated by a different colour. The simultaneous occurrence of different colours/orientations at the same locations were interpreted as multiple phases of use.

Other sites with ard marks were compared with Hoogkarspel Tolhuis to draw conclusions for West Frisia in general.

Ard marks at Hoogkarspel Tolhuis, find spot F

An overview of the existing ard marks in Hoogkarspel Tolhuis find spot F, and their orientations, can be seen in Figure 6.10. What is apparent from Figure 6.10a is that there seems to be a differentiation between and within the north and south half of the excavation with regard to the orientation of the ard marks. Each of the different colours of ard marks observed in Figure 6.10a presumably indicates a different use phase in which the orientation of ploughing is slightly different to the previous year. Orientations which are not observed at other locations may indicate a different arable field altogether (Roessingh in prep.). In this manner, five of such orientation differences were recognised by Roessingh in an attempt to identify different fields present at Hoogkarspel Tolhuis find spot F (Figure 6.10a). The sizes of these arable fields are as large as 75 x 75m.

Several of the most densely marked areas of the excavation were examined in more detail (*e.g.* Figure 6.10b). Almost every area with ard marks

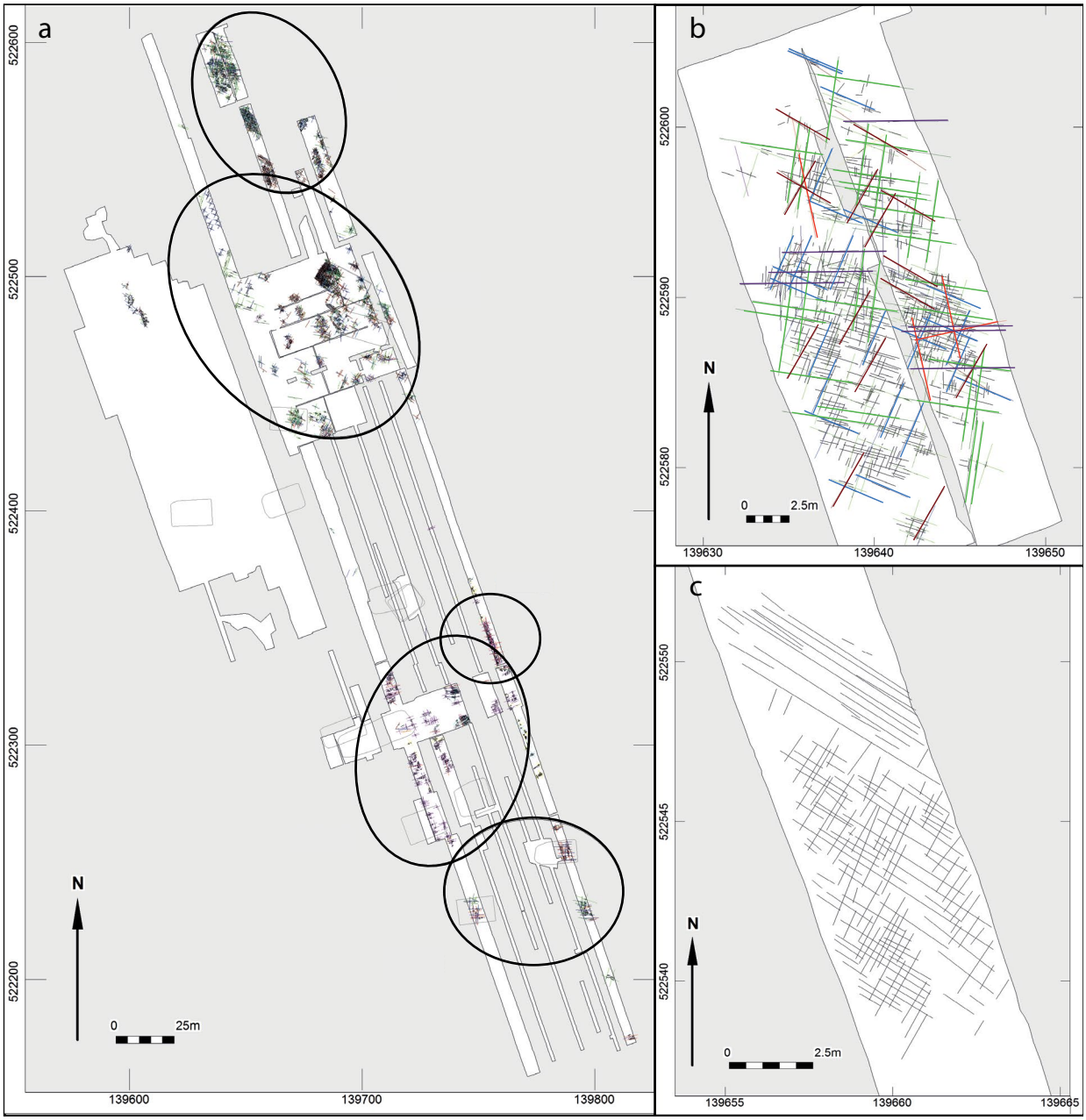


Figure 6.10. Ard marks from Hoogkarspel Tolhuis F; a: overview of the ard marks and their orientations; circles denote possible arable fields (cf. Roessingh in prep); b: detail of the different orientations of ard marks (centre); c: an example of a possible field boundary can be observed, which was similar to Bronze Age field boundaries from Denmark (cf. Figure 6.5).

showed multiple orientations, indicating that arable fields were used for more than one phase, and up to six phases (Figure 6.10b). How long each use phase lasted is unknown, but in general, the ard marks could be relatively dated based on other features to the Early Middle, Middle, and Late Bronze Age (pers. comm. W. Roessingh), indicating the use of the same arable fields over long periods of time.

No clear boundaries of arable fields have (yet) been established, but several examples of possible boundaries do exist. Comparisons with field boundaries in Denmark (*i.e.* parallel ploughing) were found at several locations in Hoogkarspel (*e.g.* Figure 6.10c). Possible boundaries did not occur on all sides, which meant that the exact size of the arable fields could not be measured, but as already mentioned, the minimal field size based on the ard marks was around 75 x 75 m. This minimal field size translates to around 0.6 ha and is slightly larger than the observed field sizes based on ethnographical parallels, but it does concur with the expected size of Bronze Age arable fields based on expected nutritional requirements (cf. Fokkens 1991, 157; Bakels & Zeiler 2005; section 6.3.1).

However, 0.6 ha is hardly enough to sustain one family, let alone an entire settlement, so it must be concluded that more and possibly larger fields must have been present around the settlement, such as was observed at Noorderboekert, West Frisia (section 6.3.1).

Crops

Crop composition

The botanical remains from the West Frisian (WF) sites (including Bovenkarspel Het Valkje, Enkhuizen, Hoogkarspel Tolhuis, Hoogkarspel Watertoren, Hoogwoud, Westwoud, Medemblik Schepenwijk II, and Twisk) were compared with the data presented by Stika and Heiss for the Bronze Age in Europe (Stika & Heiss 2013; Table 6.4). Similar to their research, the West Frisian botanical remains derived from all the different kinds of settlement contexts, and included all states of preservation. Unfortunately, no botanical remains of the EBA were analysed in West Frisia so far. Therefore, only the MBA and LBA remains are available for comparison. The results are summarized in Table 6.5. Mainly emmer and barley are discussed in this part of the research (Appendix A1.9), since the other crops were most likely of secondary importance to the food economy. These other crops, including broomcorn millet (*Panicum miliaceum*) and linseed/flax (*Linum usitatissimum*) (Appendix A1.9), are only shortly discussed where appropriate in the main text, but their importance to subsistence in other ways, and the reasons why they are most likely not contributing much to the food economy are discussed in more detail in sections 6.4.8.2 and 6.4.8.4.

Bronze Age

When comparing West Frisia with the other regions, several things stand out. First of all, throughout the two periods, emmer seems to be just as dominant or even more dominant than barley in West Frisia, whereas in other regions, barley is the dominant crop. Since these crops are most frequently and constantly identified, the main focus of the crop husbandry practices in subsequent sections is on these cereals. Other crops are shortly discussed in the various sections in 6.4.8.

Middle Bronze Age

In the Middle Bronze Age, most cereal crops, except emmer, follow the pattern of southern Scandinavia and the North Sea coastal sites. However, in West Frisia, linseed appears to be more frequent, and one charred flower base of cultivated oat was found in Medemblik Schepenwijk (Schurmans 2010, 227). In addition, several records of wild oat (*Avena fatua*) were made in Bovenkarspel Het Valkje and Westwoud (Buurman unpublished data; Buurman 1996, 118-9) and remains of oat species in general (*Avena* spec.) were frequent, also in house ditches, which may be related to its other use: fodder (see section 6.4.8.4). Pulses were, as expected, mainly absent from West Frisia in the Middle Bronze Age, which is comparable to the Southern Scandinavian and North Sea Coastal situation. Still, remains of vetch (*Vicia* spec.) were frequent, especially in house ditches. Finally, the presence of linseed/flax was higher in West Frisia than in both of the other regions. Broomcorn millet was also found, but in low frequencies at both Bovenkarspel Het Valkje and Hoogkarspel Watertoren.

Table 6.5. Comparison of West Frisian cultivated plants compared with the neighbouring regions in Europe.

		MBA			LBA		
Taxa	**English name**	**SSc and NSC**	**WCE**	**WF**	**SSc and NSC**	**WCE**	**WF**
Cereals							
Hordeum vulgare	Barley	+++	+++	+++	+++	++	++(+)
var. *vulgare*	Hulled barley	+	+	+	+		+
var. *nudum*	Naked barley	+	+/-	+/-	+		+/-
Triticum dicoccum	Emmer wheat	++	++	+++	++	++	+++
Panicum miliaceum	Broomcorn millet	+/-	+	+/-	+/-	++	+/-
Avena sativa	Oat	-	-	+/-	+/-	+	-
Pulses and Legumes							
Vicia sativa	Common vetch	-	-	+/-	-	+/-	-
Oil-containing Plants							
Linum usitatissimum	Linseed/ Flax	+/-	-	+	+	+/-	+/-
*Brassica rapa**	Field mustard	?	?	+/-	?	?	+/-

In this table, only species that have been found in West Frisia are mentioned. The species that were not found here, but were in the other areas, can be observed in Table 6.4 instead. *Although field mustard (*Brassica rapa*) is included in the table as a potential oil-containing plant, as it has been cultivated for this property from Roman times onwards (Weeda *et al.* 1987, 46), many varieties of these plant exist that are only exploited for their vegetative parts. Therefore, for the Bronze Age it is considered to have been collected for this latter purpose (see Chapter 8). +++=dominance, ++=subdominance, +=present, +/-=low amounts, -=absent (adapted from: Stika and Heiss 2013, 358-9).

Late Bronze Age

The West Frisian Late Bronze Age is characterized by the presence of very few cultivated crops. Only barley and especially emmer were found, with minor evidence for broomcorn millet, linseed, and narrow-leaved common vetch. In this respect, West Frisia still resembles Southern Scandinavia (SSc) and the North Sea coast (NSC) the closest, although here, at least some records of other cereals and the oil-containing crop gold-of pleasure were made. A reason for the low amount of crop plant species in West Frisia could be that the Late Bronze Age contexts are far less prevalent than those from the Middle Bronze Age (n=173 and n=23, respectively) decreasing the chance of finding the more obscure plant species which were uncovered in the other regions. Field mustard (*Brassica rapa*), of which varieties have been cultivated for their oil since Roman times (Weeda *et al.* 1987, 46), was uncovered at comparable frequencies to linseed/flax. However, in this research, this plant is considered to be collected for its vegetative parts (*i.e.* wild turnip variety) during the Bronze Age (cf. Chapter 7, section 7.4.2).

Broomcorn millet and linseed/flax, which were also present in the Middle Bronze Age, seem to be stable or decreasing in frequency, although this latter observation may be related to the fewer amount of samples available for the Late Bronze Age.

Overall, West Frisia seems to resemble the southern Scandinavian and North Sea coastal sites the closest. The focus lies on cereal crops, with a clear dominance of emmer over barley, whereas pulses and oil-containing crops only occur in low frequencies throughout the Bronze Age. The reason for a dominance of emmer wheat might be related to environmental conditions, human preference or selection, or yield/ha. Environmental conditions are however not likely to have influenced the shift to emmer, since the conditions of the arable fields remains largely the same throughout the Bronze Age (section 6.4.5). The marked presence of wild oat, and several types of vetch (*i.e. Vicia* spec., *Vicia hirsuta*, *Vicia sativa* ssp. *angustifolia*) might point towards the exploitation of these types of wild plants rather than cultivating pulses and oil-containing plants on the settlement (see Chapter 7, section 7.4.2.1 and 7.4.5).

Intensive vs. extensive and gardens vs. fields

In West Frisia, no definite boundaries of settlements have been identified. This indicates that not many clear off-site situations have been excavated, which hinders the analysis of how intensive crop cultivation was. It is, for example, unclear exactly how far arable fields were situated from the houses; it is hard to assess whether ard marks and other features are contemporaneous due to a lack of overlapping features (section 6.4.5). At the Early Bronze Age site of Enkhuizen Rikkert, however, a large area of ard marks was uncovered without clear indications of habitation. This observation shows that at least during this time, fields were situated further away from the houses. Based on this single example it is hard to assess the intensiveness of crop husbandry. However, the close proximity of Middle Bronze Age settlement sites (Figure 6.1) does indicate that at least during this period, fields could not have been situated too far from the settlements, which is more compatible with intensive crop husbandry practices. Still, it was not possible to evaluate the level of intensiveness of crop husbandry practices during this period or the Late Bronze Age based on features and relative distances. The absence of only annual crop weeds in both periods (section 6.4.2) does however indicate that intensive crop cultivation was occurring in the (later) Bronze Age throughout West Frisia.

Besides the presence of borders, the presence of garden cultivation could also not be established. The absence of indications for garden cultivation might very well be related to the fact that if gardens were cultivated, it was most likely done by hand (*e.g.* with a hoe; section 6.3.1), which often leaves no recognisable features in the soil. Since hand tools usually protrude less deep into the ground than a plough, evidence for their use may only be uncovered by micro-morphological analysis (Huisman & Raemaekers 2014). Another reason why gardens are difficult to recognise is the fact that in these plots, often other types of crops are cultivated such as root crops and vegetables (section 6.3.1), which are also almost never found archaeologically. Therefore, it could not be assessed whether gardens were cultivated in West Frisia.

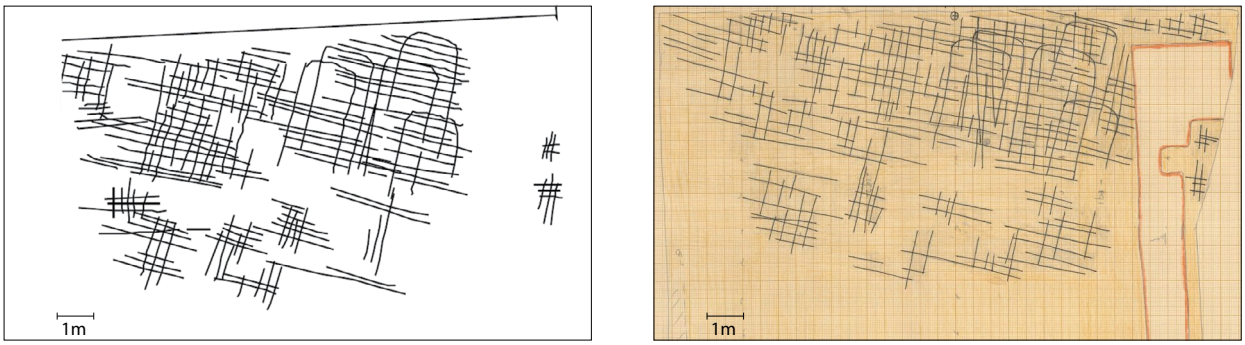


Figure 6.11. Examples of features interpreted as possible turning points uncovered at Bovenkarspel Het Monument. The turning radius observed however, is too small for cattle with plough (Appendix A1.10). a: digitalized image of the plough marks at Bovenkarspel Het Monument; b: scan of the original field drawing of the the plough marks at Bovenkarspel Het Monument.

6.4.2 Soil preparation

Ploughing

The presence of ard marks from different phases throughout the Bronze Age at almost every site indicates that ploughing occurred regularly in West Frisia.

A possible interesting insight into past ploughing practices was observed at the excavation Bovenkarspel Het Monument (Roessingh in prep.). Here, five possible marks of the turning point of an ard were excavated, indicating that a pair of cattle and the plough may have turned at this point to continue ploughing in the opposite direction (Figure 6.11a). In order to assess whether indeed these features could be related to the turning of a cattle pair and ard, the turning radius of such a configuration was calculated (Appendix A1.10). Under the assumption that the cattle pair turned with the plough remaining in the soil during the turn, which would results in a continuous feature as observed in Figure 6.11a, the minimal turning radius of cattle pair and plough would be ca. 3.5-5.0 m (Appendix A1.10). This radius is of comparable relative size to radii observed with larger traction animals (ca. 5.0-7.0 m: Lerche 1986, 139-142). The calculated turning radius of a cattle pair and plough is, however, far too wide to match the 0.75 m radius observed in Figure 6.11. Other reasons why the marks observed at Bovenkarspel Het Monument most likely do not represent turning points are that in the original field drawing (Figure 6.11b) the turning point angles are intermixed with continuing vertical plough marks, and additional horizontal marks are visible to the north of the turning points, neither of which would support the hypothesis that the turning points represent the border of an arable field.
Alternative principles of turning a plough are observed in other areas of the world even today, where simple ploughs such as the ard are lifted from the ground at the field border and are again placed into the soil when the turn is completed (Varisco 1982, 167; Lerche & Steensberg 1983, 237; Schjellerup 1986, 185). Such a practice remains invisible in the archaeological record, because the turning process cannot be recorded in the soil. Perhaps this is a more appropriate option for the ploughing practices in Bronze Age West Frisia, at least until other plausible evidence for turning points are observed. The observed features at Bovenkarspel Het Monument remain unclear in their original function, but can for now be ruled out as turning points.

Burning

Burning of arable fields after harvest can be considered a plausible crop husbandry practice in West Frisia. This was established by the analysis of a Bronze Age arable field, which contained a black layer in the soil, which is seen at many West Frisian excavations. The arable field soil was analysed with the aid of pollen analysis, phytolith analysis, and micro-morphological analysis. Both the pollen analysis and the micro-morphological analysis have identified the presence of charcoal particles in the arable field layer. Phytolith analysis has also shown

that phytoliths from grasses (Pooideae) were present in the layer, although it could not be established with certainty that those were cereals. However, the fact that the phytoliths were discoloured black in a sample from an arable field indicates that vegetation on the field was burned. Stubble could have been burned, or, alternatively, the vegetation on the arable field may have been burned after a fallow period. Regardless of the type of vegetation burned, arable field burning appears to have been practiced in West Frisian Bronze Age crop husbandry. The extent of this practice and more details regarding the practice will have to become apparent after more (micro-morphological) research has been completed (Pronk in prep.).

Crops in West Frisia were most likely harvested at a maximum height of 40-60 cm (section 6.4.3). For adequate crop stubble burning, at least 3-4 inches (*i.e.* 7-10 cm) of material needs to be left on the field in order to allow for adequate burning (Kansas Forage Task Force 1998). It seems that the height of the stubble in West Frisia would have allowed for stubble burning.

Fallow

The presence of fallow periods is assessed in archaeobotanical assemblages by the presence of perennial crop weeds. Such weeds, as opposed to annual weeds, live for more than one year. When these perennial crop weeds are found amongst the grain on a settlement, it means that they were able to reach maturity and that the arable field where they originated experienced years in which ploughing or weeding did not occur (*i.e.* fallow).

In West Frisia, the crop weeds from every Middle and the Late Bronze Age site were annual weeds (Table 6.6). This implies that (near-)continuous cultivation was occurring during this time. Based on these results, it is highly possible that the method ofcultivation practiced by West Frisian farmers tendered towards Boserup's annual cultivation land use model (Table 6.3). The close proximity of settlements to each other (section 6.4.1) also indicated the probability of more intensive cropping practices than was expected.

6.4.3 Cultivation

Sowing

Spring or autumn sowing?
The sowing season of cereal crops can be reconstructed based on the composition of accompanying crop weeds. Only crop weeds deriving from locations related to arable fields (*i.e.* eco group 1a and 1c[11]; Tamis *et al.* 2004) were used, therefore excluding plants such as fat hen (*Chenopodium album*) and fig-leaved goosefoot (*Chenopodium ficifolium*), which belong to eco group 1e. The results are summarized in Table 6.6 for both the Middle and Late Bronze Age. Enkhuizen Kadijken is only represented by Middle Bronze Age remains.

Middle Bronze Age
The most frequently found weeds are chickweed (*Stellaria media*), black nightshade (*Solanum nigrum*), red leg (*Persicaria maculosa*), barnyard grass (*Echinochloa crus-galli*), field speedwell-type (*Veronica agrestis-type*[12]), and prickly sow thistle (*Sonchus asper*). Chickweed is a summer/winter annual, which would not give consistent indications of time of sowing crops, similar to field speedwell. Black nightshade, red leg, and barnyard grass however, are summer annuals, which grow together with spring-sown crops. The combination of these weeds therefore points towards spring sowing.

Late Bronze Age
In the Late Bronze Age, the assemblage of crop weeds changes very little. The only change visible is a decrease in the number of species in comparison to the Middle Bronze Age. This however, can be attributed to the lower amount of Late Bronze Age samples.

11. Eco groups reflect the general preferred location at which a plant occurs. The used eco groups here are 1a: arable fields on nutrient-rich, non-calcareous soil; 1c: arable fields on medium nutrient-rich, poor calcareous soil; 1e: brushwood on rarely trodden, nutrient-rich, non-humous or calcareous, dry soils (after: Tamis *et al.* 2004; also see: Chapter 7, Table 7.4).
12. Includes the species field speedwell (*Veronica agrestis*), grey field speedwell (*Veronica polita*), and dark speedwell (*Veronica opaca*) based on morphological characteristics.

Middle Bronze Age				
Taxa	**English name**	**Life cycle**	**Summer/winter crop weed**	**Height range (cm)**
Anagallis arvensis	Scarlet pimpernel	Annual	Inconsistent	5-50
Chenopodium polyspermum	Manyseed goosefoot	Annual	Summer?	10-80
Echinochloa crus-galli	Barnyard grass	Annual	Summer	10-120
Euphorbia peplus	Petty spurge	Annual	Summer?	7-30
Fallopia convolvulus	Black bindweed	Annual	Summer?	100-120
Fumaria officinalis	Fumitory	Annual	Summer?	10-50
Lamium purpureum	Red/Purple deadnettle	Annual	Summer?	10-30
Persicaria maculosa	Red leg	Annual	Summer?	20-100
Silene gallica	Common catchfly	Annual	Summer?	15-50
Solanum nigrum	Black nightshade	Annual	Summer?	5-60
Sonchus asper	Prickly sow thistle	Annual	Summer	30-60
Stellaria media	Chickweed	Annual	Inconsistent	10-40
Urtica urens	Annual nettle	Annual	Summer	15-60
Veronica agrestis-type	Field speedwell	Annual	Summer?	7-30
Veronica hederifolia	Ivy-leaf speedwell	Annual	Summer?	5-30
Veronica persica-type	Birdeye speedwell	Annual	Summer?	15-30
Vicia hirsuta	Hairy tare	Annual	Summer?	15-60
Late Bronze Age				
Echinochloa crus-galli	Barnyard grass	Annual	Summer	10-120
Fallopia convolvulus	Black bindweed	Annual	Summer?	100-120
Persicaria maculosa	Red leg	Annual	Summer?	20-100
Solanum nigrum	Black nightshade	Annual	Summer?	5-60
Sonchus asper	Prickly sow thistle	Annual	Summer	30-60
Stellaria media	Chickweed	Annual	Inconsistent	10-40
Urtica urens	Annual nettle	Annual	Summer	15-60
Veronica agrestis-type	Field speedwell	Annual	Summer?	7-30
Vicia hirsuta	Hairy tare	Annual	Summer?	15-60
Vicia hirsuta/ tetrasperma	Hairy/smooth tare	Annual	Summer?	15-70

Since the crop weed composition is practically the same, spring sowing is also assumed for the Late Bronze Age.

The likelihood of summer crop cultivation, and therefore spring sowing, was also indicated by the presence of cultural landscape-related bird species which prefer this crop variety over winter crops as a habitat for nesting during breeding season (Chapter 2, section 2.4.5.3).

Sowing practices
The reconstruction of actual sowing practices was not possible, since sowing regimes cannot be identified in the archaeological record. Due to the inherent characteristics of smaller seeds such as emmer and barley grains (cf. section 6.3.3) it is assumed that broadcasting was the sowing method used. Seeds would subsequently have been covered with soil by harrowing, for example.

Maslin
Although emmer wheat and hulled barley were often found in comparable frequencies (Table 6.5), it is not assumed that maslin crops were cultivated. The relatively low reaping height of crops (see Harvesting below) indicates that people may have used the straw of crops for different purposes (cf. section 6.3.3). Sorting the straw after harvest will have been a tedious task which is easily avoided by growing different crops on separate fields.

Rotation

Pulses and legumes, which are often used to replenish nutrients in arable fields after cereal cropping, are rare in West Frisia in the Bronze Age, and throughout the North Sea coast and southern Scandinavia (Table 6.5). It was therefore not possible to establish a possible rotation scheme of crops.

On the left: Table 6.6. Crop weed species identified in West Frisian house ditches (MBA and LBA). Summary of remains from the sites Bovenkarspel Het Valkje, Westwoud, Enkhuizen Kadijken, and Medemblik. Crop weed composition was overall comparable at each site.

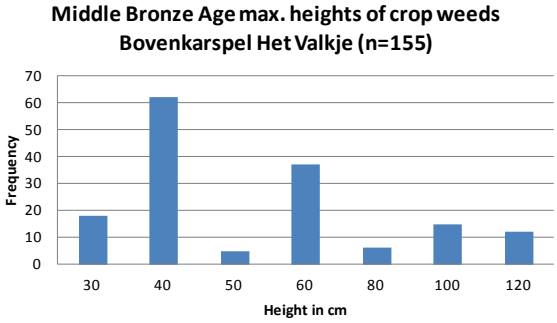


Figure 6.12. Overview of the maximum height of the crop weeds from Bovenkarspel Het Valkje for the Middle Bronze Age; n=155.

Weeding

Several species of crop weed were identified amongst the charred grains in house ditches (Table 6.6).
It can therefore be assumed that weeding was not intense enough to reduce the frequency and species range of the weed species observed.

Harvesting

The height of harvesting can be assessed by the maximum height of accompanying crop weeds. The results of four West Frisian sites are summarized below for both the Middle and Late Bronze Age (cf. Table 6.6).

Middle Bronze Age
The lowest maximum crop weed height identified is 30 cm at nearly every site, followed by a high frequency of crops with a maximum height of 40 cm (Figure 6.12-Figure 6.15). These low maximum heights could point towards harvesting practices where the stems of the crops are cut/removed relatively low, especially considering the low minimum crop weed heights as well (Table 6.6). Harvesting techniques could include reaping low with the use of a sickle or uprooting entire plants. The only high crop weed found (reaching 100-120 cm) is black bindweed (*Fallopia convolvulus*). This is a winding plant, easily collected during the harvest regardless of harvesting technique as it is attached to the cereals.

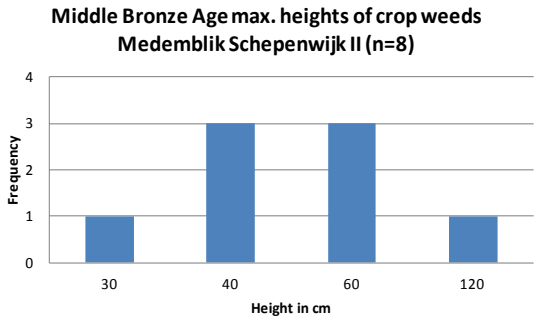


Figure 6.13. Overview of the maximum height of the crop weeds from Medemblik Schepenwijk II for the Middle Bronze Age; n=8.

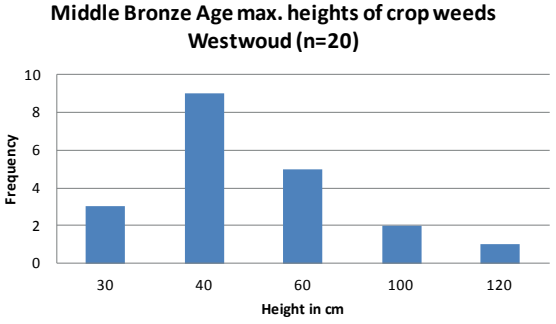


Figure 6.14. Overview of the maximum height of the crop weeds from Westwoud for the Middle Bronze Age; n=20.

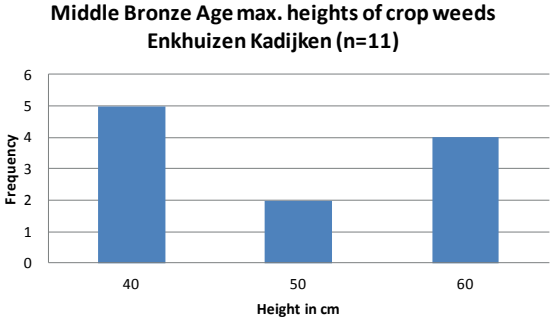


Figure 6.15. Overview of the maximum height of the crop weeds from Enkhuizen Kadijken for the Middle Bronze Age; n=11.

Late Bronze Age

Markedly few botanical remains were found for the Late Bronze Age in comparison with the previous period, so results must be interpreted with care. Also, since Enkhuizen Kadijken yielded no botanical remains from the Late Bronze Age, it is not discussed here. Nonetheless, the results for the Late Bronze Age are summarized in Figure 6.16-Figure 6.18.

Although there are far fewer remains, it seems that the lowest maximum crop weed height of 30 cm is still observed in Bovenkarspel Het Valkje, followed by a high frequency of remains of crop with a maximum height of 40-60 cm and low minimum growth heights, which all still point towards harvesting practices including either low reaping or uprooting.

Reaping or uprooting?

In Westwoud, many charred culm bases were found, with roots still attached (Buurman 1996, 127-8). Although impossible to identify to species level, the concurrence of these large grass culm bases with cereal culm nodes and harvesting waste indicates that they most likely belong to cereal crops. Reeds were excluded as a possible source of the culm bases due to the absence of their indicative creeping rhizomes. These remains derived from later Bronze Age ditch contexts, dating to roughly 1200-900 BC (Buurman 1996, 113). The presence of these culm bases may provide evidence for uprooting practices. However, since many non-winding, free-standing species of crop weed were also found (Table 6.6), reaping low on the culm remains an equally plausible possibility. Still, regardless of the harvesting method, the low reaping or uprooting practice indicates the importance of the culm for other purposes such as bedding, thatching, or basketry (see section 6.4.8.4).

Manner of harvesting

Reaping of culms usually occurs with the use of sickles. However, although remains of flint sickles have been found in West Frisia, use-wear analysis has indicated that these were not used to harvest cereals (van Gijn 2010). In Denmark, similar sickles have been used for harvesting (van Gijn *et al.* 2014, 314). Besides flint sickles, bronze sickles may also have been used for harvesting, but these are rare, and only one example is known from West Frisia (van

Gijn *et al.* 2014, 315). Still, the absence of evidence for harvesting tools does not imply that they were not used/present, and the general scarcity of for example bronze finds exemplifies that many practices cannot be reconstructed based on objects in West Frisia.

Harvest yield, loss, and crop yield factor

It is not possible to accurately reconstruct the yields and losses of prehistoric crops. Therefore, the average yields and losses based on the ethnographic parallels (section 6.3.3) are assumed for West Frisia. This means an average yield of 1.7 t/ha for emmer wheat and 1.2 t/ha for hulled barley, translating to roughly 2,400 kg of emmer wheat or 1,600 kg of barley per household after detraction of 20% losses, and an assumed arable field size of 1.8 ha (cf. section 6.3.1). The crop yield factor is similarly impossible to calculate, so it is assumed that it was comparable to the 1:8 ratio observed in parallel small-scale farming communities.

6.4.4 Crop processing and storage

Post-harvest crop processing in West Frisia

The method of Stevens (Fuller *et al.* 2014) was applied to the West Frisian data to investigate the post-harvest crop processing practices in West Frisia (cf. section 6.3.4). Similar to the selections made by Stevens, a sample was only included in the analysis when it contained sufficient numbers of cereal grains (*i.e.* N > 30) and weed seeds (*i.e.* N > 20). Seeds were considered small when their dimensions were smaller than the width of a cereal grain (*i.e.* 2.5 mm). Seeds were considered large when their size exceeded 2.5 mm, or when they contained characteristics such as appearing in seed heads, possessing appendages, or any other characteristic which increased the likelihood of retention with the grain during sieving. All seed measurements were obtained from the Online Seed Database (Plantatlas 2016) and additional characteristic information from Stevens (pers. comm.). Ratios of large and small weed seeds, as well as total grain to weed seeds were calculated, and the results are shown in Figure 6.19. In this figure, all the data from all the contexts of the sites was included for both the MBA and LBA combined.

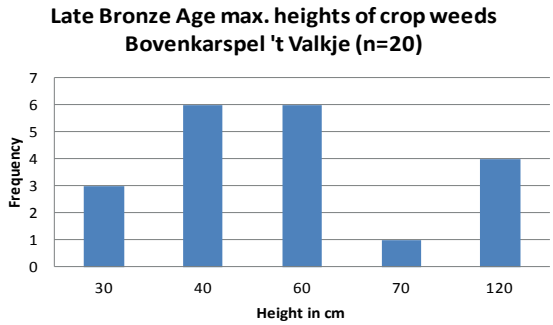


Figure 6.16. Overview of the maximum height of the crop weeds from Bovenkarspel Het Valkje for the Late Bronze Age; n=20.

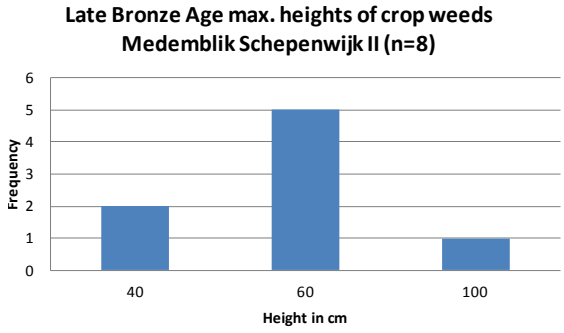


Figure 6.17. Overview of the maximum height of the crop weeds from Medemblik Schepenwijk II for the Late Bronze Age; n=8.

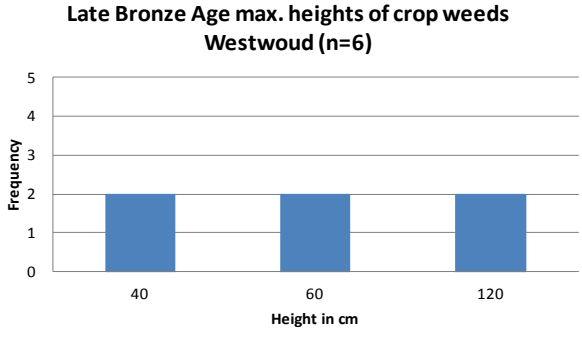
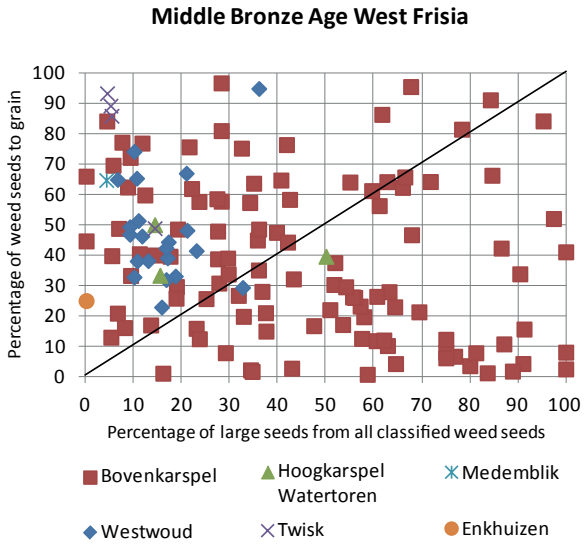


Figure 6.18. Overview of the maximum height of the crop weeds from Westwoud for the Late Bronze Age; n=6.



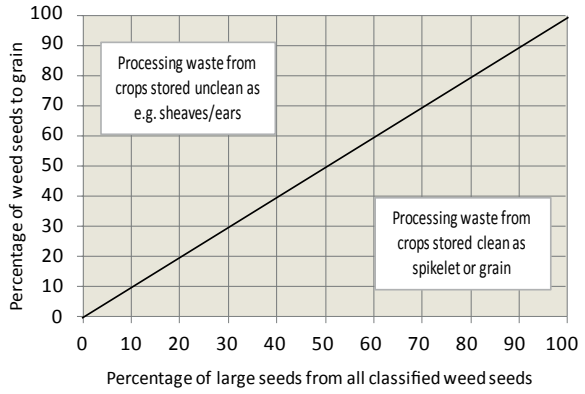


Figure 6.19. Post-harvest crop processing characteristics of all contexts from six West Frisian sites of the Middle and Late Bronze Age combined (above), and interpretative graph of Stevens (cf. Figure 6.8) for comparison (below).

What this graph of the Bronze Age in general shows is that at most of the West Frisian sites, the households can be categorised as small households (data left of the 45 degree angle line). Although most sites did not contain a large number of appropriate samples for the analysis, this small household level organisation trend seems to imply that most sites reflect settlements with houses with few inhabitants. Bovenkarspel Het Valkje however, is an exception which seems to possess both small and large household level organisations for crop

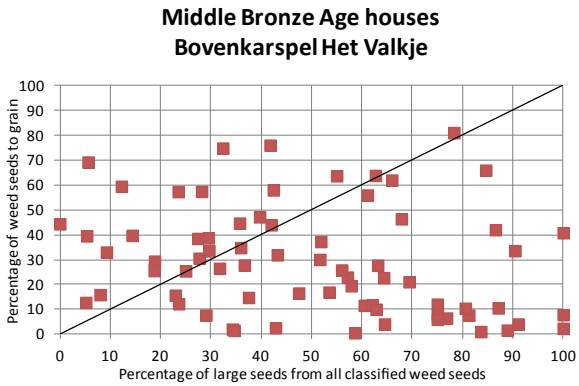


Figure 6.20. Spread of the Middle Bronze Age house data from Bovenkarspel Het Valkje. Clearly, both small and large households seem to be present during this time

processing. Therefore, it was investigated whether the differences observed in Bovenkarspel Het Valkje could be explained by differences between individual households, the location of houses at the settlement, and perhaps even time period.

Post-harvest crop processing in Bovenkarspel Het Valkje

Bovenkarspel Het Valkje has yielded many data which allowed for an in-depth comparison of crop processing characteristics. Since it is assumed that crop processing occurred in and around the house, only house contexts, in this case house ditches, were used to assess differences. The samples from house ditches were used to investigate the Middle Bronze Age situation, and the samples from ditches for the Late Bronze Age situation.

Middle Bronze Age

The data from the Middle Bronze Age houses was summarized in Figure 6.20. Of the total number of identified MBA house plans (Roessingh in prep.), only 24 were selected for analysis based on the richness of their samples. The overall spread of MBA data seems to indicate that during the Middle Bronze Age, both small and large households were present at Bovenkarspel Het Valkje.

In order to gain insight into the characteristics of the individual houses, it was assessed whether the data of each house reflected small households (samples left

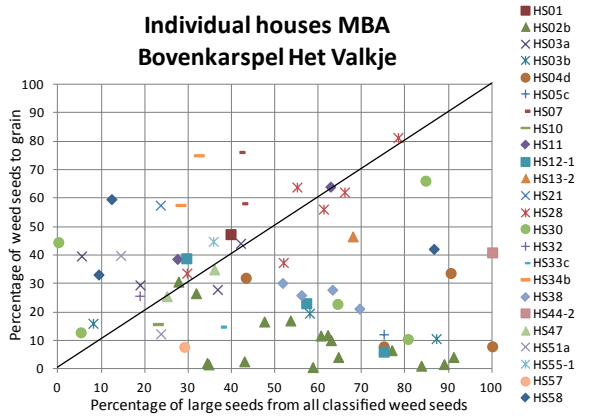


Figure 6.21. The Middle Bronze Age house data from Bovenkarspel Het Valkje, subdivided into individual households to investigate the level of organisation (small household, mixed, or large household). For every house, all the analysed samples are depicted with the same symbol.

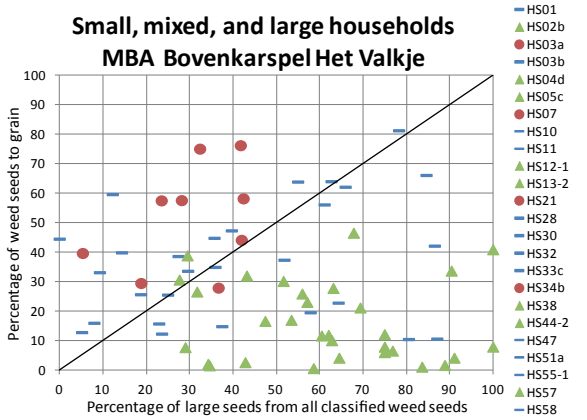


Figure 6.22. Translation of the Middle Bronze Age house data from Bovenkarspel Het Valkje from Figure 6.21, showing the level of organization per household. Houses of which samples are generally left of the 45 degree line are considered small, houses samples generally right of the 45 degree line are considered large, and all households showing ambiguous samples are considered mixed.

of 45 degree angle line), a mixed situation (samples either all on the line or clearly on both sides of the line), or large household level organisation (samples on the right side of the line). In Figure 6.21 all the house ditch samples of the individual houses from Bovenkarspel Het Valkje are plotted, and in Figure 6.22 these houses are designated as either small or large households or a mixed situation. It was not possible to safely place the mixed samples in either the small or large household categories. Therefore, these houses were excluded from further analysis.

Four houses were identified as consisting of small households (House 03a, 07, 21, and 34b), and eight houses as large households (House 02b, 04d, 05c, 12-1, 13-2, 38, 44-2, and 57). Of these small and large household houses, plots were made on the excavation plan of Bovenkarspel Het Valkje to assess whether the location on the settlement could provide further explanations for the differences observed (Figure 6.23 and Figure 6.24).

Clearly, both small and large households are dispersed over the settlement, which does not provide clear indications for a spatial differentiation of separate areas with different practices. Interestingly however, a possible temporal difference was observed, since the four small households are all either first phase houses or single phase houses located separate from other features (Roessingh in prep.). This observation implies that perhaps the different levels of crop processing organisation might also reflect settlement changes through time. Suppose that the four small households are the first houses of the settlement Bovenkarspel Het Valkje. Not many people and therefore hands would have been available to harvest the fields, resulting in small household level organisation of post-harvest crop processing. As the Middle Bronze Age progresses, more houses and people inhabit the settlement, gradually increasing the number of inhabitants of houses to include large households. Indeed, in two instances it was possible to assess the stratigraphy of the houses, and house 3a (small household) shifts to a mixed situation in the next phase, house 3b, indicating a movement towards larger households. A similar shift is observed in house 10 (mixed) towards the next phase of the house, house 12-1 (large household). In all the instances in which stratigraphy could be assesses, there is never a movement in the opposite direction (from large to small household level) visible for the Middle Bronze Age.

Late Bronze Age

Both Middle and Late Bronze Age data are summarized in Figure 6.25. The Late Bronze Age samples derive from deep Late Bronze Age ditches,

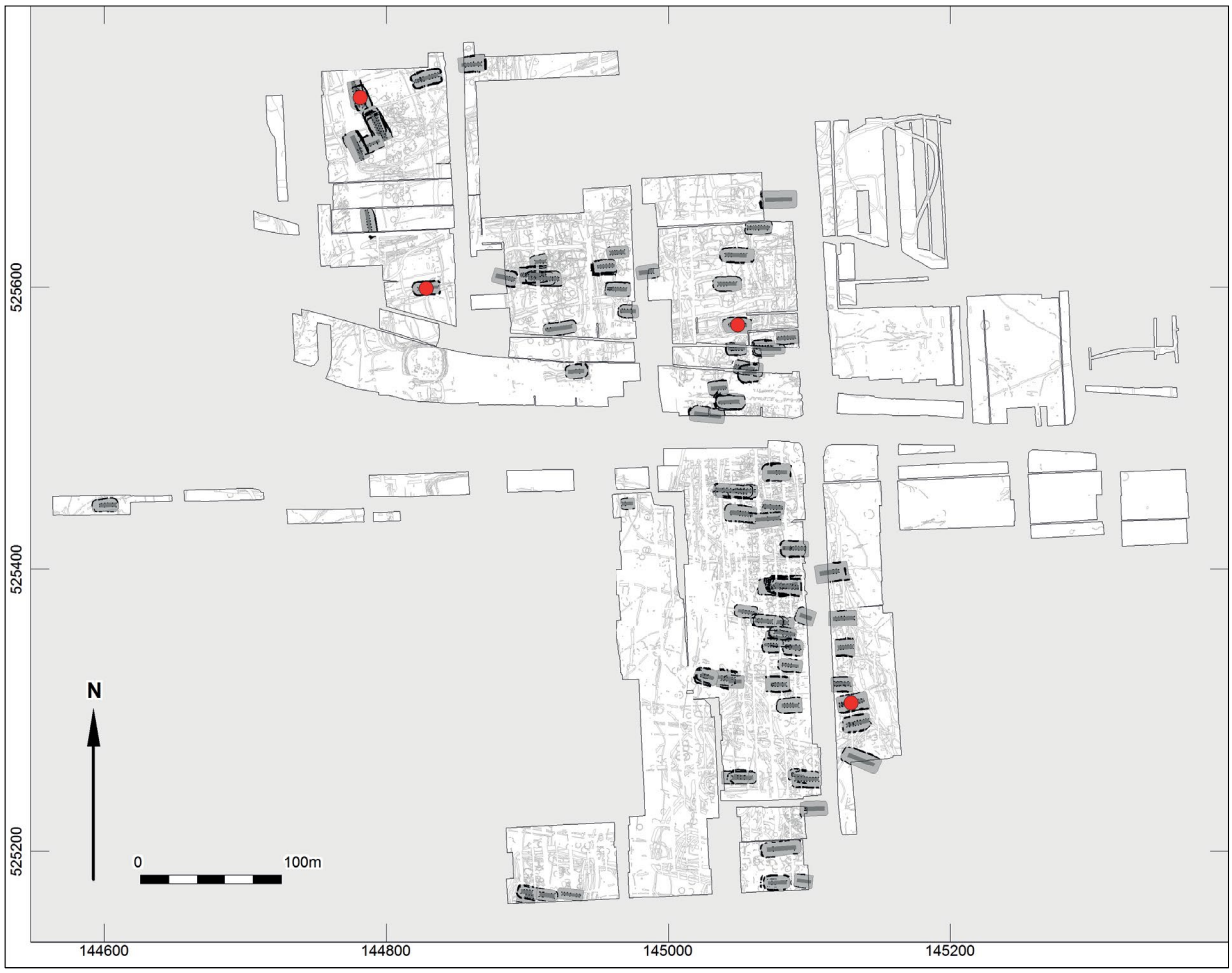


Figure 6.23. Plot of the small households (red dots) on the excavation plan of Bovenkarspel Het Valkje.

which are assumed to be comparable to the Middle Bronze Age house ditches.

Where in the Middle Bronze Age both small and large households appear, the Late Bronze Age samples seem to almost solely reflect small household level organisations: a change in post-harvest crop processing organisation seems to be occurring, where, similar to the four small households in the Middle Bronze Age, again fewer people or less time are available for harvest processing.

A possible reason for the observed change in practice in the Late Bronze Age might be explained by the increasing wetness in the environment (Chapter 2). The resulting shortage of land would mean that less people could have sustained themselves in West Frisia during this time (Chapter 8). In turn, the decrease in available hands may have resulted in a relapse into small household level organisation of crop-processing, similar to the four houses in the Middle Bronze Age.

Possible other explanations for the differences observed

Many other forms of social organisation may also have existed. Households may for example have worked together during harvest and harvest processing, similar to what is observed in the ethnographic parallels (section 6.3.3). However, there is no time advantage to this practice when only small households participate that also have to complete their own harvest. This

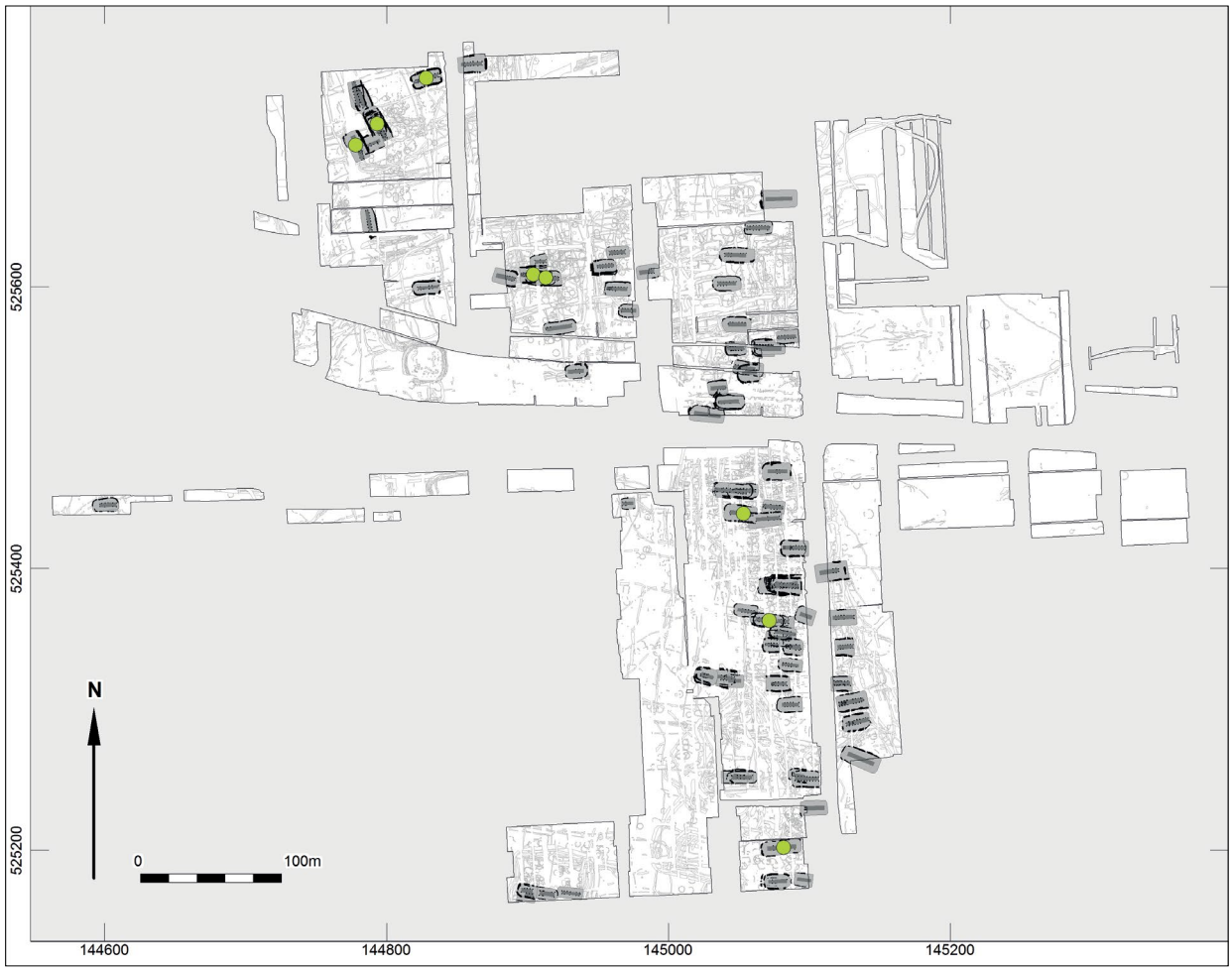


Figure 6.24. Plot of the large households (green dots) on the excavation plan of Bovenkarspel Het Valkje

means that even if small households work together, they would not be able to reflect the practices of large households. Therefore, collaboration between small households in this manner will in the larger picture not be distinguishable from normal individual small household practices.

An alternative possible explanation for the difference in household size may be the result of the combination of two types of storage within one settlement (pers. comm. Stevens); each (small) household may have its own unclean store of grain, whereas a larger communal clean store of grain may also be present. It is possible that such practices explain the presence of mixed households or buildings with an entirely different function, as observed in Chapter 8 (section 8.5).

Storage

Possible storage locations in West Frisia are not so clear compared to other, contemporaneous areas in the Netherlands. At these locations, storage is assumed to have been in granaries or silos which are separate from the main house. In West Frisia however, no such types of storage structures have been found. The only configuration of features which has been connected to the storage of cereals is the ring or post hole ditch (Figure 6.26) based on the presence of charred grain in one of the post holes of one post hole ditch (Buurman 1996, 205). However, in none of the other excavated ring or post hole ditches have any remains been found that would concur with the conclusions drawn previously by Buurman. Therefore, until further evidence is found

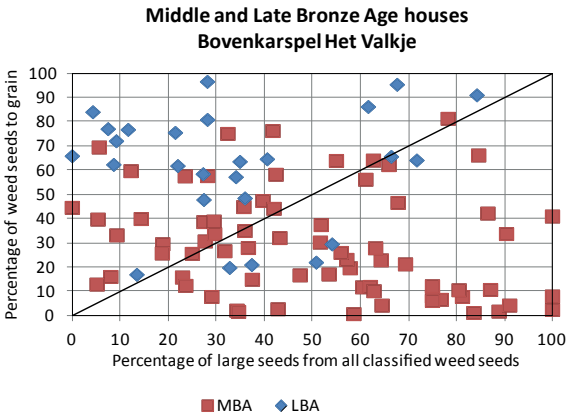


Figure 6.25. Spread of the Middle and Late Bronze Age house data from Bovenkarspel Het Valkje. Clearly, Late Bronze Age houses cluster more in the small households category.

for the function of these features, they are not assumed to be connected to the storage of harvested cereals and will not be discussed any further in this thesis.

Without a clearly defined structure for cereal grain storage present at the West Frisian settlements, the grain may have been stored in the attic of the house (cf. section 6.3.4). The average house in West Frisia possesses around 45 m^3 of attic space (Appendix A1.12). Since grain should not be kept over possible barn areas, and the living quarters are hypothesized in the western part of the house (cf. section 6.3.4), the available appropriate attic storage space in West Frisia will most likely be 22.5 m^3 or less, depending on the size of the barn area. The expected 4 m^3 of space required for the storage of an average annual harvest in spikelet form is easily accommodated by this space; even storage in ears or sheaves, presumed for smaller households, would be possible. The remaining space could be used to store possible other goods such as dried or salted meat or fish (Chapter 4, section 4.4; Chapter 5, section 5.4), and fodder (Chapter 5, section 5.4).

6.4.5 Improvement and location of arable fields

Soil conditions

The growing conditions of crops on arable fields were analysed using the Ellenberg values (Ellenberg

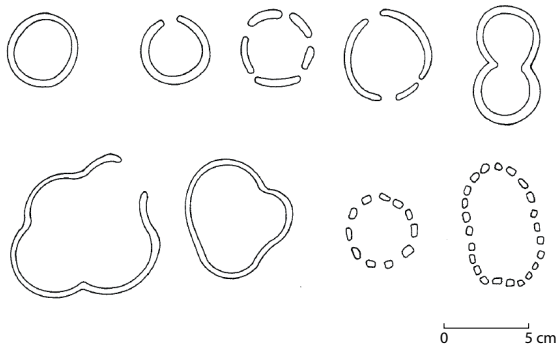


Figure 6.26. Examples of ring and post hole ditches that are postulated to be connected to the storage of cereals grains (after: Buurman 1996, 205).

et al. 1991) of the crop weeds from four sites: Bovenkarspel Het Valkje, Enkhuizen, Medemblik, and Westwoud. These values of crop weeds provide information on abiotic environmental factors such as salinity, moisture, pH levels, and nitrogen levels, the results of which are shown below for both the Middle and Late Bronze Age (Figure 6.27-Figure 6.30).

Salinity

Figure 6.27 shows the average salinity tolerance of the crop weeds from West Frisian arable fields. It becomes clear that both in the Middle and Late Bronze Age, fields were under fresh water conditions, since all crop weeds are intolerant of even low levels of salinity.

Moisture

West Frisia is known for its increasing wetness throughout the Bronze Age. The arable fields however, as can be seen in Figure 6.28, were situated at such locations, that at least during the growth period of the plant, no excessive moisture was present on the arable field. The moisture levels vary through time, but do not show a definitive trend towards higher moisture content in the Late Bronze Age. The range of moisture portrayed by the crop weeds reflects ideal circumstances for cereal growth. In addition, no indicators for flooding were found (data not shown).

pH value

The pH of the soil of the arable fields was very favourable (Figure 6.29). Most plants reflect a pH of 7.0, which is neutral and very good for plant growth.

There is no clear change between the Middle and the Late Bronze Age.

Nitrogen

The results from the nitrogen level of crop weeds (Figure 6.30) shows that nutrient conditions on the arable fields were very high, although some lesser values are observed in the Late Bronze Age. Such high nitrogen levels are often related to the practice of manuring, which is further discussed next.

Manuring

Manuring was not expected to have been practiced, but a recent nitrogen isotope experiment has shown that artificially heightened nitrogen levels did exist in the West Frisian soils (Appendix A1.11).

Although the exact source of nitrogen cannot be established based on such an analysis, it is clear that some form of fertilizer has been applied to the arable fields. Possible types of fertilizer include household waste, green manure (nitrogenous plant material), and animal manure (*i.e.* animal dung mixed with straw etc.).

Since it is assumed that West Frisian farms were mixed farms, the potential use of animal manure is likely. However, some factors need to be taken into consideration before a definite conclusion can be drawn. First, how much manure was actually available per farm? Second, how much manure is minimally required to fertilize the arable fields? And third, is the application of animal manure a probable option for West Frisia?

In order to answer the first question, it is necessary to make several assumptions. It is assumed that the main manure suppliers in the West Frisian Bronze Age were small cattle, sheep/goat, and pig. Parts of the cattle and sheep/goat herd (valuable and vulnerable animals) were kept inside during winter months (cf. Chapter 5, section 5.4.3), providing manure from roughly November to February. Pig manure could be used year-round, since pigs would probably have been kept in a delimited area within the settlement (Chapter 5, section 5.3.4).

The manure production of Dexter cattle, which is of comparable size to Bronze Age cattle, lies around 15 litres of solid manure on a daily basis (pers. comm. A. Slagter, Dexter cattle breeder). This amounts to around 1.83 m^3 when it is assumed that cattle was kept inside for four winter months (*i.e.* 122 days). Pigs produce on average 4.6 m^3/yr of manure (Alberta 2013, 43-4). If we assume that on a settlement of two houses, two pigs were kept year-round, as well as five adult cattle were stalled inside in winter, the total amount of manure available for a settlement (including pig and cattle manure) would be 18.4 m^3.

In order to calculate the amount of necessary manure to fertilize the arable fields, the example of Sukumaland, Tanzania was used (section 6.3). Farmers in Tanzania possess small-scale mixed farms on mostly clayey soils and need to transport 7.5-20 t/ha of manure to fertilize fields (Meertens *et al.* 1995, 78; Carton & Magette 1999). This amounts to 21-57 m^3 of manure per hectare.

The Bronze Age settlement, consisting in this example of two contemporaneous houses, possesses in total 3.6 ha of arable fields. Using the example values of Tanzania, these fields would therefore require a total of 42-114 m^3 of manure to fertilize. It is clear that there is a considerable imbalance between manure supply and demand, similar to what was observed in Asturias, Spain (section 6.3.5). Either cattle was not just kept inside during winter, allowing for enough manure to be produced, manure was collected in a different manner, or manuring with animal dung was not practiced on a large scale in West Frisia.

Alternatively, if all cattle was kept inside year-round or manure was collected in some other way, a total of 57 m^3 of manure (7 adults and 2 immature animals, producing full amounts of manure, and 3 young, producing half) could have been produced and collected. Together with the pig manure, this would have been enough to fertilize all fields. However, the amount of labour which needs to be employed in foddering animals year-round versus letting them graze, as well as the effort of transporting all the manure to the arable fields would not have been a feasible practice for such small settlements.

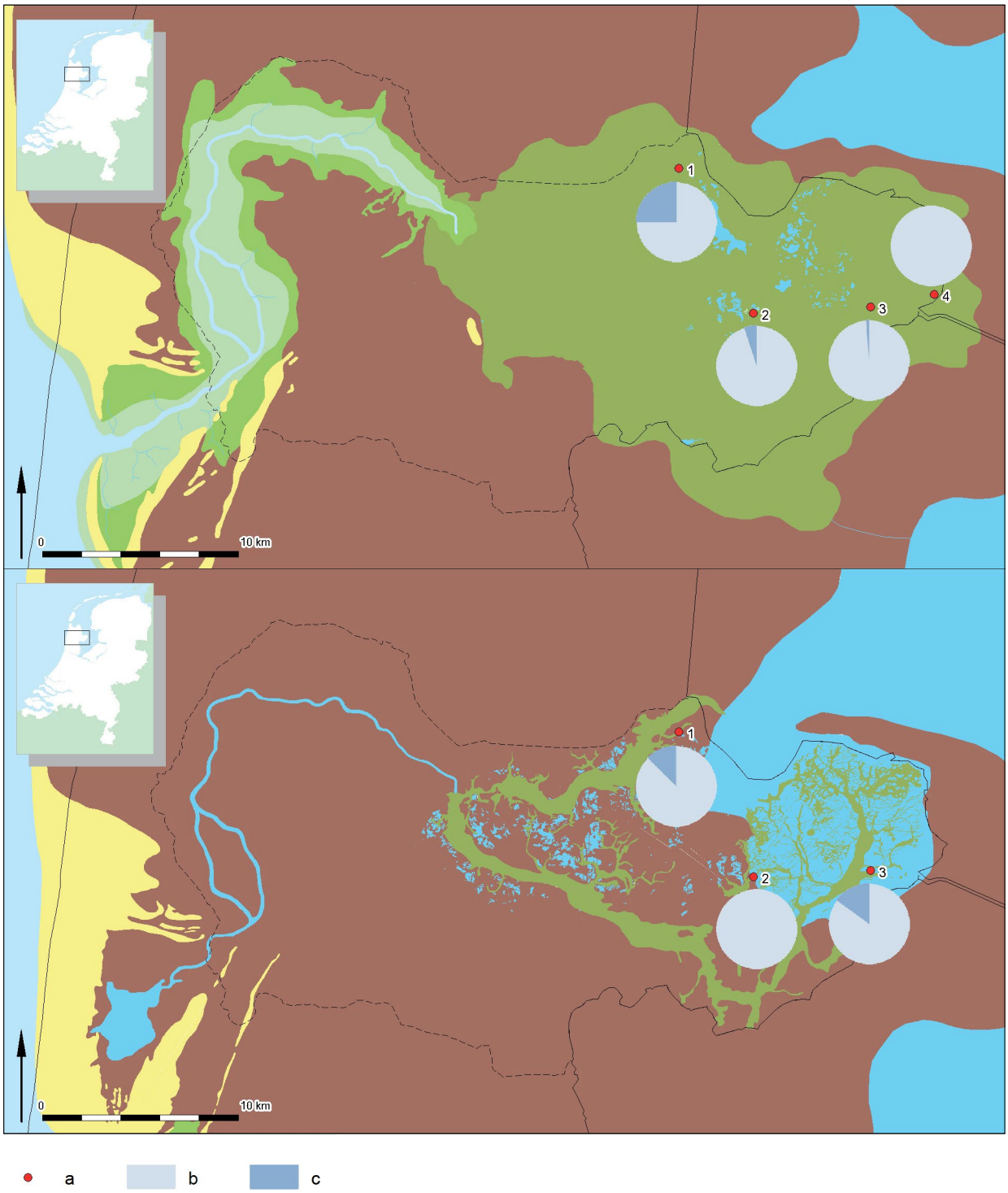


Figure 6.27. Soil salinity tolerance levels of crop weeds from Middle Bronze Age (top) and Late Bronze Age (bottom) arable fields. 1: Medemblik, n=8; 2: Westwoud, n=20; 3: Bovenkarspel Het Valkje, n=155; 4: Enkhuizen Kadijken, n=11; a: location of excavated site; b: does not tolerate salt (*i.e.* fresh water); c: extremely low salt toleration (*i.e.* fresh water).

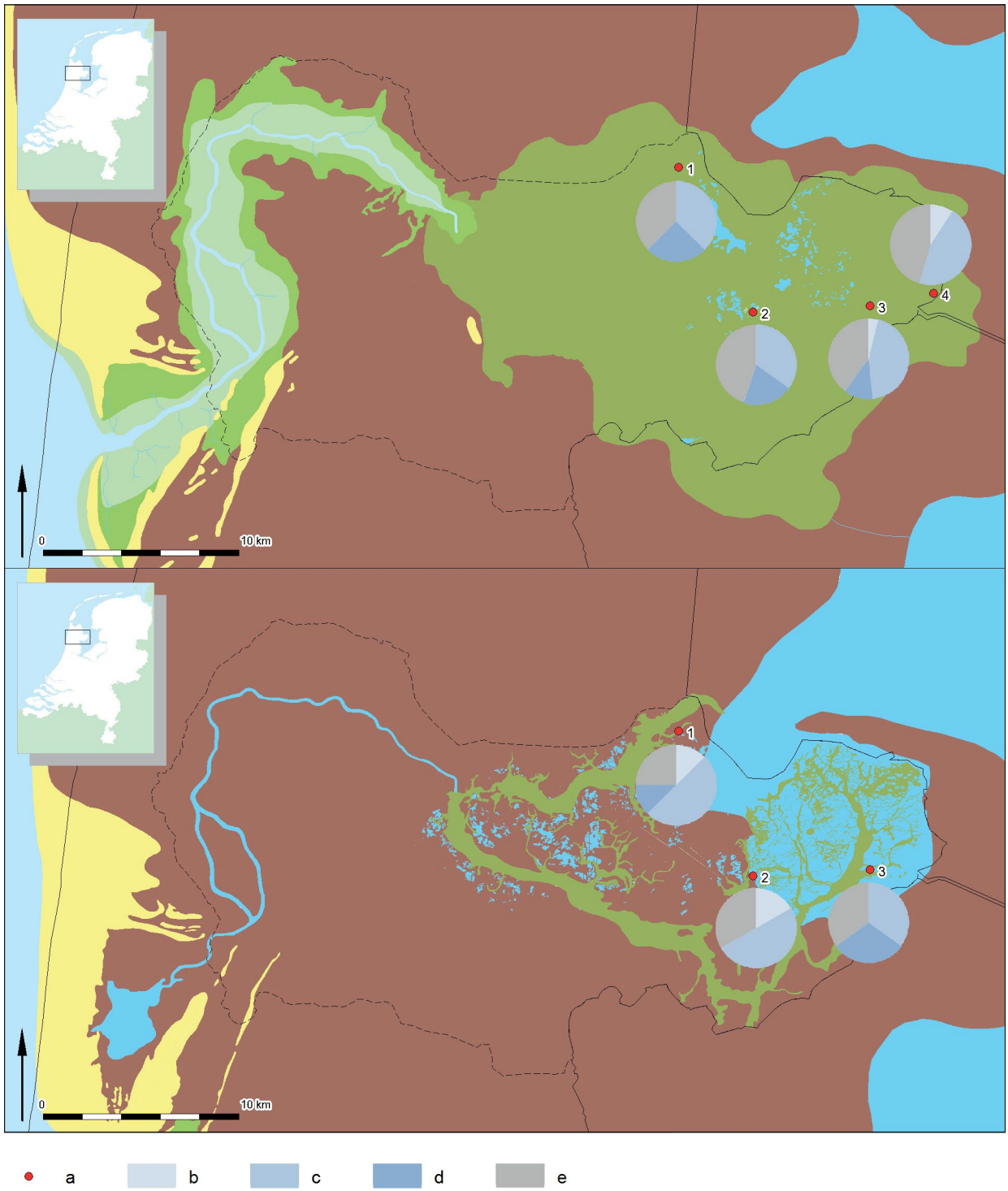


Figure 6.28. Soil moisture levels of crop weeds from Middle Bronze Age (top) and Late Bronze Age (bottom) arable fields. 1: Medemblik, n=8; 2: Westwoud, n=20; 3: Bovenkarspel Het Valkje, n=155; 4: Enkhuizen Kadijken, n=11; a: location of excavated site; b: dry – medium moist; c: medium moist; d: medium moist – moist; e: indifferent.

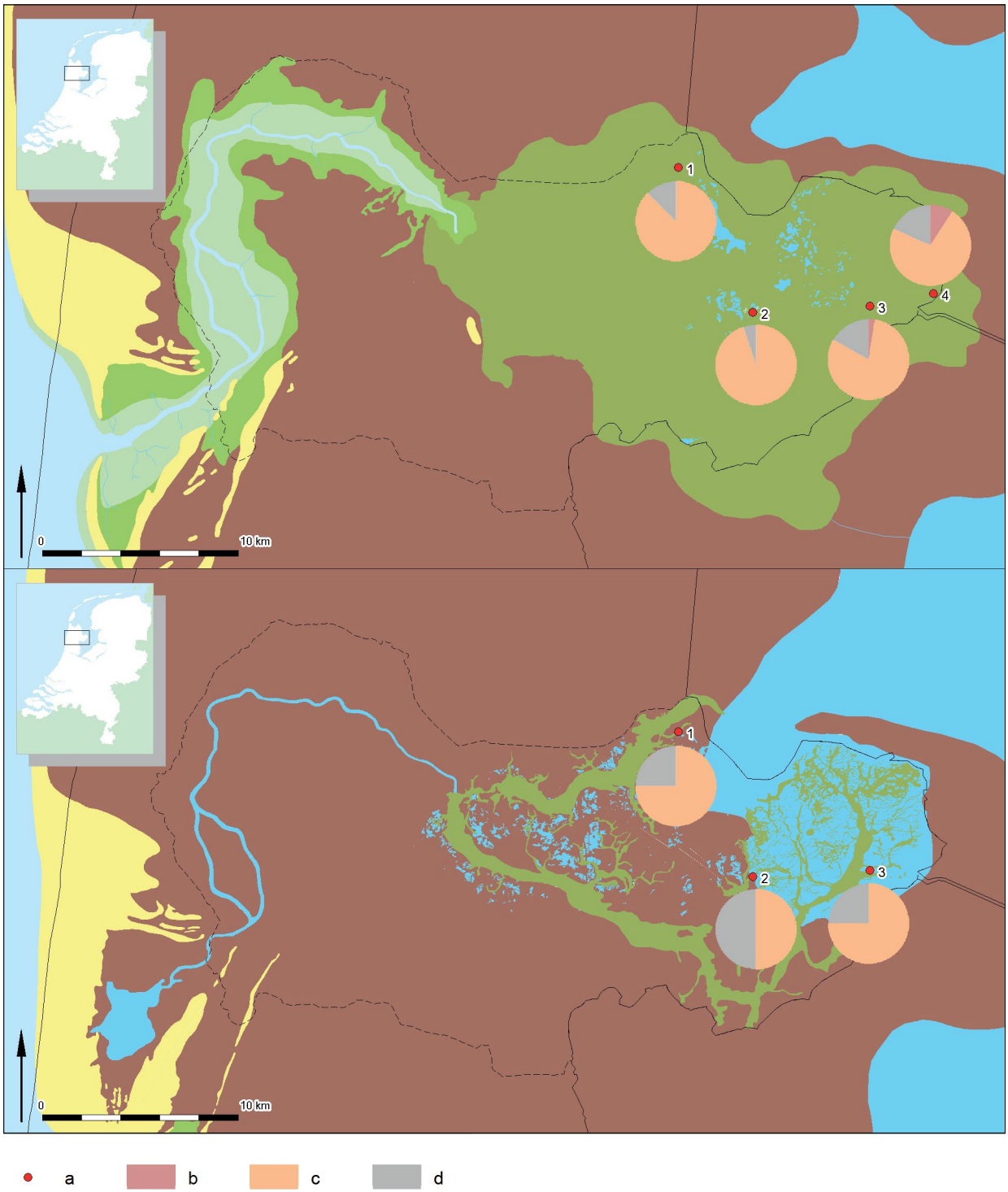


Figure 6.29. Soil pH levels of crop weeds from Middle Bronze Age (top) and Late Bronze Age (bottom) arable fields. 1: Medemblik, n=8; 2: Westwoud, n=20; 3: Bovenkarspel Het Valkje, n=155; 4: Enkhuizen Kadijken, n=11; a: location of excavated site; b: medium acidic – slightly acidic; c: slightly acidic – slightly alkaline; d: indifferent.

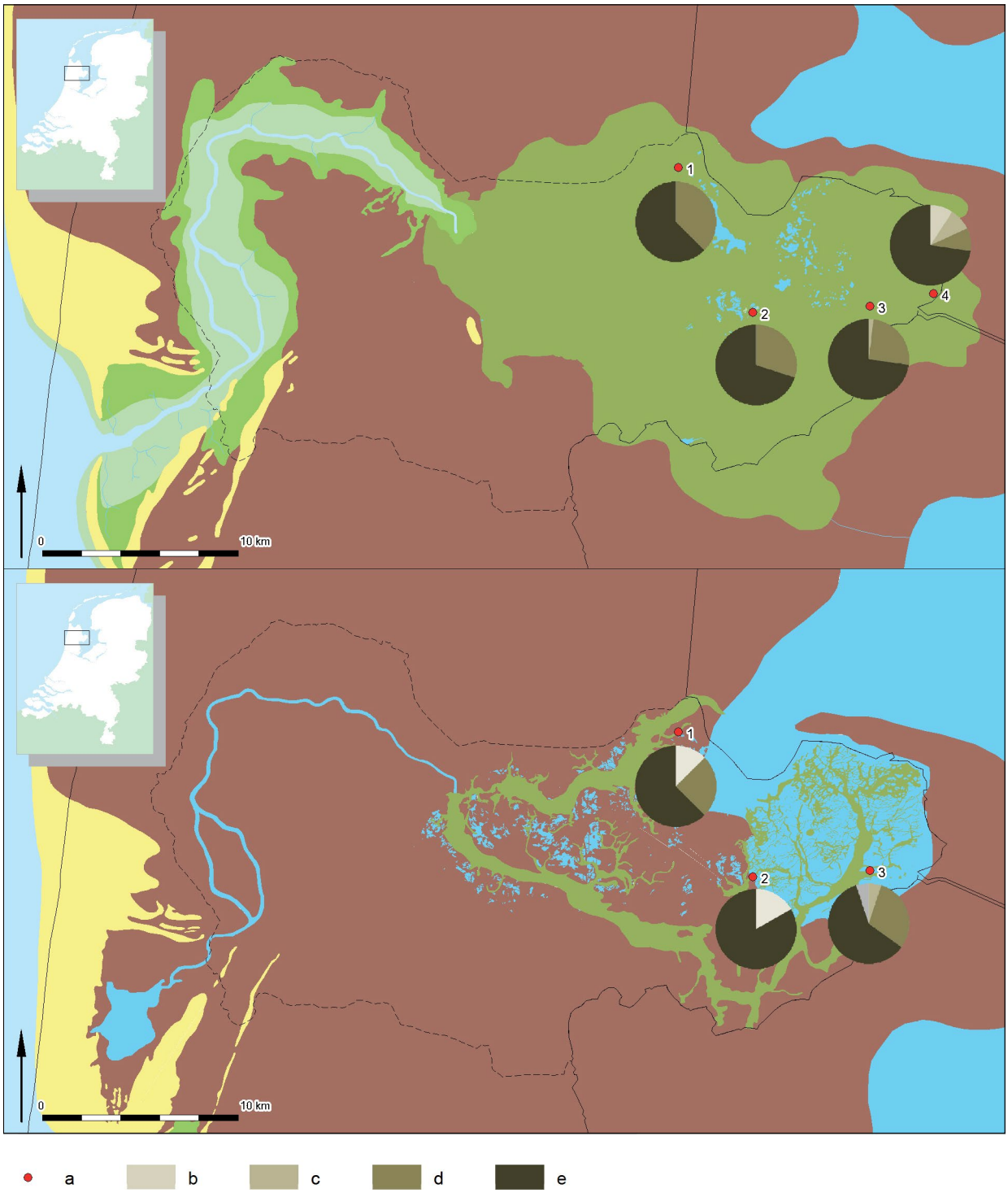


Figure 6.30. Soil nitrogen levels of crop weeds from Middle Bronze Age (top) and Late Bronze Age (bottom) arable fields. 1: Medemblik, n=8; 2: Westwoud, n=20; 3: Bovenkarspel Het Valkje, n=155; 4: Enkhuizen Kadijken, n=11; a: location of excavated site; b: nitrogen poor – medium nitrogen rich; c: medium nitrogen rich – nitrogen rich; d: nitrogen rich; e: nitrogen rich – extremely nitrogen rich.

To summarize, the use of only animal manure by the small-scale settlements of West Frisia was most likely not enough to enhance arable soils. Enrichment of the soil was established based on nitrogen isotope analysis however, showing that fertilizing might not have occurred using only animal manure (Appendix A1.11). A combination of other types of fertilizer with animal manure was probably applied to the arable fields. The possible use of household waste as a fertilizer was already indicated by Buurman based on the presence of small fragments of bone, and ceramics in plough layers (Buurman 1996: 25, 190), which could have assisted the fertilization of arable fields. Therefore, the use of animal manure could have been a viable option for West Frisia, but it should be realized that it was not sufficient on its own to manure all fields on an annual basis.

Other indications for the limited application of manure can be related to the fact that the use of animal manure in waterlogged conditions is not recommended, because nutrients leach quickly (Professional Nutrient Management Group & Environment Agency 2014, 22). Manuring in the vicinity of waterways or ditches can actually cause serious health issues, especially if these ditches are connected to each other, and possibly also form the source of drinking water of a settlement (Professional Nutrient Management Group & Environment Agency 2014, 25). Since West Frisian settlements have many interconnected ditch systems, the use of manure within the settlement could have been a problem.

Concluding, manuring in West Frisia would have consisted of applying a combination of several types of fertilizer, since animal manure alone would not suffice, and could even have contaminated the drinking water supply of the settlement. Alternatively, the use of household waste and green manure will have been additional options for fertilizing the arable fields, or a combination of all these types (cf. section 6.3.5). It is even conceivable that different fields were treated in different ways and frequencies, depending on the distance from the settlement, the type of crop cultivated, and the eventual use of the crop. Similar to the ethnographic examples in section 6.3.5, gardens and fields cultivated with barley are often treated differently than crops grown for straw. Such differences could also have occurred in West Frisia.

Location of arable fields

From section 6.4.1 it has become apparent that arable fields were probably not all located in the immediate vicinity of the settlement, since the reconstructed arable field size areas (0.6 ha) did not amount to the minimum size of arable fields observed in small-scale farming communities (1 ha/household). Of course, the reconstructed field size is also a minimum, due to the differential ground penetrating properties of the ard, so the original field size may have been larger. It could thus not be concluded whether the arable fields were smaller in the Bronze Age than in present-day small-scale farming communities.

However, since more than one cereal was cultivated, and maslin crops are not assumed, different crops would have been cultivated at different arable fields. This division in crop cultivation automatically means that total arable field size (*i.e.* 1.8 ha) would have been divided into smaller separate plots, similar to what is observed in small-scale farming parallels (section 6.3.1). In this case, the reconstructed size of the West Frisian arable field of at least 0.6 ha may reflect only a single smaller and separate plot, not the total area of arable fields owned by the household.
The exact location of arable fields was hard to establish, because it was not always clear whether houses and plough marks at an excavated site were contemporary. However, it can be assumed based on the analysis of Hoogkarspel Tolhuis find spot F (Roessingh in prep.), that some fields were at least in close proximity to the settlement. An indication that fields were probably also located further away from the direct surroundings of the settlement is provided by the observation that burning of arable fields was practiced (section 6.4.2). Since it is unlikely that fields were burned close to the (thatched houses of the) settlement, it can be assumed that these were located at some distance, to a maximum of 2.5 km away (cf. section 6.3.5). It is even conceivable that some fields were only burned in autumn and ploughed in a shallow manner in spring to prepare

the soil for sowing (cf section 6.3.2). This practice, and therefore these types of arable field, would then only be recognisable based on a specific type of black layer. More in-depth interdisciplinary research (cf. section 6.4.2; Pronk in prep.) is required to establish these practices and recognise the arable fields which would have been treated with this technique.

6.4.6 Seasonality

Sowing season
It was established in section 6.4.3 that West Frisians cultivated summer varieties of cereal crops. This means that sowing occurred, weather permitting, roughly between February and March (van den Brink 2005; Table 6.7).

Harvesting and burning season

Harvesting of spring sown cereals occurs in August (United States 1997; Table 6.7), with the precise moment depending on the ripeness of the crop which in turn depends on the environmental conditions during the growing season. Harvesting can therefore also occur much earlier in the year than August for crops with short growing seasons.

Emmer wheat, in addition, is usually harvested early in the morning or during the night, since dew present during those times binds the grains to the ear, which reduces losses in this brittle crop (Hajnalová & Dreslerová 2010, 187).
Burning of stubble is performed close after harvest, before weather conditions become increasingly wet. Therefore it is assumed that burning was practiced between late August and (early) September (Table 6.7).

Ploughing, manuring, weeding season
It has not (yet) been possible to establish when ploughing occurred in West Frisia, although micro-morphological research may shed light on this in the future. For now, hypothetical seasonal information from ethnographic parallels is applied to the West Frisian data for further interpretation (Table 6.7). It should be kept in mind that ploughing cannot occur too early in the year in certain clayey areas when the soil is still too wet. Therefore, a slightly later spring ploughing and sowing also remains a possibility.

Manuring was occurring in West Frisia (section 6.4.5), and this needs to happen right before ploughing; a substantial loss of nutrients through leeching can occur when manure is left on the field without being worked into the soil (Brandjes *et al.* 1996). For spring-sown cereals, manure should be incorporated in the soil just before sowing, which, depending on the weather conditions, is performed from late January to early March, preferably a month before the summer crop is sown (Peña Chocarro 1995, 114; Professional Nutrient Management Group & Environment Agency 2014, 22; Table 6.7).

Weeding was not performed very intensively in West Frisia, evidenced by the range of crop weeds present in the botanical assemblages. When practiced however, it is expected to be performed in the early stages of crop growth, which, depending on the time of sowing, lasts from February to May (Table 6.7).

6.4.7 Summary

The arable fields in West Frisia could be reconstructed to a minimum size of 0.6 ha based on ard mark spread and orientation. This size on its own is insufficient to sustain a family (*i.e.* 1-3 ha), but could form a smaller plot of the total owned land by a household. Other fields may have be situated further away from the settlement, probably to a maximum distance of 2.5 km, or half an hour's walk from the settlement. Fields were used several times, shown by the fact that multiple different orientations of ard marks were uncovered at the same location.

The major crops cultivated throughout the Bronze Age are emmer wheat and hulled barley, of which the former increases in frequency in the Late Bronze Age, at the expense of the latter. Very few other cultivated crops were uncovered in West Frisia, which is in line with the observations made in areas such as the North Sea coast and southern Scandinavia. The only possibly cultivated crops in West Frisia include broomcorn millet, linseed/flax, and a rare find of cultivated oat in the Middle Bronze Age. This absence of other cultivated plants in the Late Bronze Age however, in comparison with both the other areas as well as the West Frisian Middle Bronze Age, could be explained by the fewer samples

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ploughing								?	?	?		
Manuring												
Weeding												
Burning												
Sowing												
Harvesting												

	Ploughing occurring most often		Burning occurring most often
	Ploughing occurring less often		Burning occurring less often
	Manuring occurring most often		Sowing occurring
	Manuring occurring less often		Harvest occurring most often
	Weeding occurring		Harvest occurring less often

Table 6.7. Seasonality information regarding crop husbandry practices.

available from this time period.

Ploughing of the fields occurred with the ard in a criss-cross fashion, evidenced by the discovery of many ard marks throughout West Frisia. However, this was not the only possible activity which occurred on the arable fields after harvest and before sowing. Burning of stubble after harvest was also practiced instead of ploughing in some instances, to rid the fields of crop residue in an efficient manner. This practice ensured that weed seeds were destroyed, and that fields were ready and fertilised for the following sowing and growing season. Livestock would not have been allowed to graze on fields at which crop residue burning was intended to occur, since their presence would reduce the amount of stubble available for burning, as well as the efficiency with which weed seeds were burned, due to trampling. Whether this practice was performed in specific regions, time periods, or different crop fields remains unknown, and further research is needed to establish these aspects. Fallow periods in West Frisia were most likely short to absent, indicating an intensive form of land use: possibly more intensive than the short fallow system proposed based on the model of Boserup.

Sowing of crops was performed in spring in both the Middle and Late Bronze Age, and this was probably done by broadcasting or sowing in furrows. Weeding of crops was not very intensive, since many crop weeds were still present amongst the grain.

Harvesting occurred relatively low on the stalk, with a height of 40-60 cm prevailing in both the Middle and Late Bronze Age. The practice of harvesting was most likely performed by reaping with a sickle, or practicing uprooting by pulling the crop from the soil.

After the harvest, it appears that the harvest was stored in different ways at different sites. Most sites in West Frisia stored their grain in a relatively unclean manner (*i.e.* still including many weeds), which is probably due to the limited amount of people (*i.e.* small households) and time available. In Bovenkarspel Het Valkje, however, a difference was observed in that in the Middle Bronze Age, a combination of clean and unclean grain was stored by different households, possibly signifying a difference in household size. In the Late Bronze Age, all households seem to revert back to storing of unclean grain, which may be related to deteriorating weather conditions during this time and therefore (more) restricted time for the harvest. Alternatively, the wetter environment may have been able to sustain less people than in the previous period, which also results in storage of unclean grain. Of course, also a combination of the two factors could be the cause for the observed change.

Grain was probably stored in the western part of the house, since the eastern part of the house is assumed to be the barn part of the house (Chapter 5, section 5.4.3), and grain should not be stored over barn areas. The attic was probably used for storage, since storage of dried grain requires elevated, well-ventilated and dry conditions, and no clear outside storage structures have been identified.

The soil conditions on the arable fields were very favourable for crop husbandry, in both Bronze Age periods, with an absence of saline and acidic conditions, and adequate moisture and nitrogen levels.

Enrichment of the soil was established, indicating the use of fertilizer on arable fields. The fertilizer will most likely have consisted of a combination of animal dung, household waste, and remains of stubble burning.

Crop husbandry practices will have mainly been performed during sowing and harvest time and related activities, which occurred from roughly February-March and August-September.

6.4.8. Discussion

6.4.8.1 Methodology

Crop husbandry practices in West Frisia are mainly reflected in settlement contexts, since off-site locations are rarely excavated. Furthermore, it can be expected that most harvest processing, as well as the storage of this harvest, occurs in or around the house. It is therefore very important that house contexts are sieved systematically during future excavations. Only with data acquired in this manner can more firm indications be obtained of the differences regarding crop processing between households, as well as social organisation of the settlement at large. A combination of magnetic susceptibility, loss-on-ignition, phosphate analysis, and botanical analyses has already been able to show activity areas in relation to crop husbandry (Grabowski & Linderholm 2014). In addition, such data can even provide insight into the potential use of the building, and possible activity areas within it (Chapter 8, section 8.5).

A further methodological step which would help the research towards crop husbandry forward is the interdisciplinary research towards ploughing practices, burning practices, and manuring related to arable fields. By combining disciplines such as micro-morphology, phytolith analysis, and pollen analysis, much information can be gained on how the individual practices were performed, and possibly also shed light on their seasonality. Adequate sampling should be performed to ensure that this multi-proxy approach can be realised.

6.4.8.2 Taphonomy

In section 6.4.1, it was made clear that only the most frequent crops emmer wheat and hulled barley would be discussed in the main text. However, other crops, which were less frequent in the assemblages need not have been equally less important (cf. Chapter 4; Chapter 7).

One of the main reasons that for example linseed/flax was not frequently found in West Frisian settlements could very well be related to taphonomy, not importance or cultivation frequency.

Flax/linseed can be grown for either its seeds (linseed) or it fibres (flax); the quality of one of the two diminishes when the other improves. Alternatively, flax/linseed can be harvested for both purposes, but the quality of fibres and seeds will be lower.

If flax was grown for textile production, it would not be surprising that few remains were found, since harvest would occur before full maturation of the crop: most plants would not have set seed yet. The seeds would derive from the sowing seed required for the following year, which would be obtained from a small part of the crop left on the field after harvest for fibres was already completed. This inherently means that these seed remains are unlikely to become charred.

If flax/linseed was grown for the oil-containing seeds, it is still logical to find few remains if we assess the harvest processing of flax. Flax harvesting and processing would have been performed in bulk annually. Similar to the harvest processing of cereals (section 6.3.4), this means that results from such once-a-year actions will be underrepresented in the archaeological record in comparison to daily activities. In addition, linseed does not require fire for its preservation, as opposed to emmer and barley, and, like other oil-containing plants, preserves poorly in charred form (Buurman and Pals 1974).

The bad preservation of flax/linseed can therefore be related to the original absence of seed on the plant during harvest for fibre and/or low preservation chances of seeds. Linseed is thus unlikely to preserve in general, but will be slightly better represented in uncharred form.

The above examples illustrate the probable gross underrepresentation of linseed in the archaeological record, regardless of the purpose of the plant (Figure 6.31).

Therefore, it must be emphasized that the presence of a few remains of linseed is not necessarily an indication for the unimportance of this crop to subsistence, and that only charred remains do not accurately reflect the cultivation of flax/linseed. Furthermore, the presence of flax/linseed at four Middle Bronze Age West Frisian sites (Bovenkarspel Het Valkje, Enkhuizen, Westwoud, and Hoogkarspel

Watertoren), might actually point towards cultivation in the Bronze Age. The fact that these uncharred remains are uncovered at every site, but in low amounts, may point towards the cultivation of this plant for its fibres. Where this may have been the case, it is important to be aware of flax fibres and woody plant parts in future archaeobotanical investigations of waterlogged material in West Frisia (Chapter 11), which may underline this cultivation practice.

In the Late Bronze Age, no linseed remains were found, but, combining the low chance of finding linseed outlined above with the low number of samples researched, this does by no means indicate that flax/linseed was not cultivated in the Late Bronze Age as well.

Broomcorn millet and oats were also uncovered in low amounts at the West Frisian sites. However, these plants are not affected by taphonomy in the same manner and level as linseed/flax. Broomcorn millet preserves well under waterlogged conditions, where especially its chaff is easily identifiable due to its distinct appearance. The few indications for this plant do indicate that it was cultivated, because it is not a native plant to the Netherlands. The low frequency and number of remains of this plant, however, mean that overall, it was cultivated to a lesser extent than for example emmer wheat and barley.

Cultivated oats can only be distinguished from wild oats by the base characteristics of the rachis. Since these remains are scarcely found, it is hard to determine whether the remains of oats belong to cultivated or wild species. It is therefore unclear whether the many remains of unidentifiable oats species in the West Frisian record belong to the cultivated or wild variety. Thus, it is hard to assess to which extent oats were cultivated in the West Frisian Bronze Age. However, if this crop was cultivated, oats chaff should have been recognised in relatively high amounts in settlement contexts, since these remains preserve well. Since this was not the case, it can be assumed that the cultivation of oats played a minor role in West Frisia.

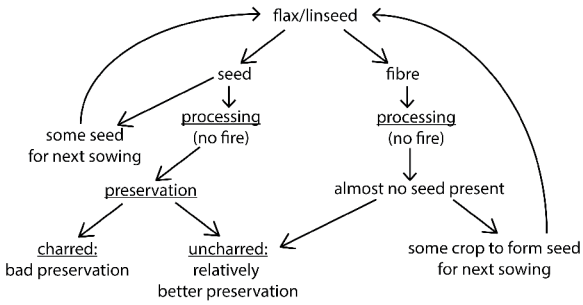


Figure 6.31. Preservation potential of linseed for both its use for fibre or seed.

6.4.8.3 Possible selection criteria for consumption

The range of crops available in the Bronze Age in the area of West Frisia was already examined in section 6.4.1, based on a general comparison with other areas along the North Sea and southern Scandinavian coasts. This comparison has indicated that some differences existed, which may be the result of a conscious selection by West Frisians from the total available crops during this time. This selection may have been made based on criteria including a possible local preference for certain crops, crop-specific growing possibilities within the area, and access to the different species of crops. Growing conditions are, however, not a likely reason, since climate and geographical location of especially the North Sea coast and southern Scandinavia are comparable to West Frisia. This means that only local preference and access to crops remain as possible reasons for the range of crops observed.

Overall, West Frisia stands out in comparison to other areas based on the appearance, absence, or frequency of certain crops that appear to be unique for West Frisia.

For example, the range of cereals in West Frisia is rather limited in comparison to other areas, actually only including emmer wheat and hulled barley, with a minor addition of naked barley and broomcorn millet in the Middle Bronze Age. In other coastal areas, spelt wheat and einkorn also belong to the range of crops.

Vice versa, crops present in West Frisia are not always present in neighbouring areas during this

time. For example, cultivated oat was established in one instance, as well as linseed at four sites (Bovenkarspel Het Valkje, Enkhuizen, Westwoud, and Hoogkarspel Watertoren). Especially linseed is more dominant than in other areas, but this may be related to the good preservation of waterlogged remains present in West Frisia (section 6.4.8.2). It is debatable whether people in West Frisia preferred this small range of crops, since the larger the range of crops, the better the spread of risk is accomplished. In essence, West Frisia appears to have a rather limited range of crops which may in fact be related to its relatively isolated position in the Netherlands, which would have provided access to some, but not all crops available in the Bronze Age. Perhaps since animals were imported from the eastern part of the Netherlands (Chapter 5, section 5.4.3), it can also be assumed that crops may have originally derived from there, which would restrict the range of crops in West Frisia to what was available in eastern regions. It is interesting to investigate whether crops from these locations resemble the West Frisian crop range, and this will be attempted in Chapter 9.

6.4.8.4 Other reasons for crop husbandry

In this chapter, the main focus was on subsistence production for human consumption. Besides this reason, of course other reasons exist for the production of crops. They are shortly discussed here for the crops: emmer wheat, hulled barley, and linseed/flax.

Animal consumption
Depending on the number of non-grazing animals, additional fodder may have been required for certain periods of time (Chapter 5, section 5.3.5). Cereal crop remains (*i.e.* straw) from crops grown for human consumption can be used as fodder, although, as stated in section 6.3.3, not every crop species is suitable for this purpose. Emmer wheat for example, is tough and sharp and not used for fodder purposes in for example Slovakia and the Mediterranean (Hajnalová & Dreslerová 2010, 187; Halstead 2014, 86), but is used in other activities (see below). Barley straw on the other hand, is widely accepted as a valued fodder crop (Ertuğ 2000, 177; Halstead, 2014, 68). The straw of flax is unfit for animal fodder, but flax seeds may be given to livestock (Oplinger *et al.* 1989). Chaff of cereal crops is usually not consumed by livestock, unless it is mixed with water. Wild oat (*Avena fatua*) has, until recently, been known to be harvested and foddered to livestock in for example Spain (Peña Chocarro 1995, 99).

Raw material
Emmer wheat straw, which is not suitable for animal fodder, is often used as a raw material for *e.g.* thatching or basketry (Hajnalová & Dreslerová 2010, 187; Stephens & Langlands 2011, 373; Halstead 2014, 86). Chaff of either emmer wheat or barley may be used as fuel or as temper in pottery making (Fuller *et al.* 2014, fig. 10). Flax cultivation is often linked to the excellent fibres which can be obtained from this plant. These fibres are used in textile production (*i.e.* linen).

6.5 RECONSTRUCTION OF CROP HUSBANDRY

The reconstruction of crop husbandry was achieved by comparing the results of the new analyses made in this chapter with the current model's main components. The contribution of the different proxies applied in this analysis as well as the general approach of this chapter are outlined below. Furthermore, the validity of each of the main components of the current model of West Frisian crop husbandry is assessed in section 6.5.2. Finally, the valid current main components as well as the components which were incompatible with the new results and were reformulated are combined to form a new model for crop husbandry in Bronze Age West Frisia (section 6.5.3).

6.5.1 Contributions of proxies and approach to the reconstruction of crop husbandry

Ethnography has, as in other chapters, provided valuable information on the basic crop husbandry practices in small-scale mixed subsistence farming communities from around the world. The added use of ethnobotany has enabled an even more detailed expectation of specific practices regarding the cultivation of emmer wheat and hulled barley, as well as quantitative values for harvest yields, losses,

etc. Ecological data on crop weeds has provided information on the favourable soil characteristics of arable fields, showing that West Frisian farmers were very capable of finding appropriate locations for the cultivation of their crops throughout the Bronze Age. The biological information on crop weeds has identified crop husbandry practices such as spring sowing, harvesting at low heights, and the (near-) absence of fallow periods, enabling the recognition of specific practices performed by West Frisian farmers. Archaeobotany has provided a clear overview of the range of crops available in neighbouring areas to West Frisia. A comparison between these regions has enabled the identification two specific crops selected by West Frisian farmers, even though a wider range was available during this time period. In addition, a new crop husbandry practice for West Frisia and the Bronze Age period in the Netherlands was recognized (*i.e.* stubble burning) through, phytolith and pollen analysis, and micro-morphological analysis. A further result from the detailed analysis of crop and weed remains from house contexts in this chapter has enabled the possible identification of different types of social organisation of harvest processing practices within one settlement. Features uncovered during archaeological excavations have provided indications for possible available arable field sizes and shapes, as well as the manners in which the harvest may have been stored. Isotope studies finally, have confirmed the enrichment of arable field soils by the addition of fertiliser, as well as the recognition of import of domestic animals to West Frisia from more eastern areas.

In this chapter, the main approach was similar to the previous two chapters in that it was attempted to show the complexity of crop husbandry through the analysis of its basic activities, with the aid of different proxies. Ethnographical parallels have again proven to be invaluable in creating an expectation of the different aspects related to crop husbandry, especially those that are not (immediately) apparent based on an archaeobotanical assemblage. The assessment of the effects of archaeological methodology and taphonomy on such an assemblage has created a better understanding of why certain crop husbandry related activities are not visible (anymore). The analyses made in this chapter have covered the entire crop husbandry subsistence strategy and have resulted in a complete image of the different elements of this main form of food production in the Bronze Age.

6.5.2 Assessing previous main components

The results produced in this chapter regarding the role and praxis of crop husbandry in Bronze Age West Frisia are compared to the main components of the current model in this section. Whenever a current main component is not in concurrence with the newly acquired results, the former is reformulated to match the latter.
Main component 1 was formulated as follows:

(1) Arable fields in West Frisia were sometimes wet and contained only one crop species at a time.

Based on the analysis of crop weeds, it is clear that arable fields in West Frisia were not wet during the growing season. It is unclear whether the waterside vegetation observed in the assemblages arrived at the settlement together with the harvest, or whether it is a reflection of other practices. What is apparent is that crops were harvested relatively low, which means that cereal straw may have been used for purposes including raw material and fodder. Since the use of emmer straw (*i.e.* raw material) differs from the use of barley straw (*i.e.* fodder), the chance that the two crops were grown mixed within the same field is reduced. This observation has provided additional indications that indeed crops were grown on separate fields. Therefore, main component 1 is only partly reformulated to match the new results:

(N1) Arable fields in West Frisia possessed very favourable conditions for crop husbandry, without excessive moisture during the growing seasons, and only contained one crop at a time.

Main component 2 was formulated as follows:

(2) West Frisian crops were mainly emmer wheat and hulled barley for most of the Bronze Age.
(2a) In the Middle Bronze Age, emmer wheat and hulled barley were of equal importance.
(2b) In the Late Bronze Age, solely hulled barley was cultivated.

Based on the re-analysis of the West Frisian botanical samples, emmer wheat and hulled barley were indeed most frequently present. However, emmer wheat, rather than hulled barley, becomes more frequently present in the Late Bronze Age samples. The cultivation of emmer wheat in the Late Bronze Age is not exclusive either, since hulled barley still appears during this time, only at slightly lower frequencies. Linseed was also cultivated, but it is hard to assess its importance in relation to the cereals, due to its bad preservation characteristics. The importance of crops should thus not be directly related to their frequencies. Main components 2, 2a, and 2b are (partly) reformulated accordingly:

(N2) West Frisian crops were probably mainly emmer wheat and hulled barley, which are present at equal frequencies in the Middle Bronze Age, whereas in the Late Bronze Age, emmer wheat becomes more dominant.

Main component 3 was formulated as follows:

(3) Sowing of crops occurred in spring.

Based on the analysis of the old and new data on crop weeds, it can be concluded that indeed crops were most likely sown in spring. Therefore, main component 3 does not require reformulation.

Main component 4 was formulated as follows:

(4) Fertilising fields was achieved by applying a combination of household waste and animal dung.

Based on new nitrogen isotopic data, it was confirmed that fertilisation of fields occurred in West Frisia. Although the specific type of fertilizer could not be established based on this analysis, it was clear that animal dung alone would not suffice. The limited amount of livestock kept per household would simply not have been able to produce enough to manure all the arable fields. Additional fertilizer would have to be supplied, most likely in the form of household waste. This conclusion matches with the postulated main component 4, and therefore it does not need to be reformulated.

Main component 5 was formulated as follows:

(5) Harvesting ripe crops was performed by reaping low on the stalk with a bronze sickle, and in the Late Bronze Age, by uprooting crops.

Based on the absence of archaeological evidence of (bronze) sickles, it was not possible to establish what type of harvesting tool was used in West Frisia. However, the low harvesting height observed indicates that such a tool must have existed. Uprooting may also explain the low harvesting height and could have occurred as well. Since the average harvesting height does not seem to change between the Middle and Late Bronze Age, it is unclear whether a definite change in harvesting practices occurred between these periods. A re-formulation of main component 5 is in order:

(N5) Harvesting ripe crops was most likely performed by reaping low on the stalk or by the uprooting of crops.

Main component 6 was formulated as follows:

(6) Processing of the harvest occurred in and around the house and harvest was stored in sheaves.

Based on the analysis of crop processing waste and accompanying weeds in the assemblage, it is assumed that daily harvest processing occurred in and around the house. The bulk processing before storage of the crop however, could either occur on the fields or within the settlement. The reflection of crop processing waste indicate that in most instances, crops were stored in an unclean state, which indeed means either in ears or sheaves. However, in Bovenkarspel Het Valkje, the remains from some houses show that crops, in the Middle Bronze Age at least, were also stored in a clean state, or in spikelet form. Main component 6 is therefore reformulated as follows:

(N6) Processing of the daily harvest occurred in and around the house, and the harvest was either stored in ears or sheaves, but occassionally also in cleaned spikelet form.

Main component 7 was formulated as follows:

(7) In the Late Bronze Age, people were not able to practice crop husbandry to the extent required to complete subsistence.

Based on the harvest processing waste in the Late Bronze Age, fewer people and/or less time were available to process the harvest to a relatively clean state. Both this decrease in inhabitants and/or unfavourable weather conditions for growing and harvesting the crop could be related to the deteriorating environmental conditions in the Late Bronze Age, which was established based on the landscape reconstruction (Chapter 2). There are, however, no indications that the people that were still inhabiting West Frisia during this time could no longer sustain themselves: the arable fields still consisted of favourable soils for crop husbandry based on the present crop weeds. The current main component and the new results are not compatible and main component 7 is therefore newly formulated:

(N7) In the Late Bronze Age, the total acreage of available arable land was reduced, so fewer people were able to practice crop husbandry to a satisfactory level; the quality and conditions of these remaining fields were, however, still favourable.

Main component 8 was formulated as follows:

(8) Stubble burning may have been applied to clean arable fields after harvest for the subsequent sowing season.

Based on a combination of micro-morphological, phytolith, and pollen analyses, the likelihood of the practice of stubble burning was indeed established in one instance in West Frisia. The seasonality of this practice, as well as other details regarding its execution and spatial organisation remain to be investigated. In the meantime, main component 8 is reformulated as follows:

(N8) Stubble burning was practiced in West Frisia to clean arable fields, although the extent and seasonality of it are still unknown.

Based on the above comparison, most of the main components of the model of Buurman remain valid, or only require minimal adjustments. However, some new insights are also gained in this chapter, and together, the accurate current and new main components are combined and integrated to form the new model for crop husbandry.

6.5.3 New model for crop husbandry

Crop husbandry formed the main food strategy in the small-scale farms of West Frisia in the Bronze Age, providing people with staple food year-round. The cultivated crops in West Frisia mainly consisted of emmer wheat and hulled barley, with a possible addition of linseed and millet. Emmer wheat appears to become more dominant in the Late Bronze Age. The available crops were cultivated on separate field plots of a minimum of 0.6 ha, which is postulated to have amounted to a total cultivated area of 1-3 ha per household, with an average of 1.8 ha. Fields were likely located both close to the settlement and further away. The presence of gardens is expected, although it has not (yet) been identified. This difficulty of identification may be related to the different manner in which these plots are usually tilled (*i.e.* by hand or hoe), and planted (*i.e.* with vegetables), which both are hard to recognise in the archaeological record.
Arable fields were cultivated several times at the same location, which started with ploughing the soil with an ard in spring to prepare the seed bed. Ploughing during this time was performed in a shallow manner, since ploughing at a deeper level would disrupt the soil. Sowing of the summer cereals would occur by broadcasting seeds or sowing the seeds in furrows, after which light harrowing was performed to cover the grain. Weeding was not practiced intensively, but would probably occur several times during the growing season to remove the most evasive weeds. Harvest time would start in late July, by reaping the crop relatively low on the stem, possibly with the use of sickles, or uprooting practices. Directly after harvest, the arable fields were either ploughed, or the stubble was burned, both in order to clear the fields for subsequent sowing in spring. Alternatively, fields were left to lie fallow, but if this was practiced, fallow periods probably only lasted a year.
All the crop husbandry practices together indicate

that land use in West Frisia can be characterised as an intermediate form between a short fallow system and annual cultivation, since activities of both land use types are represented.

After harvest, the crops were processed in bulk on the fields or at the settlement, after which they were stored on attics in the western part of the houses at the settlement. The previously postulated role of structures related to ring or post hole ditches in storing of harvested cereals could not be confirmed. Storage of crops was most often performed in an unclean state by small households, meaning that it was stored in ears or sheaves. However, some households were large enough and/or had enough time to store their grain in a clean state (*i.e.* spikelet form), requiring less daily labour to process the grains for consumption purposes. In the Late Bronze Age, all households appear to revert to being small and/or having less time to harvest, which may very well be related to the deteriorating weather conditions during this time, reducing the amount of appropriate land for crop husbandry and therefore subsistence, in West Frisia.

The soil conditions of the arable fields were, however, favourable in both periods of the Bronze Age, indicating that the inhabitants of West Frisia were very well able to sustain themselves based on crop husbandry. Furthermore, besides providing a stable food source throughout the year, crop husbandry may also have provided extra sources of fodder for livestock in winter months, or sources of raw material for other activities.

Crop husbandry may therefore be considered as possibly the most integral part of Bronze Age subsistence, both because of its many activities which are performed to ensure a good harvest and stable food source, but also the food it provides for both human and animal consumption, and as a source of raw material for home and, eventually, hearth.

7. Wild plant gathering

7.1 INTRODUCTION

In this chapter, the final subsistence strategy that is a part of small-scale subsistence farming is researched: wild plant gathering. This strategy is not often considered as an important part of farming life, and its contribution to subsistence in the Bronze Age is investigated in order to confirm or contradict this image. The role and praxis of wild plant gathering is assessed by re-evaluating old and new available data, similar to the previous data analysis chapters 4, 5 and 6. The old data used also included unpublished work, mainly by Buurman. Her elaborate work on wild plants from sites such as Bovenkarspel is published here for the first time. Similar to previous chapters, the current view towards wild plant gathering and its main components are listed first, after which they are challenged with the new results of the analysis made in this chapter. It is important to note that consumption is the main reason for discussing the collection of wild plants in this chapter. Other reasons for gathering these plants (which can be manifold and equally important to subsistence) are discussed in section 7.4.6.4. Also, throughout this chapter, the term fruit is applied to stone fruits (such as sloe plum) and pome fruits (such as apple), whereas the term berry refers to true berries (such as bilberry) as well as aggregate berries (such as blackberry).

7.1.1 Previous research

Wild plant gathering has been appointed a similar unimportant role as hunting for the Bronze Age (cf. Chapter 4). Bronze Age farmers are even collectively summarized as starting to live with their back towards nature (1) (Louwe Kooijmans 1993, 80; Brinkkemper 2013: 171, 186). Bio-resources in general seemed to have played a very restricted role during this time (2) (Louwe Kooijmans 1993, 104), a theory which is mostly based on the general scarcity of wild plant remains in the Bronze Age archaeobotanical record. These wild plant species, which do not possess edible parts such as nuts, fruits, or berries, are often characterized as weeds instead (3). In some areas, such as in West Frisia, a wide array of wild plant species was uncovered, both in charred and uncharred form (*e.g*. Buurman 1996, 107-56). Also in the West Frisian list of wild plant species, not many obviously collected plants, such as nuts and berries are found, which seems to be a trend in the Bronze Age in general (Brinkkemper 2013). The near-absence of remains of seeds, fruits, and nuts has led to the conclusion that edible wild plants were practically abandoned during the Bronze Age (4) (Brinkkemper 2013, 186), which would be related to a lack of interest in these sources of food or ideological restrictions (Brinkkemper 2013, 184). Based on the few remains of berries, fruits, and nuts found at Bronze Age settlements, it is concluded that these plants were only scarcely collected during autumn (5).

The clear absence of evidence for wild plant collecting has been related to the growing importance of crop and animal husbandry in the Bronze Age in the western Netherlands. In comparison to the Late Neolithic, Bronze Age farmers in the western Netherlands, and by extent West Frisia, are thought not to have needed or wanted wild plants for their subsistence, since communities are viewed as having been able to sustain themselves by fully relying on their own production system (Louwe Kooijmans 1993, 100): because people were farmers, they had no apparent need for the addition of wild plants to their subsistence, since they could produce their own crops. By placing all their confidence in this traditional agricultural production (6) (Louwe Kooijmans 1993, 104), Bronze Age farmers were able to maintain their subsistence without the need for wild resources.

It is unclear what this need for wild resources would include, but they may have been part of the diet and/or have been a source of raw material for people. Therefore, according to the current view on the use of wild resources, both types of use were not necessary on the farm. Thus, the current view towards the collection

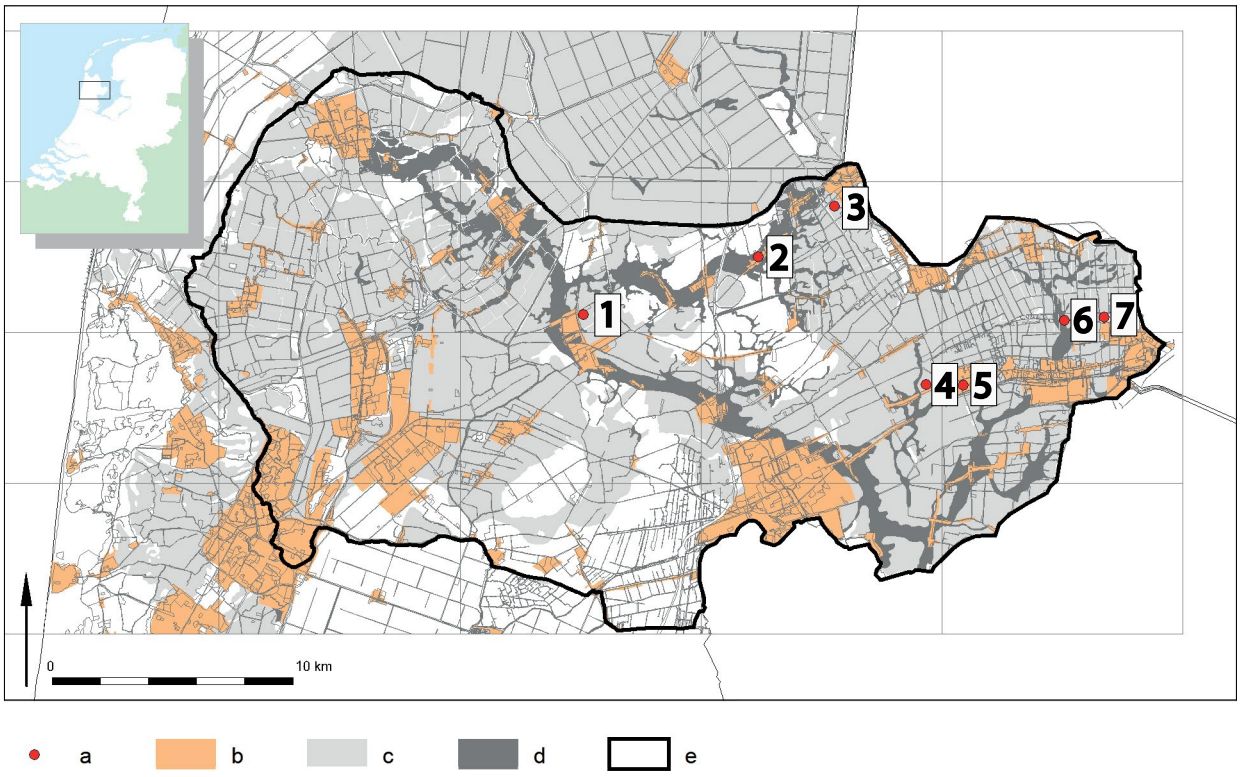


Figure 7.1. Overview of the researched sites of West Frisia that yielded wild plant remains. 1: Hoogwoud Opmeer; 2: Twisk; 3: Medemblik Schepenwijk II; 4: Westwoud; 5: Hoogkarspel Tolhuis and Hoogkarspel Watertoren; 6: Bovenkarspel Het Valkje; 7: Enkhuizen Kadijken; a: location of an excavated site; b: present-day urban areas; c: tidal marsh deposits; d: creek deposits; e: outline of present-day West Frisia.

of wild plants implies that this practice is not required because of the availability of cultivated crops, and that it is not practiced, except for occasionally picking berries or gathering nuts in autumn.

7.1.2 The proxies and the sites

In this chapter, the used proxies for the re-evaluation and re-analysis of data from both the old as well as the more recent excavations include ethnography, ethnobotany, ecology, and archaeology (section 7.2). Information from these different proxies has been gathered and combined for the creation of an expectation of the practice of wild plant gathering in a small-scale mixed farming community (section 7.3). The analysis of the data and a comparison with the expectation was used to re-evaluate the current view on wild plant gathering within a farming community (section 7.4).

The information on the sites which yielded wild plant remains are shown in Figure 7.1 and Table 7.1, including location, name, date, dating method, and 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.

7.1.3 Main current model components

The current view of wild plant gathering consists of the following main components, which are challenged in this chapter:

(1) People started to live with their backs towards nature in the Bronze Age.
(2) Bio-resources play a very restricted role in Bronze Age subsistence.

(3) Wild plant remains which are not considered to have been collected, such as nuts, fruits, or berries, belong to plants which can be described as weeds.
(4) Collection of edible wild plants is almost abandoned during the Bronze Age, evidenced by the near-absence of remains of nuts, fruits, and berries.
(5) The few finds of berries and nuts indicate only occasional collection of wild plants during autumn.
(6) All confidence was placed in agricultural production in the Bronze Age, eliminating the need for the collection of wild plants.

7.2 METHODS

The investigation into the role and organisation of wild plant gathering in Bronze Age West Frisia, as well as the evaluation of the current view towards this practice, is done by using the same main approach as that used in the previous three chapters. First, the basic activities related to wild plant gathering (Table 7.2) are used as a starting point for the creation of an expectation of crop husbandry practices (section 7.3), as well as for the analysis of the West Frisian data (section 7.4). The main proxies with which both the expectation is created and the analyses are performed are briefly discussed below. The application of multiple proxies enables the recognition of the activities related to wild plant gathering, but most of all shows the importance of this practice for farming life. After the separate components of the expectation and the data analyses have been compared and discussed, the effects of taphonomy and methodological archaeological practice are evaluated. The impact of these effects on the interpretation of the missing components of wild plant gathering that have become apparent during the creation of the expectation of practice or during comparison with the data are discussed in section 7.4.6. Through this discussion, it has become clear that some vital aspects of wild plant gathering may in fact be nearly invisible to archaeology when only one discipline is used for analysis.

Finally, the new results are re-combined and re-integrated to form a new model for wild plant gathering in small-scale mixed farming subsistence (section 7.5).

Table 7.1. Information on the sites of West Frisia used for the analysis of wild plant gathering.

Site location	Toponym	Excavated	Date	Dating method	Sieving mesh size	Reference(s)
Bovenkarspel	Het Valkje	1974-1978	1500-800 cal BC	14C-dating and pottery typology	0.25-1.0 mm	Buurman 1996, 83-104
Enkhuizen	Kadijken	2007-2009	1500-800 cal BC	14C-dating and pottery typology	0.25-1.0 mm	Moolhuizen & Bos 2011, 259-69
Hoogkarspel	Watertoren	1973-1978	1500-800 cal BC	14C-dating	0.25-1.0 mm	Pals 1977, 189-225
Hoogwoud	Opmeer	2004	1300-1100 BC	pottery typology	0.25-1.0 mm	van Haaster 2005, 50-4
Medemblik	Schepenwijk II	2007	1450-800 cal BC	14C-dating and pottery typology	0.25-1.0 mm	Kooistra 2010, 125-42
Twisk		1980	1300-1100 BC	14C-dating	0.25-1.0 mm	Buurman 1996, 37-68
Westwoud	1988	1988	1400-800 cal BC	AMS-dating	0.25-1.0 mm	Buurman 1996, 107-56

Table 7.2. Basic activities related to wild plant gathering.

Preparation
locating worthy gathering spots
Gathering
collecting wanted plants/plant parts
Processing
short-term (direct use)
long-term (preservation for later use)
Optional
storage

Similar to the previous Chapters 4, 5, and 6, the multiple activities related to wild plant gathering were analysed individually (Table 7.2) to first create an understanding of each separate basic activity, before finally viewing gathering practices in their entirety.

7.2.1 Ethnography

The ethnographical work by Murdock (1981) was studied to create a general idea of the importance of wild plants for the subsistence of mixed farmers. Similar to the previous three chapters, a selection was made on the available culture groups studied by Murdock, so that only cultures remained that most closely resemble the Dutch Bronze Age situation. Again, the selection criteria were: more than 50% of the food economy needed to consist of crop and animal husbandry (*i.e.* full-time farmers); the type of agriculture needed to be intensive agriculture on permanent fields with short fallow; crops needed to consist of cereals; settlement size needed to be relatively small, consisting of homesteads, hamlets, or compact settlements; animal husbandry should be focused on bovine animals. N.B.: The work of Murdock only reviews the food economy part of subsistence.

7.2.2 Ethnobotany

Several ethnobotanical studies were consulted to investigate the range of wild plant species used by European (farming) communities, irrespective of geographical location or climate (Ertuğ 2000; 2004; Łuczaj 2010, 2012; Kalle & Sõukand 2012). Furthermore, an online ethnobotanical database (PFAF 2016) was consulted to evaluate the edibility of the West Frisian wild plants, as well as the part of the plant used for consumption. It is assumed that gathering and consumption of wild plants remained the same throughout the Bronze Age.

7.2.3 Ecology

The ecological groups to which the found plant species belong were based on the work of Tamis *et al.* 2004. These groups were applied to the species in order to identify if plant species could have grown strictly locally or whether it was morev likely that the assemblage was the result of intentional gathering from the further surroundings.

7.2.4 Archaeology

Some archaeological indications for prehistoric wild plant collecting and consumption were listed by Behre (2008). This information is mainly based on the presence of wild plant seeds in the stomach of bog bodies and also as pure concentrations uncovered on excavated settlement sites.

7.3 CREATING AN EXPECTATION OF WILD PLANT GATHERING

Wild plant gathering is an integral part of hunter-gatherer communities. As presented in the introduction it is often thought that farmers would not have needed wild plant foods. In order to evaluate whether this is true, the role of wild plant gathering in small-scale mixed subsistence farming communities was investigated. This was researched by employing the work of Murdock (1981), similar to the previous chapters. A summary of the selected cultures from this work resulted in an average contribution of wild plant gathering to subsistence of 3% (Appendix

A1.3). Although this share is very low, it is clear that gathering is still practiced in relatively recent small-scale mixed farming communities. The role of gathering is however, hard to assess based on this contribution percentage alone, since Murdock is ineffective in his description of what is meant by this contribution, and to its importance to subsistence in general (cf. Chapter 4, section 4.3).

To further investigate the role of wild plant foods in farming communities, more specific ethnobotanical research was consulted. In recent ethnobotanical studies on farming communities from Poland, Slovakia, Estonia, and Turkey, the role of wild plant gathering to aid subsistence is clear: people collect on average 120 different edible wild plant species and collecting occurs on a weekly basis (Ertuğ 2000; 2004; Łuczaj 2010; Kalle & Sõukand 2012; Łuczaj 2012). Such a regular and substantial activity cannot be regarded as unimportant for subsistence, and thus contradicts the value provided by Murdock.

Therefore, in order to create a clear expectation of the practice and role of wild plant gathering in Bronze Age subsistence, in this section, each of the activities related to plant gathering are analysed in turn.

7.3.1 Preparation

The collection of wild plants as a practice is not particularly difficult, but does require preparatory steps in order to be successful. In particular the knowledge of the available (edible) plants in the environment, where to find them (*i.e.* location), and when they are available (*i.e.* seasonality) must form the basis for wild plant gathering.

Gathering location

Different plants can have different preferences for their growing conditions and are therefore often found at particular locations. So, when wild plants are uncovered at a site, an overview of their individual growing conditions can provide insight into the different places visited by people for collection. Since some plants may have grown near or within the settlement itself, this would not directly confirm active gathering by people. However, when wild plant seeds from (different) areas outside the house/settlement are uncovered together in one context, this gives a stronger indication for gathering practices.

By investigating the plant species from house contexts and their habitat preferences, clear indications for the visited gathering locations can be identified. The habitat preferences (*i.e.* eco groups) of past plants can be reconstructed based on recorded present-day plants species' preferences (Ellenberg *et al.* 1991; Tamis *et al.* 2004), under the assumption that the general characteristics of plants remained the same since the Bronze Age.

Seasonality

Plants are immobile, which means they remain at the same location throughout their lives, adapting to the environment around them. Seasonality of plants is therefore not related to migration, such as with animals, but rather to a difference in appearance and growth stage throughout the year. For most plants, growth (re-)commences after winter, after which several life stages are passed. These life stages are related to the part of the plant which is actively growing or already matured, which in turn can have an effect on its availability and palatability/edibility. In general, a deciduous annual or perennial plant goes through its life stages in the following order: in spring, young shoots and stems appear as well as flower buds; in summer, flowers and stems mature; in late summer/autumn, green parts of plants wilt and seeds, fruits, and nuts are produced, and roots and tubers store the nutrients required for the following growth period; in winter (depending on the species and type of plant), non-woody parts die off. Annual plants perform all life stages in a year, whereas perennial plant may require several years to flower and set seed.

Regardless of the type of plant however, people exploit the different available parts of a plant each season, and take advantage of the different life stages of a plant.

In Figure 7.2, a summary is made of the available plant parts throughout the year, thus indicating the times at which certain plant parts can be collected for consumption.

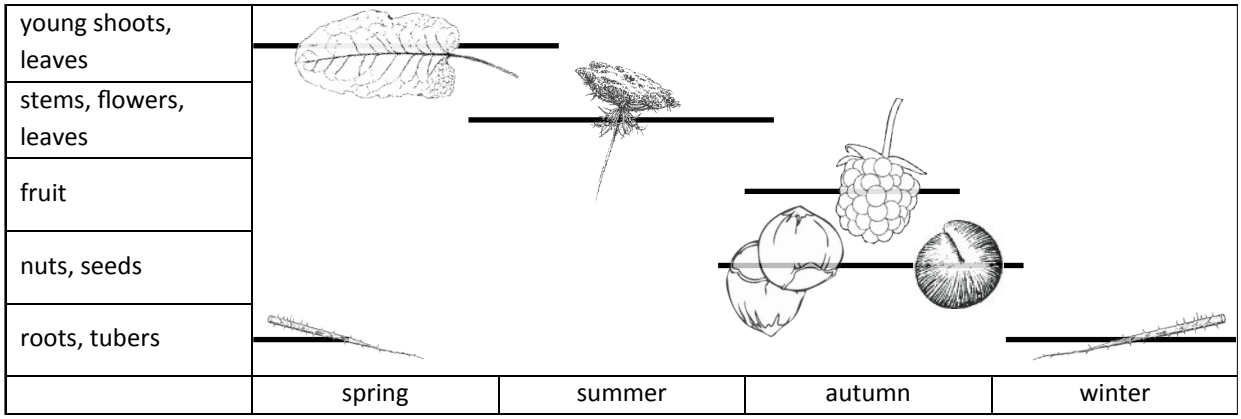


Figure 7.2. Seasonality diagram of the availability of different plant parts throughout the year.

Ethnobotanical indications for seasonality
In Turkey, wild greens are the most consistent component of the diet, consisting of mostly leaves and shoots (Ertuğ 2000, 170; Ertuğ 2004, 164). These plant parts are most required from October to June, and can even still be collected when snow has fallen (Ertuğ 2000, 170-1). However, the available diversity of species is lowest during this time, being highest in (early) spring (Figure 7.3). In addition, bulbs and fruits are gathered, indicating a year-round collection of wild plants (Ertuğ 2000, 176).

In other, more northern countries (*i.e.* Slovakia, Poland, Estonia), there is a less strong preference for green wild plant parts, but many different plant parts (including flowers, fruits, subterranean parts, and green parts) are gathered, indicating collection throughout the year (Łuczaj 2010; Kalle & Sõukand 2012; Łuczaj 2012).

Archaeological indications for seasonality
The seasonality of gathering is hard to assess based on archaeobotanical assemblages: at most excavated sites seeds are only preserved, and subsequently uncovered, in charred form. The charring of seeds only logically occurs through contact with fire, but, as is observed in section 7.3.3, many wild plants are often consumed raw. In addition, even if wild plants come in contact with fire, the chance of preservation of most of their individual parts is very low. Although seeds and fruits will sometimes become charred and therefore preserved, most vegetative parts either completely burn, or become so unrecognizable after the charring process that adequate identification to the genus or species level is no longer possible. Vegetative edible plant parts which are not cooked and thus not charred will, through normal plant degradation processes, also disappear completely. It is clear that although vegetative plant parts are most often collected based on ethnobotanical research (section 7.3.2), this gathering practice, which occurs throughout most of the year, may be near invisible due to taphonomical processes. It is therefore wrong to assume that people only collected plants in autumn, purely based on the fact that only charred remains of nuts and fruits were preserved.

7.3.2 Gathering

The practice of gathering was first researched by trying to create an expectation of which plants were usually gathered in farming communities. To aid this investigation, ethnobotanical studies were combined with archaeological indications for the gathering and consumption of wild plants (section 7.2.2 and 7.2.4). The second part of this section consisted of identifying the praxis of gathering in farming communities, also based on the ethnobotanical studies mentioned in section 7.2.2.

Gathered plants

Ethnobotanical indications for gathered plants: recent farmers.
The wild plants which are collected for consumption differ per community and region, but in general,

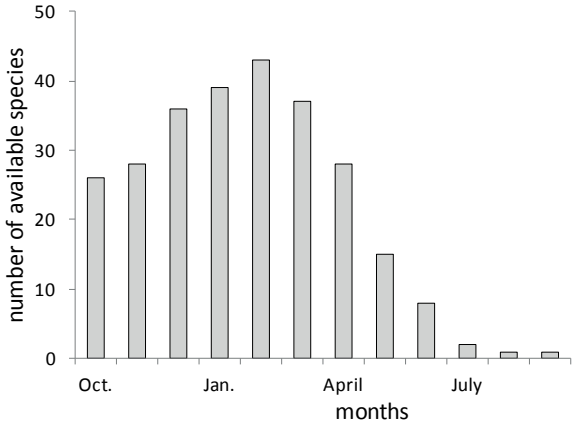


Figure 7.3. Availability of edible wild plant species collected for their greens in Bodrum, Turkey (from: Ertuğ 2004, 164, Table 2).

mostly vegetative parts are collected, such as in Turkey (Ertuğ 2000, 170; 2004, 165). Ethnobotanical studies from more northern countries (*i.e.* Slovakia, Poland, Estonia) show less preference for mainly vegetative wild plant parts, but plant greens remain an important addition to subsistence (Kalle & Sõukand 2012; Łuczaj 2010, 2012). The wild plant species most often collected in these communities are summarized in Table 7.3. Note that plants included in the table are those considered to have been collected and brought to the farm (excluding *e.g.* tree sap), for direct consumption or to be processed for indirect consumption (*e.g.* tea), and are considered to have grown in Bronze Age north-western Europe.

Archaeological indications for gathered plants: prehistoric farmers

Behre has provided an overview of prehistoric contexts which can be related to the collection and consumption of wild plants. These contexts include the stomachs of bog bodies and large clean stores of wild plant seeds (Behre 2008). Based on this overview, he has indicated several plants potentially gathered in prehistory, which are summarized in Table 7.3. Although emphasizing that green plant parts are also important in reconstructing the prehistoric diet, Behre only includes seeds, since leaves, bulbs, roots, and/or rhizomes are rarely preserved. However, some plant species were rejected by Behre for unclear reasons, even though these plants occur at similar frequencies as the plant species that he does include in his final conclusions (Behre 2008, 68, Table 2). In order to not miss any plant species for comparison in this research, every species uncovered from bog body stomachs was included in Table 7.3 as edible collected plant. Although some plants were not found in large concentrations, they still indicate consumption, and so they are added to the table as well. Plants which were found in bog body stomachs, but which were not present in Behre's final list of collected plants are characterized as potentially collected in Table 7.3.

Gathering practices

For gathering plants, not many tools are required: usually a digging stick, a cutting tool, and a container suffice (Ertuğ 2000, 175). Gathering of plants is often a social activity performed by women and children (Ertuğ 2000, 175; 2004; Figure 7.4). In Turkey, the maximum distance travelled from the settlement for gathering was 1-1.5 km (Ertuğ 2000, 175), and similar trends are observed in other areas of present-day Europe, indicating that plant collecting mainly occurs relatively close to the home (Schulp *et al.* 2014, 303). Often, groups of women and children collect several species of edible plants within 2-3 hours, which their family consume in 3-5 days (Ertuğ 2000, 175). Interestingly, gathering wild plants is independent of the level of income, and seems to be more related to nutrition and taste, rather than economic need. Still, middle and poorer income women tended to gather greens more often and less selectively than women with higher incomes.

Such differences in selectivity also become directly apparent from the taxa lists from ethnobotanical research. In some cases, several species of plant, sometimes not even within the same plant family, are given the same local name by people (Ertuğ 2000, Table 1; 2004, Table 3; Łuczaj 2010, Table 2; Kalle & Sõukand 2012, Table 1; Łuczaj 2012, Table 1). It is interesting to note that apparently, these people cannot or do not care to differentiate between species when the plants have the same use/taste/appearance. Of course, when a specific plant characteristic is important, due to its particular use or because the plant is poisonous, people will take care to select the right species.

Table 7.3. Overview of collected wild plant species in recent and past European farming communities.

		Prehist. Europe	Recent Europe			
Taxa	**English name**	**NSC**	**TUR**	**POL**	**SLO**	**EST**
Plants collected for fruits, berries, and nuts						
Corylus avellana	Hazel (nut)	2		n/a	2	2
Fragaria spec.	Strawberries		2		2	2
Juniperus communis	Juniper berry	2			2	2
Malus spec.	Apples	2			2	2
Prunus spinosa	Sloe plum	2			2	
Quercus spec.	Oak (acorn)	2			2	2
Rosa spec.	Rose(hip)s		2		2	2
Rubus fruticosus	Blackberry	2				
Rubus ideaus	Raspberry	2			2	2
Rubus spec.	Berry	2			2	2
Sambucus nigra	Elderberry	2	2		2	
Vaccinium myrtillus	Bilberry	2			2	2
Other wild plants						
Atriplex spec.	Orach/Saltbush			2		2
Berula erecta	Cutleaf waterparsnip		2			
Brassica nigra	Black mustard		2		2	
Bromus secalinus	Rye brome	2				2
Capsella bursa-pastoris	Shepherd’s purse	1	2			2
Chenopodium album	Fat hen	2	2	2		2
Chenopodium spec.	Goosefoot	2	2	2		2
Cirsium spec.	Thistle			2	2	2
Daucus carota	Wild carrot		2		2	
Echinochloa crus-galli	Barnyard grass	1				
Equisetum arvense	Field horsetail			2	2	2
Erodium cicutarium	Stork’s bill		2			
Eryngium campestre	Field eryngo		2			
Fallopia convolvulus	Black bindweed	2		2		
Filipendula ulmaria	Meadowsweet					2
Fumaria officinalis	Fumitory					2
Galeopsis tetrahit	Common hempnettle	1				2
Glechoma hederacea	Ground ivy			2	2	
Glyceria fluitans	Floating manna grass	2				
Hyoscyamus albus	White henbane		2			
Lamium album	White deadnettle				2	2

		Prehist. Europe	Recent Europe			
Taxa	**English name**	**NSC**	**TUR**	**POL**	**SLO**	**EST**
Other wild plants						
Lamium spec.	Deadnettle		2		2	
Malva sylvestris	Common mallow		2	2	2	
Malva spec.	Mallow			2	2	2
Mentha spec.	Mint		2	2		2
Menyanthes trifoliata	Bogbean					2
Nasturtium officinale	Watercress		2		2	
Oenanthe pimpinelloides	Meadow parsley		2			
Oxalis spec.	Woodsorrel		2	2	2	2
Persicaria lapathifolia	Curlytop knotweed	2				
Phragmites australis	Common reed					2
Plantago lanceolata	Ribwort plantain	1				
Plantago major	Common plantain				2	2
Polygonum spec.	Knotweed		2	2		
Polypodium vulgare	Adders fern				2	2
Potentilla erecta	Tormentil				2	2
Prunella vulgaris	Self-heal			2		2
Raphanus raphanistrum	Wild radish	1	2	2		
Rumex acetosella	Sheep’s sorrel	2	2	2		2
Rumex spec.	Sorrel		2	2	2	2
Salvia spec.	Sage		2			
Sanguisorba spec.	Burnet		2			
Schoenoplectus tabernaemontani	Great bulrush					2
Setaria spec.	Foxtail	2				
Silene vulgaris	Bladder campion		2	2		
Sinapis arvensis	Charlock		2	2		2
Sisymbrium spec.	Mustard		2			
Solanum nigrum	Black nightshade		2			
Sonchus asper	Prickly sow thistle		2			2
Sonchus cf. *oleraceus*	Sow thistle		2			2
Spergula arvensis	Corn spurrey	2				
Stachys palustris	Marsh woundwort				2	
Stellaria media	Chickweed	1	2	2		
Stratiotes aloides	Water soldier			2		
Symphytum officinale	Comfrey			2	2	
Taraxacum officinale	Dandelion		2		2	2

		Prehist. Europe	Recent Europe			
Taxa	**English name**	**NSC**	**TUR**	**POL**	**SLO**	**EST**
Other wild plants						
Trifolium spec.	Clover				2	2
Tussilago farfara	Coltsfoot				2	2
Urtica dioica	Stinging nettle		2	2	2	2
Urtica urens	Annual nettle			2		
Valeriana spec.	Valerian				2	2
Veronica spec.	Speedwell			2	2	
Viola spec.	Violet	1				2

Prehist.=Prehistoric. NSC=North Sea Coast, in the case of potentially and likely gathered plants surmising the sites treated by Behre (2008). Although some of his researched sites also lie in Western Central Europe (WCE), his general conclusions are based on the NSC sites. TUR=Turkey, surmising the parallels researched by Ertuğ (2000, 2004). POL=Poland, surmising the parallel researched by Łuczaj (2010). SLO=Slovakia, surmising the parallel researched by Łuczaj (2012). EST=Estonia, surmising the parallel researched by Kalle and Sõukand (2012). 1=potentially collected, 2=collected, n/a=information not available.

A similar manner of gathering can be proposed for Bronze Age people. It is sometimes already difficult for a botanist to differentiate between species in for example the sorrel (*Rumex*) and sedge (*Carex*) genera, so it can be assumed that Bronze Age people might have even been unaware of these differences. Therefore, it can be expected that within such genera or families where characteristics are very similar, people may have collected a range of species for the same purpose.

7.3.3 Processing

The processing of wild plants for consumption can range from just rinsing the plant when consuming the plant raw, to cutting and cooking it, and to drying it for long-term use. The manner and level of processing differs for each plant part. Tender young shoots, leaves, berries, and flowers can often be consumed raw; but most roots and tubers, older leaves, and stems are usually boiled before consumption (Kalle & Sõukand 2012, Table 1). Alternatively, these plant parts can be dried for later use, but this does decrease their nutritive properties. Nuts and seeds can be consumed raw in some instances, but normally these are part of cooked dishes or dried with the aid of fire for later use, similar to cereals.

What these above examples show is that when it is assumed that wild plants were mostly gathered for their vegetative parts (cf. section 7.3.2), it can be expected that the visibility of these remains will be relatively low in comparison to plants collected specifically for their seeds.

Taphonomical considerations

The main plant parts which survive in the archaeobotanical record are seeds (and fruits), usually in charred form. When plants are collected for their seeds, and require subsequent processing with fire, it can be expected that these species will be well represented in the soil by many charred seeds. Vegetative parts of plants preserve poorly, and plants collected for this reason will almost always be under-represented. In addition, since these plants are often collected during seasons where no seed is present (cf. Figure 7.2), their underrepresentation is even more pronounced. However, in some instances, a few seeds may accompany the plant to the settlement. For example, when plants are collected in (late) summer, some of the flowers of a plant may already have been replaced by seeds, or when plants are collected for their roots/tubers in winter, some seeds may still be attached to the plant from the preceding

autumn period. Furthermore, plants collected for their fruit also contain seed, although they are not especially collected for this plant part. The seeds deriving from plants which are collected for a different plant part will, however, be far less frequent than seeds from plants collected specifically for their seed. In addition, the seeds of plants collected for their vegetative parts will often not become charred. Therefore, in summary, it can be assumed that the plants collected for their seeds will be much better represented in the archaeobotanical record and in a different manner than plants collected for other parts.

Colledge & Conolly also recently remarked on this division between crop plants and other seed-bearing edible plants, and green plant parts with regard to their preservation in the archaeobotanical record (Colledge & Conolly 2014). They emphasize that in order to the best possible reconstruction of the overall dietary breadth of plant consumption, both charred (*i.e.* plants collected for seed) and uncharred (*i.e.* plants collected for vegetative parts) remains should be incorporated in the investigation. Still, when these two preservation states are combined in one study, it is important to realise what can be expected of the behaviour of each of the plant groups (*i.e.* plants collected for seeds, vegetative parts) in terms of prevailing preservation state and frequency. When this expectation is clear, ultimately, the possible use of an edible plant species can be reconstructed.

Reconstructing edible plant use based on seeds

Two preservation conditions can be considered when dealing with botanical remains (excluding mineralized remains here): dry, favouring preservation of charred remains; and wet, favouring preservation of uncharred remains.

Under dry soil conditions, charred seeds are better preserved than uncharred seeds, and uncharred seeds are thus expected to be lower in frequency than charred seeds. In addition, seeds of plants collected for this plant part will be better represented in general than seeds of plants collected for their vegetative parts (see previous paragraph). Therefore, under these dry circumstances, it is expected that charred seeds are uncovered more frequently than uncharred seeds, and plants collected for their seeds will be best represented in general (Table 7.4).

Figure 7.4. Woman in Turkey gathering wild plants (photo courtesy of F. Ertuğ).

Under wet soil conditions, charred seeds are also well preserved, in many cases even better than under dry conditions (Jacomet 2013, 501). Therefore, it can still be assumed that charred seeds are well represented in the archaeobotanical record. Uncharred seeds will now also be relatively better represented than under dry conditions. Plants collected for their seed will however, still be represented by a relatively higher number of charred seeds than uncharred seeds (Table 7.5), since their processing often requires the use of fire. Plants collected for their vegetative parts will be represented by a higher frequency of uncharred seeds than charred seeds under these conditions, but their overall frequency in comparison with plants collected for seed will still be low.

What Table 7.4 and Table 7.5 aptly illustrate is that low frequencies of (charred) plant seeds should by no means be interpreted as plants of lower importance

Table 7.4. Hypothetical table showing the expectation of frequencies of uncovered seed remains from plants collected for the seeds or vegetative parts, under dry soil conditions.

	Dry soil conditions	
	Preservation state of seeds	
	Charred	Uncharred
Plant collected for:		
Seeds	++	+
Vegetative parts	-	--

++=frequent, +=present, -=rarely found, --=(nearly) absent.

Table 7.5. Hypothetical table showing the expectation of frequencies of uncovered seed remains from plants collected for the seeds or vegetative parts, under wet soil conditions.

	Wet soil conditions	
	Preservation state of seeds	
	Charred	Uncharred
Plant collected for:		
Seeds	+++	++
Vegetative parts	-	+

+++=very frequent, ++= frequent, +=present, -=rarely found

or as proof of absence of gathering practices. The parts of the plant collected, the processing with or without fire, and the preservation conditions all affect the resulting archaeobotanical assemblage. Overall, the indications for a particular use of a plant can be derived from relative frequency and preservation state: low frequencies of seeds of both charred and uncharred preservation states under dry soil conditions indicate use of vegetative parts. Under wet soil conditions, relatively low frequencies in general, with a tendency towards uncharred seeds, also point in the direction of vegetative plant part use. High frequencies of charred seeds most probably indicate plants collected for their seed, regardless of preservation condition. It must be kept in mind however, that sample size must be high enough to conclude anything about the relative frequencies of remains.

7.3.4 Storage

Storage of plants mainly occurs in dried form. Most green plant parts are traditionally dried by hanging them upside-down (Figure 7.5). Nuts, seeds, and fruits can be dried, similar to the processing of cereals before storage. Dried plants require, similar to the other dried food groups mentioned in the previous chapters, dry, well-ventilated, and elevated storage areas. In addition, when for example roots or tubers are stored, they additionally require dark conditions to prevent sprouting.

Storage also requires that pests cannot access the stored food, and pure concentrations of wild plant seeds (sometimes within a vessel) uncovered from prehistoric Danish and German sites (Behre 2008, 68-9 and references therein) indicate that wild plant seeds were collected and stored in containers for later use.

7.3.5 Summary and additional main components

Wild plant gathering for consumption purposes within small-scale farming communities was researched by separately analysing the activities of which this practice consists. First, preparatory activities were researched, which include gathering location and seasonality: in order to successfully collect required plants, it must be known where and when plants are available. Plants often prefer specific growing conditions and when these locations are known, they can provide information on the locations visited by people for gathering. Information on seasonal gathering is most related to the time in which certain plant parts are available for collection. In many communities, plant parts which contain more nutrients in a particular season are usually collected

for consumption during that time: young shoots and flower buds in spring; flowers, leaves, and stems in summer; nuts, fruits, and seeds in autumn; and roots and tubers in autumn, winter and early spring.
Gathering itself was analysed by employing ethnobotanical studies on the matter from several areas in Europe, including Turkey, Poland, Slovakia, and Estonia. The gathered edible wild plant species from these areas were summarized and so formed an expectation of the range of plants and variety of parts consumed by recent farmers. It was observed that a vast amount of species were collected solely for their vegetative (*i.e.* not bearing seed) parts. An expectation of prehistoric collection and consumption of wild plants was established by employing species lists created after analysis of prehistoric bog body stomachs, as well as pure concentrations of wild plant seeds at excavated sites. This list of species however, only included wild plants that were most likely collected for their seed, and so was considered incomplete, since many plants are known to have been collected for other parts as well.

Ethnobotanical parallels were also used to research gathering practices. One aspect of gathering revealed by this researched seemed to be consistent regardless of region: many different plant species were considered to be the same by local people, and were even appointed the same local name. This means that for many wild plants, local people could not, or would not differentiate between scientifically different species, because the appearance or taste of the plant was deemed similar. Apparently, as long as the properties of the plants were similar and not considered harmful, it is unnecessary to provide every plant a different local name.

Processing of wild plants was investigated by assessing the effects of fire, and the part of the plant used for consumption. It was concluded that seeds of plants collected specifically for that seed are more often preserved in charred form and in relatively high frequencies, since fire is usually required for processing and long-term preservation for consumption. In contrast, seeds of plants collected for their vegetative parts are expected to be present at low frequencies because, when gathered for this purpose, plants are often not bearing seed. Furthermore, these seeds are usually better preserved in uncharred form.

Figure 7.5. Herbs are traditionally dried by hanging them upside down (photo courtesy of C. Bakels).

Depending on the preservation conditions during deposition, plant seeds will be more prone to either be preserved in charred form, or in uncharred form. It is therefore expected that under dry conditions, seeds of plants collected for seeds will be found more often, in charred form. Plants collected for vegetative parts will be nearly absent from such assemblages. On the other hand, under wet conditions, seeds of plants collected for their seeds will still be uncovered most frequently, both in charred and uncharred form; seeds of vegetative parts will now be better represented in comparison to under dry conditions, since they can be preserved in uncharred form. Their overall frequency of remains will still, however, be relatively low.

Storage of wild plant parts could have occurred with the other dried food products, which consisted of cereal grains, and may also have included dried meat and fish.

The investigated gathering practices have provided insight into the skill and knowledge of the environment that would have been required by Bronze Age people. Both the preparation for gathering as well as the gathering itself meant that people were very aware of their surroundings throughout the year. However, the fact that many wild plants were collected for vegetative parts, which do not preserve well, suggests that the reflection of gathering practices in the archaeobotanical record is greatly impaired by (differential) taphonomical

processes. The effect of these processes signifies that the importance and extent of gathering in the Bronze Age should not *a priori* be underestimated based on the presence of low numbers of seeds of wild plants. Finally, an additional main component was identified related to the observations made regarding edible wild plant collecting, and the effects of processing, respectively. This main component is added to the main components of the current model, and will be challenged in section 7.5:

(7) Seeds of plants are preserved differently depending on which plant part is used for consumption.
(7a) Seeds of plants collected for their vegetative parts will always be present in relatively lower frequencies than seeds of plants collected specifically for their seeds, regardless of preservation condition.
(7b) Under wet preservation conditions, seeds of plants collected for their vegetative parts will be relatively better represented in uncharred form than in charred form, whereas the opposite is true for plants collected for their seeds.

7.4 WEST FRISIAN DATA ANALYSIS

This section is concerned with the analysis of the basic aspects of wild plant gathering outlined in section 7.2 and 7.3, including preparation, gathering, processing and storage. Each part is investigated separately in order to investigate the practice of wild plant gathering in the Bronze Age, and to elucidate which plants may have been collected for consumption. In this investigation, a careful examination is made of the possible sources of evidence present for wild plant gathering in the archaeological assemblage of West Frisia. The absence of evidence for certain activities is not directly connected to the actual absence of these activities, but rather evaluated through an assessment of taphonomical and methodological impact on the data. By incorporating multiple proxies in the analysis in this chapter, other, less visible indications for wild plant gathering are identified, which would have been missed when using a single discipline analysis. For the analysis in this chapter, only remains deriving from house contexts were considered. It is assumed that the deep Late Bronze Age ditches are comparable in function to Middle Bronze Age house ditches, with both bordering the presumed house location. These particular contexts were chosen, because it is assumed that food preparation mostly occurred in and around the house so their content should reflect this practice. Furthermore, charred material is often related to human practice due to the use of fire, which ultimately resulted in this state of preservation. Therefore, in order investigate human practice related to consumption of wild plants, mainly charred material from house ditches was researched.

However, recent research by Colledge & Connolly has indicated that uncharred remains far more accurately reflect the collection of wild plant foods than charred remains (Colledge & Connolly 2014, 193). Since they also postulate that charred data alone is not sufficient to reconstruct the breadth of the diet, uncharred remains from West Frisian house ditches were also investigated, where possible.

Plants possibly growing locally in or around the house ditch contexts have been taken into consideration during analysis (section 7.4.1). It must be kept in mind however, that since the preservation of uncharred remains in West Frisia is not directly comparable to the excellent preservation of remains at water-side pile-dwelling settlements researched by Colledge & Connolly, the reconstructed dietary breadth in West Frisia will be an under-representation of the originally existing dietary range. Other uses for wild plants are investigated in section 7.4.6.4.

7.4.1 Preparation

Wild plant remains have been uncovered at every site in West Frisia, but not every site is suitable for analysis in terms of quantity. In the summarized data, all sites were employed, however, in more specialized analyses, fewer sites were selected for further investigation, where appropriate.

Gathering location
The locations visited to gather edible plants (section 7.4.2.1, Table 7.8) were investigated by summarizing the eco groups and combined frequencies of both uncharred and charred plant species from house

Table 7.6. Summarized list of the eco groups and frequencies of edible wild plant species deriving from samples from MBA house ditches (n=174) and LBA ditches (n=23). The range of eco groups signifies a wide exploitation of the environment of settlements in West Frisia.

Ecogroup (Gorteria)	Description of ecogroup	General habitat	MBA	LBA
1a	arable fields on nutrient-rich, non-calcarious soil	Arable fields	8	5
1c	arable fields on medium nutrient-rich, poor calcareous soil	Arable fields	1	1
1d	trodden soils on dry, nutrient-rich soil	Grassland	3	3
5a	fertilized grassland on medium moist soil	Grassland	5	4
6d	grasslands on dry, medium nutrient-poor, poor calcareous, acidic soils	Grassland	1	1
8b	borders on nutrient- (especially nitrogen-)rich, non-calcareous, humous, medium moist soil	Grassland	2	1
1e	brushwood on rarely trodden, nutrient-rich, non-humous or calcareous, dry soils	Shrubland	5	3
1f	brushwood on rarely trodden, calcareous, non-humous, dry soil	Shrub land	1	0
8d	brush on medium moist to dry, nutrient-rich soil	Shrub land	1	1
9a	forests on nutrient-rich, moist to wet soil	Trees	2	0
9b	forests on mature, medium nutrient-rich to nutrient-rich, medium moist to dry soil	Trees	0	1
3b	saline and highly brackish waters, mudflats, and tidal marshes	Saltmarsh	0	1
7a	medium nutrient-rich, poor calcareous, acidic eutrophic peat bogs, and wet, humous dune valleys	Eutrophic peat	1	1
2a	nutrient-rich locations with fluctuating water levels or otherwise greatly fluctuating environmental conditions	Wet grassland	3	3
2b	open, nutrient- (especially nitrogen-)rich, wet soil	Wet grassland	3	3
2c	open, medium nutrient-rich to nutrient poor, moist soil	Wet grassland	0	1
5b	medium fertilized grassland on medium moist soil	Wet grassland	1	0
4a	fresh to medium brackish, nutrient-rich waters	Wetlands	1	1
4c	fresh, medium to very nutrient-poor waters and their periodically drying banks	Wetlands	5	8
4d	water way deposits, wet brushwood, and river-accompanying willow brush	Wetlands	2	3
			45	41

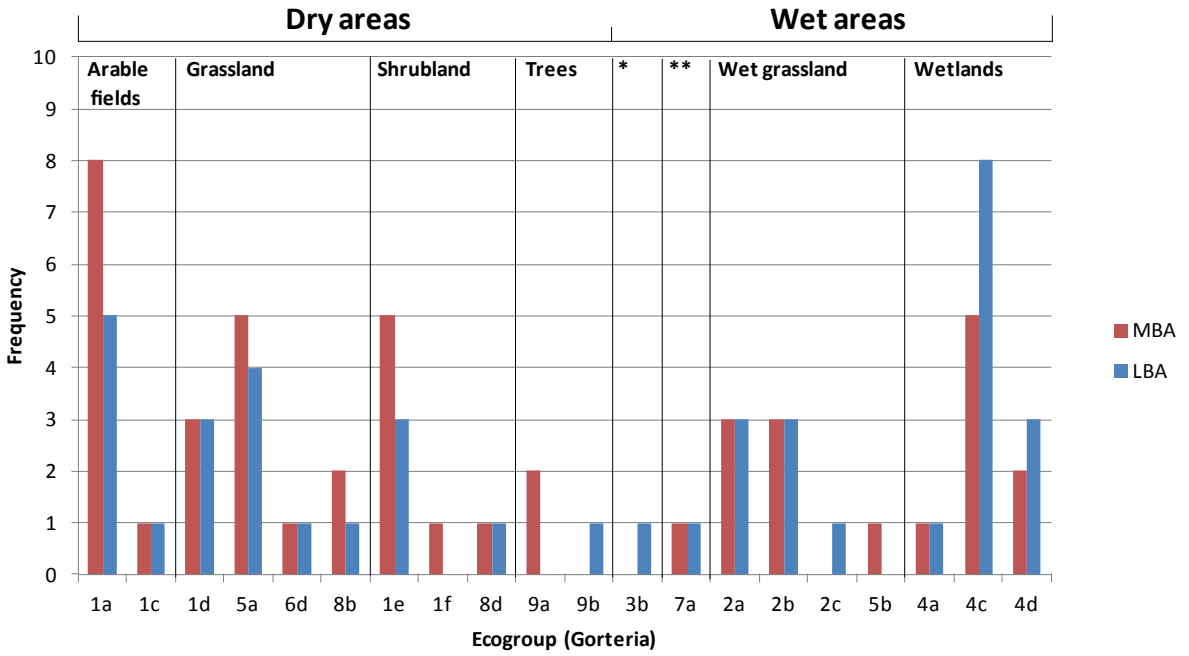


Figure 7.6. Graph of the data in Table 7.6, which shows the frequencies of the different edible plant species representing the different eco groups (cf. Tamis *et al.* 2004) and general habitats exploited in West Frisia deriving from both MBA house ditches and LBA ditches. The frequencies of the Middle and Late Bronze Age should not be compared directly, since a different number of samples was available for each period (n=174 in the Middle Bronze Age; n=23 in the Late Bronze Age). However, a general trend of exploitation per time period can be observed. *=saltmarsh; **=oligotrophic peat.

ditches. The results are summarized in Table 7.6 and Figure 7.6, for both the Middle and Late Bronze Age. What becomes immediately clear from both Table 7.6 and Figure 7.6, is that the range of locations visited by Bronze Age people in West Frisia was very wide. The range of charred plant seeds from different locations underlines that the assemblage in the house ditch was most likely not a coincidence. Rather, plants from different locations were gathered and finally deposited together in the ditch.

Visited locations for gathering wild plants for consumption are comparable for both periods, and include arable fields, (wet) grassland, shrub land, areas with trees, wetlands, eutrophic peat, and, in the Late Bronze Age, also saltmarsh.

The specific eco groups can be grouped into more generalized categories, which are comparable to the habitat types described in previous chapters. Gathering locations now include dry and wet locations, consisting of grassland, shrub land, arable fields, trees, saltmarsh, peat, wet grassland, and wetlands, of which the first three groups yields the highest frequencies of plants. Trees are not well represented. Even though wood of several tree species has been uncovered at the West Frisian settlements, and therefore presumably used in the Bronze Age (section 7.4.6.4), nuts, fruits, and catkins of trees are comparatively scarce in the archaeobotanical record. Based on Figure 7.6, it appears as if in the Middle Bronze Age more wild plant gathering occurred than in the Late Bronze Age, but this is merely related to the fewer amount of samples from this latter period (n=174 in the Middle Bronze Age versus n=23 in the Late Bronze Age). However, despite this difference in number of samples, the fact that some eco groups in the Late Bronze Age (wet grassland (2c), wetlands (4c and 4d)) show higher numbers of plants compared with the Middle Bronze Age, may indeed reflect the wetter surroundings during this period.

Gathering location in relation to the context

The eco groups and general habitats from Figure 7.6 were subsequently translated into location types (Table 7.7, Figure 7.7, and Figure 7.8) in order to more accurately assess the distance at which plants were collected in relation to the house. Plants which, based on their eco group, could have grown in the context in which the botanical remains were uncovered were termed local vegetation, plants which could have grown within the settlement were called settlement vegetation, and plants from arable fields were called arable vegetation. Plants from all other eco groups were termed off-site, since their growing conditions were not expected to exist within the settlement.

Location types were deemed local if plants could have grown in and around the (house) ditch. All other location types were categorized accordingly. Since the soil conditions of MBA house ditches differ from those of the LBA ditches, local growing conditions and therefore appointed local location types also differ between the periods.

What is apparent from Table 7.7 is that plants which could have grown locally in the Middle Bronze Age are not necessarily the same as those in the Late Bronze Age. This difference can be related to the fact that the local conditions within the sampled contexts differed throughout the Bronze Age. In the Middle Bronze Age, the house ditches were dry (Mink 2014) and probably trampled often, which resulted in local growing conditions for plants which reflect these aspects. In the Late Bronze Age however, the ditches are definitely wet for part of the year (Mink 2014), which means that local growing conditions also include additional wet eco groups. Therefore, plants which are identified as off-site in one period, can become identified as local in the other. This different wetness of contexts is further examined in relation to the inherent differences in preservation conditions and taphonomy between the Middle and Late Bronze Age in section 7.4.2.

What becomes clear from both Table 7.7, Figure 7.7 and Figure 7.8, is that edible plants derived from both settlement and arable field contexts, but also from many different off-site locations in both the Middle and Late Bronze Age. This range of off-site locations again underlines that people consciously visited many locations outside the settlement for the collection and consumption of wild plants. However, plant remains may also have derived from animal dung, indicating the locations visited by domestic animals (section 7.4.6.4).

Note again that the difference in frequency of remains between periods is related to the number of samples

Table 7.7. List of the eco groups (Tamis *et al*. 2004) of the edible plants from MBA and LBA (house) ditches and their corresponding location types.

	MBA: dry conditions	**LBA: wet conditions**
Eco group (cf. Tamis *et al*. 2004)	**Location in relation to the context (house ditch)**	**Location in relation to the context (deep ditch)**
1a	arable	arable
1c	arable	arable
1d	local	local
1e	settlement	settlement
1f	settlement	-
2a	settlement	local
2b	off-site	local
2c	-	local
3b	-	off-site
4a	off-site	off-site
4c	off-site	local
4d	off-site	off-site
5a	off-site	off-site
5b	off-site	-
6d	off-site	off-site
7a	off-site	off-site
8b	off-site	off-site
8d	off-site	off-site
9a	off-site	off-site
9b	-	off-site

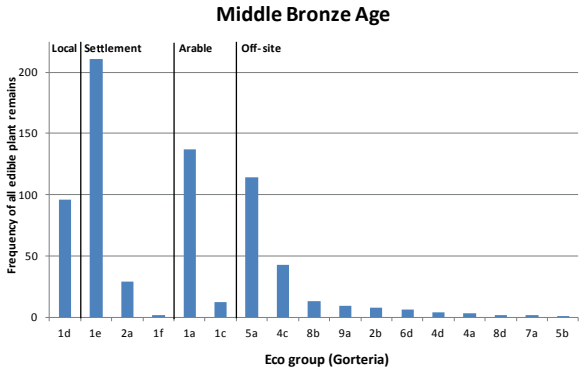


Figure 7.7. Frequencies of edible plant seeds from MBA house ditches, categorized into the different eco groups (Tamis *et al.* 2004) and location types.

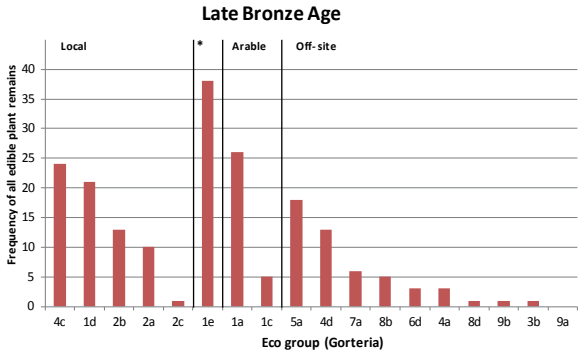


Figure 7.8. Frequencies of edible plant seeds from MBA house ditches, categorized into the different eco groups (Tamis *et al.* 2004) and location types. *=settlement.

available, not relative importance. In addition, a higher frequency of remains of a particular eco group in comparison to other eco groups does not signify higher importance or mean that a plant (group) was collected more often, as will become apparent in section 7.4.2 below.

Seasonality of gathering

Research on the collection and consumption of vegetative plant parts is, as stated in section 7.3.1, difficult. However, some techniques can be employed to identify (indirect) consumption of wild plants. In one instance, the processing of starch-containing plant parts (*i.e.* roots/tubers), was established based on the microscopic analysis of a food crust on ceramics (Kubiak-Martens & Oudemans 2011). Since no cultivation of tuber or root crops is assumed for the Bronze Age, this indicates that the collection and processing of roots, was most likely for consumption. Although this is only one indication for the consumption of the vegetative parts of wild plants, it does prove that this gathering practice still existed in the Bronze Age. More research is required to directly identify similar practices in West Frisia, and also for other plant parts. Indirect indications for the collection of plants for consumption of their vegetative parts in West Frisia were established however, based on the plant species present (section 7.4.2 below), and based on required dietary addition and general health (Chapter 8, section 8.3.2). Therefore, it is assumed that plant collecting occurred throughout the year in West Frisia, and different plant parts were collected depending on the season (cf. section 7.3.1).

7.4.2 Gathering

In order to assess which plants may have been collected for consumption, the remains from house ditches were employed for the Middle Bronze Age situation, and the remains from ditches for the Late Bronze Age situation. As stated in section 7.4.1, both charred and uncharred seeds were included in this analysis (cf. Colledge & Conolly 2014). The results for the Middle Bronze Age consist of an amalgamation of data from Bovenkarspel, Medemblik, Enkhuizen, and Westwoud; the Late Bronze Age data consisted of combined data from Bovenkarspel, Medemblik, Westwoud, and Hoogkarspel (Table 7.1).

The edibility of the West Frisian plant species was assessed by employing an online ethnobotanical database (PFAF 2016). This database consists of records of more than 7000 plant species, and provides information on plant characteristics and plant use based on an extensive bibliography list. Plant use includes both use for consumption as well as for other purposes. In the database, each plant species is appointed an edibility score ranging from 0-5, and it is noted which parts of the plant are used for consumption. In addition, information on the processing is provided, including whether fire is required. This database was used to establish the

ethnobotanical uses of (edible) plants not known from the ethnobotanical parallels, and to form a basis of comparison for the West Frisian data with the data from Table 7.3.

Each species present in the house contexts of West Frisia was researched, and plants were only considered edible when their edibility score was higher than 1, since it was observed that many plants with an edibility score of 0 or 1 were either poisonous, or not collected based on the ethnobotanical and prehistoric datasets (section 7.3.2, Table 7.3). These plants are thus not considered to have been consumed, although they may still have possessed other qualities for Bronze Age people. Of course, plants with a higher edibility score could also have been used for other purposes, so other uses of all plant species from house contexts are further explored in section 7.4.6.4.

7.4.2.1 Edible plants from house contexts

The resulting list of edible plants from house contexts is shown in Table 7.8, for both the Middle and Late Bronze Age situation. This distinction is made to assess possible differences in practice throughout time, but also because conditions within the researched contexts are not directly comparable, as is discussed in detail below.

Information on the edibility and edible plant parts was taken from the online ethnobotanical database (PFAF 2016). The specific parts of the plants consumed were also researched and noted; when plants were only collected for their vegetative parts, this was made clear in Table 7.8 by marking the particular species green. In addition, it was indicated when a species was also expected based on the expectation of collected species in prehistoric and recent farming communities (Table 7.3). In concurrence with section 7.3.2, it is assumed that plants with similar appearance and edibility may have been collected as if it were one species. Therefore, plants with such similar characteristics are combined in Table 7.8.

Collected species

A total of 55 edible plants, 47 edible after a combination of similar species, were potentially collected in Bronze Age West Frisia based on the online ethnobotanical database (Table 7.8). On average 120 edible plant species were collected based on the researched ethnobotanical parallels (Table 7.3), which means that the number of West Frisian edible plants only amounts to less than half this number. However, as stated in section 7.4, this total number of edible plants uncovered in West Frisia will form a conservative estimate of the original total amount of species collected, due to, amongst other reasons, taphonomical processes, even though the preservation conditions in West Frisia are very favourable.

Still, although only less than half of the number of expected species of edible plant was uncovered in West Frisia, there is a 62% overlap in the specific plant species collected (Table 7.8). This observation shows that regardless of geographic location, climate, and time period, it seems that a basic set of collected plants which can aid farming life may exist. The remaining species differing between regions may reflect local preference or availability (cf. section 7.3.2).

Finally, no obvious difference between the Middle and Late Bronze Age edible species was observed which reinforces the assumption that collecting species may not have differed much between the two periods.

Collected plant parts

Table 7.8 clearly shows that most edible plants in West Frisian house contexts could have been collected for multiple parts. Only one species, floating manna grass (*Glyceria fluitans*), is known to be collected for just its seeds. A further 25 species (23 after combination) are known only to be collected for their vegetative parts (including leaves, roots, oil, flowers, and roots; PFAF 2016), which amounts to 45% of the total number of edible plants in Table 7.8. Although this value is perhaps lower than expected based on the ethnobotanical parallels, it must again be realised that there is an under-representation of remains due to taphonomical processes. Furthermore, several of the plants present in Table 7.8 which can potentially be gathered for many different parts, could, in reality, have been solely collected for their vegetative parts. In order to assess whether West Frisian people may

Table 7.8. Overview of the edible plants uncovered from MBA and LBA house contexts of the summarized West Frisian sites Bovenkarspel, Medemblik, Enkhuizen, Westwoud, Hoogkarspel, and Twisk.

Taxa	English name	MBA	LBA	Present in Table 7.3?	Edible parts
Anagallis arvensis	Scarlet pimpernel	x			leaves
Atriplex hastata-type/ *patula*	Hastate/Spreading orach	x		yes	seed, root, leaves
Aster tripolium	Sea aster		x		leaves
Bidens tripartites	Burr Marigold	x	x		leaves
Bolboschoenus maritimus	Seaside bulrush	x	x		root, seed
Brassica rapa	Turnip	x	x		seed, leaves, root
Capsella bursa-pastoris	Shepherd's purse	x	x	yes	seed, leaves, oil
Chenopodium album/ ficifolium	Fat hen/Fig-leaved goosefoot	x	x	yes	seed, leaves, flowers
Chenopodium polyspermum	Manyseed goosefoot	x		yes	seed, leaves
Chenopodium glaucum/ rubrum	Oak-leaved/Red goosefoot	x	x	yes	seed, leaves
Daucus carota	Wild carrot	x	x	yes	flowers, root
Descurainia sophia	Flixweed	x			seed, leaves
Echinochloa crus-galli	Barnyard grass	x	x	yes	seed, leaves
Epilobium hirsutum	Codlins and cream	x	x		leaves
Filipendula ulmaria	Meadowsweet	x		yes	flowers, leaves, root
Galium aparine	Goosegrass	x			leaves
Glyceria fluitans	Floating manna grass		x	yes	seed
Hippuris vulgaris	Common marestail	x	x		leaves
Lamium purpureum	Red/Purple deadnettle	x			leaves
Lythrum salicaria	Purple loosestrife	x	x		leaves, root
Medicago lupulina	Black medick	x	x		seed, leaves
Mentha aquatica/ arvensis	Water/Wild mint	x	x	yes	leaves
Menyanthes trifoliata	Bogbean	x	x	yes	root
Montia fontana	Water blinks	x			leaves
Phragmites australis	Common reed	x	x	yes	leaves, root, seed, stem
Plantago lanceolata	Ribwort plantain	x	x	yes	seed, leaves
Plantago major	Common plantain	x	x	yes	leaves, root, seed
Polygonum aviculare	Knotweed	x	x	yes	seed, leaves
Potentilla anserina	Silverweed	x	x		leaves, root
Prunella vulgaris	Self-heal	x	x	yes	leaves
Rorippa amphibia	Great yellow cress		x		leaves

Rorippa palustris	Yellow marsh cress	x	x		leaves
Rubus fruticosus	Blackberry		x	yes	leaves, root, fruit
Rumex acetosella/ acetosa-type	Sheep's/Garden sorrel	x	x	yes	seed, leaves, root
Rumex crispus/crispus-type	Curly dock	x	x	yes	leaves, seed
Rumex sanguineus type	Red-veined dock	x		yes	leaves
Sambucus nigra	Elderberry	x	x	yes	flower, fruit
Samolus valerandi	Brookweed		x		leaves
Schoenoplectus lacustris/ subsp. tabernaemontani	(Great) bulrush	x	x	yes	leaves, pollen, root, seed, stem
Solanum nigrum	Black nightshade	x	x	yes	fruit, leaves
Sonchus asper	Prickly sow thistle	x	x	yes	leaves, stem
Sparganium erectum	Bur reed	x	x		root, stem
Stachys palustris	Marsh woundwort		x	yes	seed, leaves, root
Stellaria media	Chickweed	x	x	yes	seed, leaves
Urtica dioica/urens	Stinging/Annual nettle	x	x	yes	leaves, oil
Veronica anagallis-aquatica	Water speedwell		x	yes	leaves
Vicia hirsuta	Hairy tare	x	x		leaves, seed

x=present, green emphasis=edible plant only collected for vegetative parts. Yes=also present based on the expectation of collected edible plants in prehistoric and/or recent farming communities (Table 7.3).

have indeed collected less plants for vegetative matter than was expected, or whether multiple use (*i.e.* seeds and vegetative matter) plants could also be included as being collected mainly for their vegetative parts, taphonomical effects on the West Frisian assemblage were researched in more detail (cf. section 7.3.3).

Preservation differences between the Middle and Late Bronze Age West Frisia

The Middle and Late Bronze Age house contexts in West Frisia appear to possess similar edible wild plant species based on Table 7.8. However, to accurately compare the two types of context, as well as the edible uses of the plant species in them, their differing prevailing preservation conditions need to be taken into consideration. In the Middle Bronze Age, the house ditches were dry most of the time (Mink 2014), which means that charred remains have a higher chance of preservation than uncharred remains during this time; whereas in the Late Bronze Age, the deep ditches were wet for most of the year (Mink 2014), resulting in better preservation conditions for uncharred remains in comparison to charred remains. In effect, the Middle Bronze Age house contexts can be regarded as possessing a prevailing preservation condition comparable to the dry soil conditions in hypothetical Table 7.4, and the Late Bronze Age house contexts to the wet soil conditions in hypothetical Table 7.5 (Table 7.9; Table 7.10).

Therefore, the potential use of the plant for specific parts can be reconstructed, when the difference in reflection in each of the contexts is kept in mind, and when it is assumed that plants were collected for the same purpose in both periods.

Edible use of collected wild plants

Middle Bronze Age

The edible plant species from the Middle Bronze Age contexts from the sites Bovenkarpsel, Medemblik,

Table 7.9. Middle Bronze Age house contexts possess dry soil conditions. Relative frequencies of seeds of plants collected for different parts, and their uncovered states of preservation, can be expected accordingly (cf. Table 7.4).

	Middle Bronze Age situation	
	Preservation state of seeds	
Plant collected for:	**Charred**	**Uncharred**
Seeds	++	+
Vegetative parts	-	--

++=frequent, +=present, -=rarely found, --=(nearly) absent.

Table 7.10. Late Bronze Age house contexts possess wet soil conditions. Relative frequencies of seeds of plants collected for different parts, and their uncovered states of preservation, can be expected accordingly (cf. Table 7.5).

	Late Bronze Age situation	
	Preservation state of seeds	
Plant collected for:	**Charred**	**Uncharred**
Seeds	+++	++
Vegetative parts	-	+

+++=very frequent, ++= frequent, +=present, -=rarely found

Enkhuizen, and Westwoud (*i.e.* total=174 samples) were plotted with their respective frequencies of charred and uncharred seeds (Figure 7.9). Species were combined in some instances due to similarity in appearance and/or taste (cf. section 7.3.2), meaning that the combined individual frequency of these species could result in higher values than the total number of 174 samples (*e.g.* fat hen/fig-leaved goosefoot: *Chenopodium album*/*ficifolium*). For clarity reasons, species are only referred to by their scientific name, rather than their English name.

Conform Table 7.9, it was expected that plants gathered for their seeds would show relatively high frequencies of charred seeds and lower frequencies of uncharred seeds, whereas plants gathered for their vegetative parts would be reflected by low frequencies of both.

What is clear from Figure 7.9 is that only very few wild plant species appear in relatively high frequencies of charred seeds (present in more than 25 samples). These species include *Chenopodium album*/*ficifolium*, *Plantago major*, *Stellaria media*, *Plantago lanceolata*, *Solanum nigrum*, *Mentha aquatica*/*arvensis*, and *Medicago lupulina*, which can all, and especially *Chenopodium*, be considered the usual suspects within charred assemblages preserved under dry conditions. The high frequencies of charred seeds seem to imply collection for seeds.

In lower frequencies (present in between 10 and 25 samples), plants such as *Bolboschoenus maritima*, *Prunella vulgaris*, *Rumex crispus*/*crispus-type*, and *Echinochloa crus-galli* can be found. Several of the above-mentioned plants have also been uncovered from bog body stomachs (Behre 2008, Table 2).

From *Polygonum aviculare* onwards, species occur at increasingly lower frequencies (present in less than 10 samples), sometimes in combination with uncharred seeds as well. These characteristics appear to match well with the expectation of how plants collected for their vegetative parts preserve under dry conditions. Indeed, when Table 7.8 (PFAF 2016) is consulted, many of these plants are only collected for their vegetative parts (green boxes in Figure 7.9). It is tempting to assign plant use immediately, also to plants which behave in the same manner and are not necessarily only collected for their vegetative parts, such as *Brassica rapa*. However, to confirm their potential use, it is important to investigate whether the same species, now tentatively classified as being collected for their vegetative parts, behave in the same expected manner in the Late Bronze Age, during which wet soil conditions exist. When species fall within the vegetative category in both periods, a more secure conclusion can be drawn.

Species which are not behaving as expected are *Mentha aquatica*/*arvensis* and *Prunella vulgaris*.

Although usually collected for the consumption of their vegetative parts, they portray relatively high frequencies of charred seeds instead (Figure 7.9 left).

Late Bronze Age

The edible plant species from the Late Bronze Age included contexts from the sites Bovenkarpsel, Medemblik, Westwoud, and Hoogkarspel (*i.e.* total=23 samples). These species were, similar to the Middle Bronze Age, plotted with their respective frequencies of charred and uncharred seeds (Figure 7.10). Again, for clarity reasons, species are only referred to by their scientific name, rather than their English name.

It was expected that, conform Table 7.10, plants gathered for their seeds would be reflected by relatively high frequencies of charred seeds as well as uncharred seeds, whereas plants gathered for their vegetative parts would be reflected by low frequencies of charred seeds, and somewhat higher frequencies of uncharred seeds.

Figure 7.10 shows that indeed, several species with relatively higher frequencies of charred seeds than uncharred seeds were present, which were mostly the same as the species from the Middle Bronze Age. New plants in this group include *Rumex acetosella*, *Vicia hirsuta*, and *Phragmites australis*. All these species are therefore potentially collected for their seed.

Plants with higher frequencies of uncharred seeds still outnumber those of opposite characteristics, and these species would be characteristic of plants collected for their vegetative parts. Again, after consulting Table 7.8, it is clear that indeed many of the plants with these frequency characteristics are only collected for their vegetative parts (green boxes in Figure 7.10).

Similar to the MBA data, also in the LBA data some species are not behaving as expected, including *Prunella vulgaris*, *Hippuris vulgaris*, and *Glyceria fluitans*: the former two species are only collected for their vegetative parts, and show high(er) frequencies of charred seeds under wet conditions, whereas the latter is only collected for its seed, but does not yield any charred seeds.

Still, before assigning potential use to the plant species, it must be taken into consideration that not many samples were available for the LBA analysis and as such, differences observed in Figure 7.10 may be related to the low number of samples. Therefore, since it is assumed that the MBA and LBA are comparable in their species and gathering practices, both the Middle and Late Bronze Age data is combined and compared to Table 7.9 and Table 7.10 to elucidate potential plant use.

Middle and Late Bronze Age compared

The careful separate assessment of the two Bronze Age periods has brought to light several differences in preservation state and frequency of remains. Although many of the edible plants were present in both periods, it was possible to elucidate a potential use by comparing the Middle and Late Bronze Age data (Table 7.11). Each individual edible plant species was assessed for its prevailing preservation state and overall frequency in each of the periods, which was subsequently compared with Figure 7.9 and Figure 7.10 to estimate the likelihood for collection for either seed, vegetative parts, or a combination of both. In some cases, it was not possible to assign a potential use, due to the absence of data from the Late Bronze Age, which normally provides the deciding data between both uses. However, when the prevailing preservation state in the (dry) Middle Bronze Age was uncharred, collection for vegetative parts was presumed, regardless of whether Late Bronze Age data was available or not. In other cases, a mixed use was proposed, since the data reflected a mix of the expected values for the two uses. Finally, in cases where species behaved completely opposite of what was expected, another, different use than for consumption purposes was deemed likely. These particular species are further discussed in section 7.4.6.4.

The analysis of edible plant use has yielded several results. First of all, a total of 57% (*i.e.* 27/47 species) of the uncovered edible plants was most likely collected for their vegetative parts, which is very comparable to the ratios observed in Slovakia (58% edible species consumed for vegetative parts; Łuczaj 2012, 246). Although many species were known to be collected only for this purpose, also

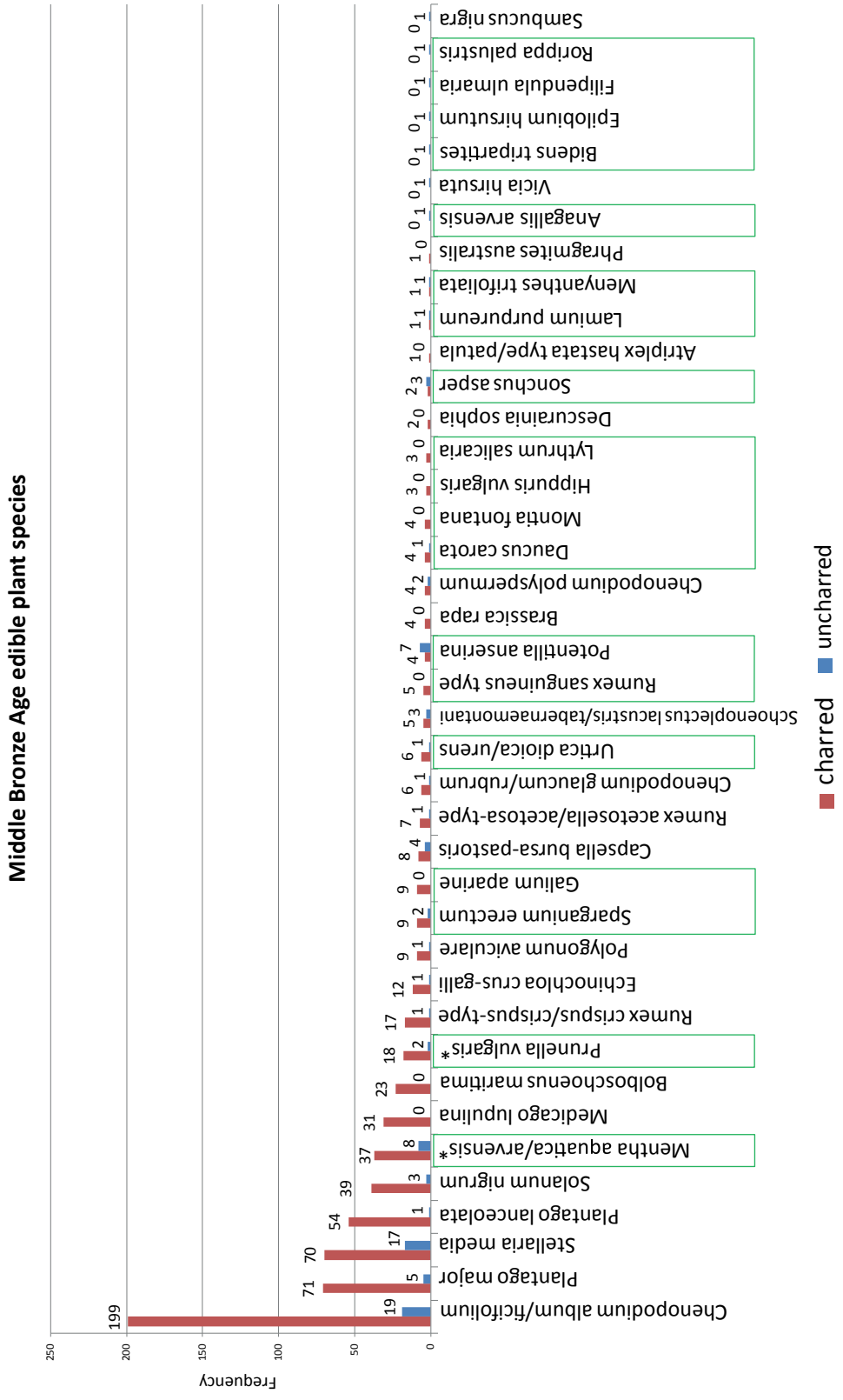


Figure 7.9. Frequencies of charred and uncharred seeds from combined edible plant species from Middle Bronze Age house contexts, from Bovenkarspel, Medemblik, Enkhuizen, and Westwoud. Green boxes denote plants collected for the consumption of their vegetative parts only (PFAF 2016).

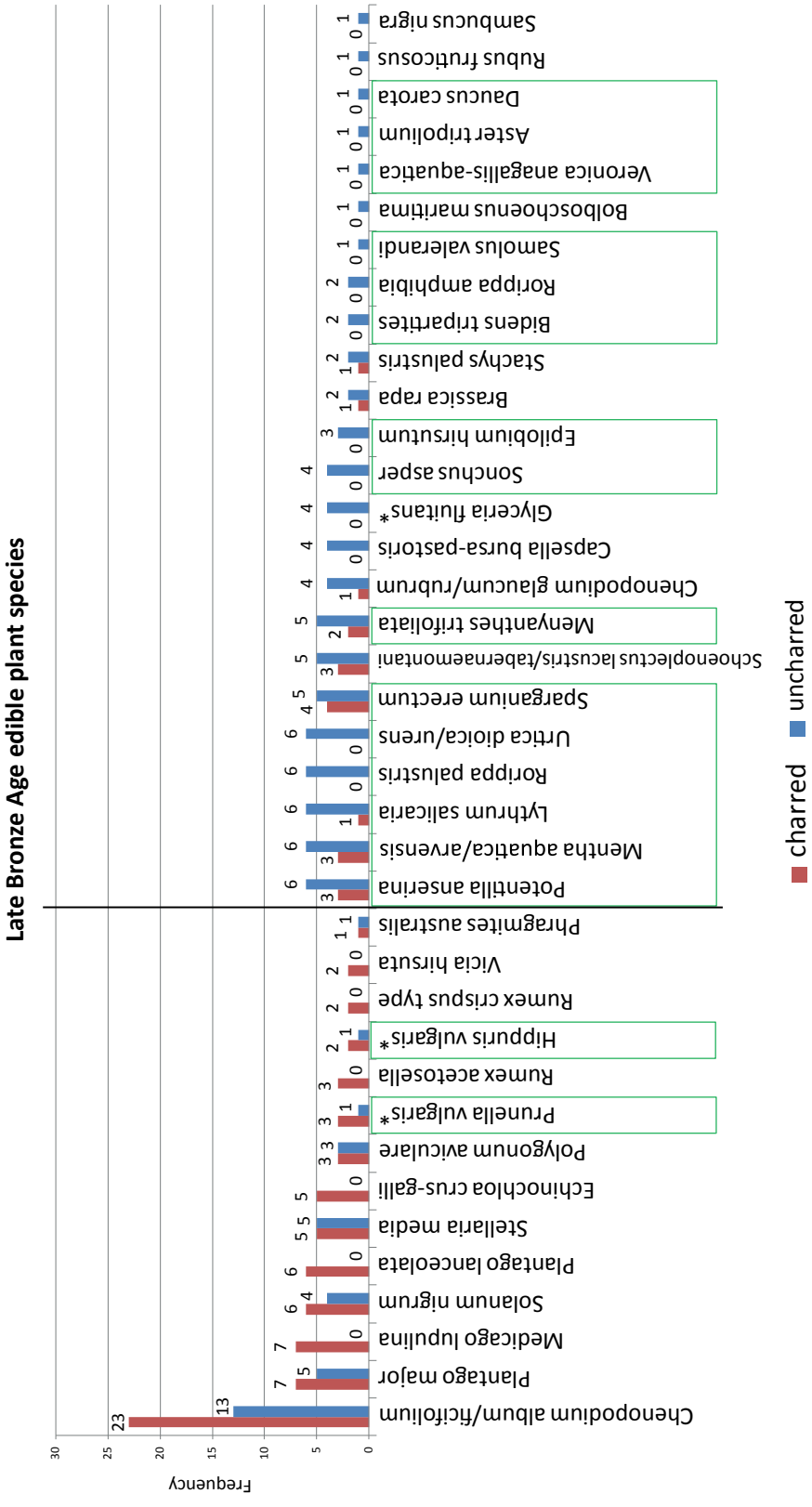


Figure 7.10. Frequencies of charred and uncharred seeds from combined edible plant species from Late Bronze Age house contexts, from Bovenkarspel, Medemblik, Westwoud, and Hoogkarspel. Green boxes denote plants collected for the consumption of their vegetative parts only (PFAF 2016).

Table 7.11. Edible plant use of species deriving from both Middle and Late Bronze Age house contexts. The elucidation of use was based on a comparison of the data in Figure 7.9 and Figure 7.10 with the expectation of prevailing preservation state and relative frequency of seeds (Table 7.9 and Table 7.10).

		Prevailing preservation state		Relative frequency		
Taxa	**English name**	**MBA**	**LBA**	**MBA**	**LBA**	**Potentially collected for:**
Anagallis arvensis	Scarlet pimpernel	uncharred	-	low	-	vegetative parts
Atriplex hastata type/patula	Hastate/Spreading orach	charred	-	low	-	cannot be determined
Aster tripolium	Sea aster	-	uncharred	-	low	vegetative parts
Bidens tripartites	Burr marigold	uncharred	uncharred	low	low	vegetative parts
Bolboschoenus maritimus	Seaside bulrush	charred	uncharred	medium	low	vegetative parts/ other use
Brassica rapa	Turnip	charred	uncharred	low	low	vegetative parts
Capsella bursa-pastoris	Shepherd's purse	charred	uncharred	low	medium	vegetative parts
Chenopodium album/ficifolium	Fat hen/Fig-leaved goosefoot	charred	charred	high	high	seed
Chenopodium polyspermum	Manyseed goosefoot	charred	-	low	-	cannot be determined
Chenopodium glaucum/rubrum	Oak-leaved/Red goosefoot	charred	uncharred	low	medium	vegetative parts
Daucus carota	Wild carrot	charred	uncharred	low	low	vegetative parts
Descurainia sophia	Flixweed	charred	-	low	-	cannot be determined
Echinochloa crus-galli	Barnyard grass	charred	charred	medium	high	seed
Epilobium hirsutum	Codlins and cream	uncharred	uncharred	low	medium	vegetative parts
Filipendula ulmaria	Meadowsweet	uncharred	-	low	-	vegetative parts
*Galium aparine**	Goosegrass	charred	-	low	-	other use
*Glyceria fluitans**	Floating manna grass	-	uncharred	-	medium	other use/local plant?
*Hippuris vulgaris**	Common marestail	charred	charred	low	low	other use
Lamium purpureum	Red/Purple deadnettle	equal	-	low		vegetative parts
Lythrum salicaria	Purple loosestrife	charred	uncharred	low	high	vegetative parts
Medicago lupulina	Black medick	charred	charred	high	high	seed
*Mentha aquatica/ arvensis**	Water/Wild mint	charred	uncharred	high	high	vegetative parts/ other use
Menyanthes trifoliata	Bogbean	equal	uncharred	low	high	vegetative parts
Montia fontana	Water blinks	charred	-	low	-	cannot be determined

		Prevailing preservation state		Relative frequency		
Taxa	**English name**	**MBA**	**LBA**	**MBA**	**LBA**	**Potentially collected for:**
Phragmites australis	Common reed	charred	equal	low	low	mixed
Plantago lanceolata	Ribwort plantain	charred	charred	high	high	seed
Plantago major	Common plantain	charred	charred	high	high	seed
Polygonum aviculare	Knotweed	charred	equal	low	medium	mixed
Potentilla anserina	Silverweed	uncharred	uncharred	low	high	vegetative parts
*Prunella vulgaris**	Self-heal	charred	charred	medium	medium	other use
Rorippa amphibia	Great yellow cress	-	uncharred	-	low	vegetative parts
Rorippa palustris	Yellow marsh cress	uncharred	uncharred	low	high	vegetative parts
Rubus fruticosus	Blackberry	-	uncharred	-	low	vegetative parts/ raw fruit
Rumex acetosella/ acetosa-type	Sheep's/Garden sorrel	charred	charred	low	medium	seed
Rumex crispus/ crispus-type	Curly dock	charred	charred	medium	low	seed
Rumex sanguineus type	Red-veined dock	charred	-	low	-	cannot be determined
Sambucus nigra	Elderberry	uncharred	uncharred	low	low	vegetative parts/ raw fruit
Samolus valerandi	Brookweed	-	uncharred	-	low	vegetative parts
Schoenoplectus lacustris/ssp. *tabernaemontanii*	(Great) bulrush	charred	uncharred	low	high	vegetative parts
Solanum nigrum	Black nightshade	charred	charred	high	high	seed, fruit
Sonchus asper	Prickly sow thistle	uncharred	uncharred	low	medium	vegetative parts
Sparganium erectum	Bur reed	charred	uncharred	low	high	vegetative parts
Stachys palustris	Marsh woundwort	-	uncharred	-	low	vegetative parts
Stellaria media	Chickweed	charred	equal	high	high	mixed
Urtica dioica/urens	Stinging/Annual nettle	charred	uncharred	low	high	vegetative parts
Veronica anagallis-aquatica	Water speedwell	-	uncharred	-	low	vegetative parts
Vicia hirsuta	Hairy tare	uncharred	charred	low	low	seed

Green emphasis in left column: plants solely collected for their vegetative parts; MBA: low=present in less than 10 samples, medium=present in between 10 and 25 samples, high=present in more than 25 samples; LBA: low=present in less than 3 samples, medium=present in between 3 and 5 samples, high=present in more than 5 samples; *=plant which does not behave according to the expectation (cf. section 7.3.3) and will probably have been used for reasons other than consumption.

some species were present of which the seeds are also edible. These species include *Bolboschoenus maritima*, *Brassica rapa*, *Capsella bursa-pastoris*, *Chenopodium glaucum/rubrum*, *Schoenoplectus lacustrus/ssp tabermontani*, and *Stachys palustris*. Apparently, these species were not (specifically/ only) gathered for their seed, but rather for parts including the leaves, roots, and stems (Table 7.8).

The edible fruit-bearing species *Rubus fruticosus* and *Sambucus nigra*, show indications for being collected for their vegetative parts, but can also be considered to have been exploited for a combination of their vegetative parts and raw fruit: since the seeds of consumed raw fruit are not specifically targeted during collection (cf. section 7.3.3), they can, in a way, be regarded as being collected as vegetative parts.

Solanum nigrum on the other hand, which also bears edible fruits, does portray high frequencies of charred seed remains. When comparing this observation with the online ethnobotanical database, it becomes clear that berries from this plant should not be consumed raw, but only cooked (PFAF 2016). Most likely, the seeds of *Solanum nigrum* arrived at the settlement through the collection of berries, but had a higher chance of becoming preserved in charred form than the other fruit-bearing plant species, as fire is required for their processing.

Only nine species from Table 7.11 (*i.e.* 19%) are suggested as being collected just for their seed. These species include *Chenopodium album/ ficifolium*, *Echinochloa crus-galli*, *Medicago lupulina*, *Plantago lanceolata*, *Plantago major*, *Rumex acetosella/acetosa-type*, *Rumex crispus/ crispus-type*, *Solanum nigrum*, and *Vicia hirsuta*. Although the seeds of some of these species can also be consumed raw, most seeds need to be cooked before consumption, such as those of *Echinochloa crus-galli*, *Medicago lupulina*, *Plantago lanceolata/ major*, and *Vicia hirsuta* (PFAF 2016), underlining their high chance of charred preservation.

A final three species from Table 7.11 show mixed signals, showing no clear preference for the collection of seeds or vegetative parts. Although this may be regarded as an actual mixed use for consumption, it could also be that collection for consumption and other uses may be both reflected here, for example of the species *Phragmites australis*, or reed. The use of these species is further investigated in section 7.4.6.4.

The relatively low number of wild species collected for their seeds in comparison with other plant parts can be explained by the fact that most of the nutrients and other properties of these seeds were already present in the cultivated cereals at the settlement. There is therefore no clear indication of the need to gather many species for this plant part, except perhaps for when cereal stores were depleting or food was scarce in general. A similar trend was observed in Poland, where the number of collected wild green plants for consumption decreased after the introduction of cultivated vegetables (Łuczaj 2010, 400-1): people collect what they cannot produce themselves. The essential nature of the collection of vegetative plant parts for the diet of a Bronze Age farmer is further explored in Chapter 8.

7.4.2.2 Gathering practices

The exact manner in which wild plant gathering occurred cannot be reconstructed based on the data available. Therefore, it is assumed that collecting was practiced in a similar manner to the other farming communities researched in the ethnobotanical parallels (cf. section 7.3.2). This means that, in order to be combined with other farming activities, gathering would most likely have occurred on a regular basis (every 3-5 days), probably for a few hours in the early morning or evening. The distance travelled from the settlement will be no further than 1.5 km away.

Since the materials required for the collection of wild plants are few and often perishable, these are not (recognisably) uncovered at West Frisian settlements. However, in one instance, evidence for basketry was uncovered in West Frisia (section 7.4.6.4), indicating that the means for gathering wild plants were available. Ironically, the evidence for basketry is of course in itself also evidence for the collection of wild plants.

7.4.3 Processing

Section 7.4.2 has indicated that wild plants were probably collected for consumption, but no clear indications for the processing of wild plants have (yet) been uncovered in West Frisia. However, many food crusts have been recognised in West Frisian ceramics, which might be analysed to investigate the use of wild plants for consumption (cf. section 7.4.1). Future analysis on these valuable sources of information should shed light on edible wild plant use in the West Frisian Bronze Age.

Another factor which limits the information on wild plant processing in West Frisia is the absence of the original Bronze Age surface, which means that hearths and rich in-house contexts are no longer present. Such contexts may provide insight into locations within the house where processing occurred, and systematic sampling of house contexts can be employed to identify possible activity areas within or around houses (Grabowski & Linderholm 2014). Finally, since no charred dried fruits specimens have been uncovered, the analysis of processing for long-term preservation could also not be completed.

Still, the different preservation states and uses of plants from Table 7.11 indirectly indicate that plants would have been processed by a range of different methods (PFAF 2016).

7.4.4 Storage

Pure concentrations of wild plant seeds were not uncovered or recognized in West Frisia. However, since it is assumed that a minority of wild plants were gathered for their seeds, due to the presence of cultivated cereals, the chance of finding such concentrations is not deemed high. Therefore, it is unclear whether storage of wild plants occurred here in the Bronze Age. The further near-absence of nuts and absence of charred fruits means that storage of seeds and fruits in general could not be established. Storage of dried vegetative parts is even harder to identify, due to taphonomic processes. Drying vegetative parts may be performed for later use of the plants, but this does affect the critical micronutrient composition (Chapter 8). Furthermore, storage needs to occur at sufficiently low and constant temperatures to prevent sprouting and decay (Calverley 1998, Chapter 3), which may not have been possible throughout the year in the Bronze Age houses. It is therefore more likely that wild plant parts were collected and consumed within a relatively short time after gathering, which is consistent with the ethnobotanical parallels (*e.g.* Ertuğ 2000).

7.4.5 Summary

In this chapter, the role of wild plant gathering for subsistence was reconstructed based on an analysis of all the different activities related to this practice. Research into the preparatory stages for gathering has revealed that many different locations surrounding the settlements were exploited based on the growing locations of edible wild plants which were found in house contexts. Both dry and wet areas were visited, and these locations were comparable for the Middle and Late Bronze Age. The seasonality of gathering could not be directly established, since only remains of seeds and fruits are usually preserved, which would indicate that gathering only occurred in autumn. Based on other indications and taphonomical considerations however, it could be concluded that gathering would most likely have occurred throughout the year, not just when fruits and nuts are available.

Gathering itself was analysed by first investigating which plants found in house ditches could have been collected for consumption. For this purpose, all plant species from these contexts were analysed for their edibility as well as their concurrence in species lists of ethnobotanical studies on farming communities. Once it was established which plants were possibly consumed, further research into the edible use of these species was undertaken. The potential edible uses of the West Frisian plants could be proposed by comparing the relative frequency and prevailing preservation state of the edible plants from Middle and Late Bronze Age house contexts with the expected values for different edible uses (*i.e.* for seed or vegetative parts). Of the total number of uncovered West Frisian edible species (n=55), 57% was potentially collected for their vegetative parts, 19% for their seed, 15% for either mixed use or a use other

than for consumption, and a final 9% could not be attributed based on the available data. The relatively low number of species collected for their seed seems at first surprising, but is in fact in agreement with observations made in recent farming communities. Here, wild plants were only collected for specific properties when these parts were unavailable in cultivated form. Since cultivated staple cereal food was available in West Frisia, the collection of wild plants for their seed was most likely less required than for example for their vegetative parts, since the cultivation of vegetable plants is not assumed for this time period. The manner in which gathering occurred exactly could not be investigated in detail, because this practice leaves few traces: both gathering tools as well as most gathered plant parts perish easily. Therefore, it was assumed that gathering practices were comparable to the investigated ethnobotanical parallels. Gathering would occur on a near-weekly basis and this activity would last for a few hours. The distance travelled to collect wild plans would probably be no further than about 1.5 km from the settlement. Processing and subsequent storage of wild plant remains could also not be established due to the lack of appropriate data. Furthermore, it unlikely that storage (of especially vegetative plant parts) for consumption played a major role in the West Frisian Bronze Age, because of an absence of adequate storage conditions for these plant parts, as well as the decrease in critical micronutrients after drying. After taking the differential taphonomic effects on plants collected for different edible uses into consideration, it has become apparent that an absence or low frequency of seeds preserved in charred form does not signify that wild plant gathering played no role in the Bronze Age. Instead, low frequencies of charred seeds preserved under dry conditions, in combination with relatively high frequencies of uncharred seeds preserved under wet conditions may indeed indicate collection of plants for parts other than seeds. The collection of plants for parts other than seeds may, although nearly invisible in the archaeobotanical record, have formed one of the most important additions to the Bronze Age subsistence, which will become apparent in the next chapter.

7.4.6 Discussion

7.4.6.1 Methodology

An attempt was made to recognize differences in wild plant composition in order to identify possible activity areas within a house (data not shown). However, the employed data derived from samples which were not taken systematically in the field, which meant that the differences observed based on the analysis could not be safely regarded as actual differences due to past practices. Therefore, to enable such analyses in the future, the main methodological aspect which would aid the research towards the use of wild plants in and around the house, which has scarcely been adopted for this area and time period, is the systematic sampling of house contexts.

Species from such samples can be analysed for their uses in order to find areas related to activities within or around a house.

Besides house contexts, it has become clear that not all activities related to subsistence are practiced in or directly next to the house. Some activities (section 7.4.6.4) require wet conditions, and the remains of rope making and basketry found in a deep pit not associated with a house context indeed indicate that some activities may be missed when the focus is only on house contexts. Especially contexts which can be assumed to have been permanently wet since the Bronze Age could be valuable sources of organic material, as well as possibly provide more direct evidence for the use of wild plants.

The consumption of wild plants in West Frisia in the Bronze Age needs to be established in more detail. By for example analysing the food crusts which are often observed on West Frisian pottery by the techniques applied by Kubiak-Martens and Oudemans, more insight can be gained into gathering practices, seasonality and consumed wild plants and their parts (*e.g.* Kubiak-Martens & Oudemans 2011).

7.4.6.2 Taphonomy

Taphonomical impact on wild plant assemblages have been extensively discussed in the main text.

Therefore, only a short summary of the effects of taphonomy and on the subsequent interpretation of uncovered remains is provided here.

Why wild plants are invisible

Although often interpreted as (crop) weeds, this chapter has shown that the virtues of wild plants lie far beyond this condescending connotation. Wild plants are however, present as a minority of plant remains in charred assemblages in the Bronze Age. Their reduced visibility in comparison to previous periods is usually related to a low importance of gathering and gathered plants for subsistence during this time.

It seems that the effects of taphonomy are not taken into adequate consideration for this conclusion. Besides the fact that not all seeds are preserved in a similar manner (Colledge & Conolly 2014, 194 and references therein), it should also be realised that plants collected for different reasons and during different times may not be reflected in a comparable manner in the archaeobotanical record either (cf. section 7.3.3). Plants collected for parts other than seeds will *always* be underrepresented: they are normally collected during times when plants do not bear seed, and their processing often does not require the use of fire. When only charred assemblages are available, many collected wild plant species will not be found, and subsequent analysis will most likely be performed on an incomplete range of wild plants. The reduced possibility for preservation of vegetative plant parts during the Bronze Age, combined with the reduced nutritional value of plants after preservation, means that these plants are often consumed directly after collection. Possible storage of seeds or dried fruits is possible, but evidence for these practices is yet to be uncovered in West Frisia. In addition, the availability of staple cereal grains reduces the necessity of the collection of wild plant seeds and subsequent storage, further reducing visibility.

Rather than immediately interpreting low frequencies of wild plant seeds as unimportant for subsistence, the above taphonomical processes should be taken into consideration first. When this is completed, the role of wild plant gathering can truly be concluded for Bronze Age farming communities.

7.4.6.3 Possible selection criteria for consumption

Very few inedible species were found in house ditches. Of the 101 different plant species uncovered in the house ditches, only 12 were deemed inedible (*i.e.* edibility score of 0; PFAF 2016). Due to taphonomy, it is hard to compare the frequency of remains with preference for certain plants, since most parts/species will not have preserved. Possible specific selections of wild plants for consumption, and their role in the human diet in general is further explored in Chapter 8, section 8.3.1.

7.4.6.4 Other reasons for wild plant gathering

Besides consumption, several other reasons for wild plant collecting exist. From the study of Ertuğ's work (2004, 165) it has become clear that 58% of all wild plants collected in Turkey are collected for other reasons than for consumption. The range of other uses of wild plants is shortly discussed below, mainly based on the study of Ertuğ's work. After this summary of known uses, indirect and direct indications for the use of wild plants in the Bronze Age are presented, and, where possible, also for in West Frisia.

Uses known from ethnography

Medicine

Medicinal plant use is a practice seen in many cultures through the ages. In the research, plants used for medicinal purposes form the second largest group (Ertuğ 2000, 177 and references therein; Ertuğ 2004, 165) after plant used for food. Ertuğ indicates that many plants used for nutritional purposes also have medicinal properties (*i.e.* 25-35%) and that in fact, often no distinction is made between food and medicine. Clearly, health and food are very closely related. It was noted however, that people separated the plants with medicinal use from those kept for food, even if the same species could be used for both purposes. Plants gathered for the treatment of livestock have also been reported in several instances (*e.g.* Ketzis *et al.* 2002; Ertuğ 2004, Table 3; Jeruto *et al.*2008; Tadesse *et al.* 2014). Although these particular species are not native to north-western Europe, it does show that wild plants can also be employed for aiding animal husbandry practices.

Fuel
Plants, especially wood, are often collected for fuel, including plants used as tinder. Again, species used in Turkey are dissimilar from plants in north-western Europe (cf. Ertuğ 2000), but still it can be expected that several species of local plant were collected in West Frisia for tinder as well.

Oil
Only two plants in Turkey were used for (lamp) oil of which one is linseed, and the other a local oil-containing plant (Ertuğ 2000, 180). Other wild plants applicable for the extraction of oil can include for example several species of mustard plant.

Animal fodder
In Turkey, cultivated fodder plants include barley, oats, and vetch. Forty-one species used as animal fodder were also used for human consumption, but different parts of the plant were collected at different times of the year as fodder for animals. Some wild plants used for fodder were cut in the summer and autumn, when plants are seed-bearing. Some of these were stored as winter fodder, such as prickly sow thistle (*Sonchus asper*).

For more northern latitudes, historical sources from Canada also describe a list of more than 60 different species used as fodder plants (Clark & Malte 1913).

Raw material

Matting
Plants used for making mats include reed (*Phragmites australis*) and bulrush (*Typha* spec.) in Turkey (Ertuğ 2000, 177).

Basketry
Wild plants used for basketry include water-bordering plants such as bulrushes, rushes, and sedges, and tree and shrub species including willow, hazelnut, birch, and oak (Ertuğ 2000, 177).

Rope
Some plants in Turkey were used to create rope. However, it is unclear from the publications exactly which species were meant (Ertuğ 2004, Table 3).

Building material
The construction of a house generally requires wood. In Turkey (Ertuğ 2000, 180), almost all available trees were used as building materials. Furthermore, reed can be used for the thatching of roofs.

Dye
Several species of plant are known to be collected for their dyeing properties. In Turkey, ten wild plant species were collected for this reason (Ertuğ 2000).

Social/ritual
Ertuğ (2000, 180) has indicated that several plants can be used in ritual and social context (*i.e.* use as amulet, incense, musical instrument, or (children's) game).

Indirect indications for wild plant use in the Bronze Age
In the Bronze Age, nearly everything required construction by the farmers themselves. It can therefore be expected that wild plants for other uses than consumption may have been even more important to Bronze Age farmers than in recent farming communities. Indirect indications for the other uses of wild plants listed above were investigated for the West Frisian data based on the online ethnobotanical database (PFAF 2016). All the different uses were noted of each species present in the house contexts of both the Middle and Late Bronze Age. These uses were then summarized for each time period, including charred and uncharred seeds, and are shown in Figure 7.11 and Figure 7.12.

Most indirect indications for other uses are similar to the known uses based on the research of Ertuğ. However, also some new uses were observed, including for soap, a source of tannin, hygiene/teeth cleaning, textile fibre, preservative, and repellent.
The most often encountered uses in the Middle Bronze Age house contexts include medicinal, dye, thatch, soap, and bedding, followed by several other uses in lower frequencies.

In the Late Bronze Age, main uses reflected are similar to the Middle Bronze Age, but repellent and tannin are now more frequent.

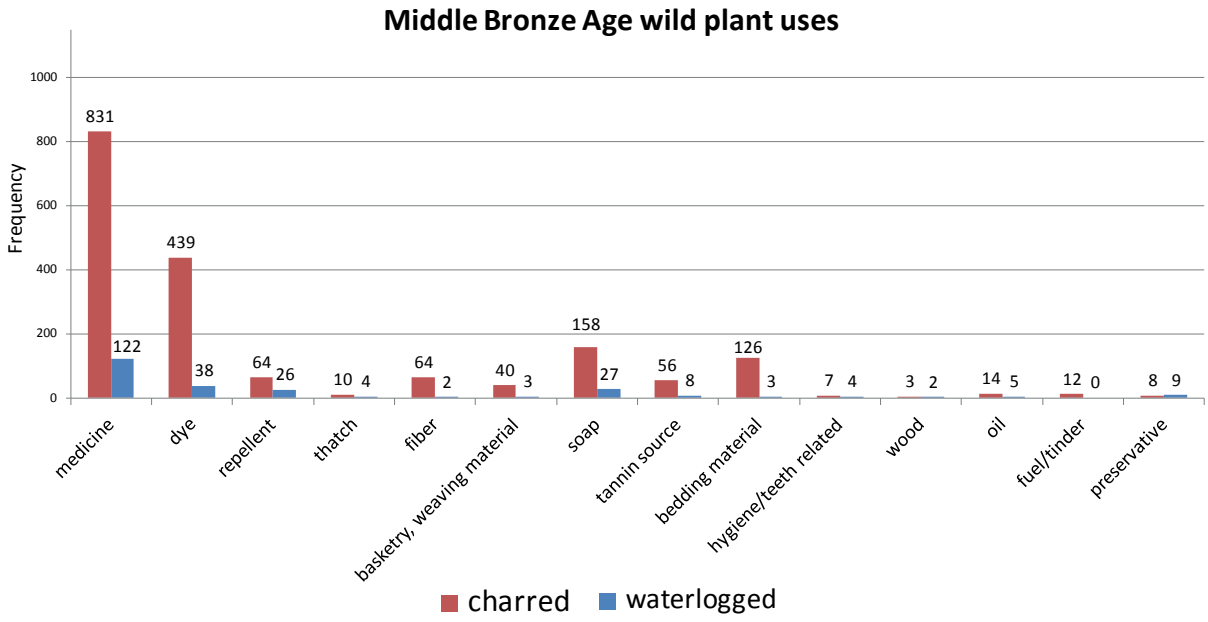


Figure 7.11. Frequencies of wild plant uses from the West Frisian Middle Bronze Age house ditches.

Differences in uses observed between the Middle and Late Bronze Age may, as was also mentioned for consumption (section 7.3.3), be related to prevailing preservation conditions and plant part used. Similar assumptions may therefore be postulated for other uses of wild plants. When, during the particular use of a plant, seeds are present, this use will be represented by relatively high frequencies of seeds. Along the same line of reasoning, when only vegetative parts of a plant are required for certain activities, these will be represented by low frequencies of seeds. Under wet preservation conditions furthermore, these latter uses will be better represented by uncharred seeds rather than charred seeds.

These assumptions seems to be confirmed by what is observed in Figure 7.11 and Figure 7.12. Uses which do not require the use of fire, such as teeth cleaning, the use of tannin for creating leather, and repellent, are much better represented by uncharred seeds in the Late Bronze Age contexts. Other uses, such as thatch and bedding, are better represented by charred seeds in both periods. Most species used for bedding include members of the sedge (*Carex*) family. The seeds of these plants are inedible and may have become charred when old bedding was ultimately used for fuel. Plants used for medicinal purposes, dyeing, and soap may have been used in their entirety, since (relatively) many seeds were uncovered, although most were preserved in uncharred state. The uses wood and thatch are scarcely represented. This near-absence can be explained by the fact that seeds/nuts of trees are not attached during building construction. Several species of tree were however found in West Frisia in the form of preserved wood itself (see direct indications for wild plant use in the Bronze Age below). The near-absence of thatch based on wild plant species may be explained by the fact that cultivated crop residue is equally applicable for thatching and this may indeed have been applied in West Frisia. Basketry and weaving, as well as plants used for their fibres are not represented well either, and this may be the result of the fact that water is required during these activities. The remains of rope making and basketry in a deep pit indicates that this activity was most likely not performed in or around the house (see below). The same may be assumed for the retting (*i.e.* forced rotting in water) of plants for the release of their fibres. Seeds of oil plants are almost exclusively preserved in uncharred form, which is logical, since oil-containing seeds completely burn after contact with fire rather than being preserved in charred state (Chapter 6, section 6.4.8.2).

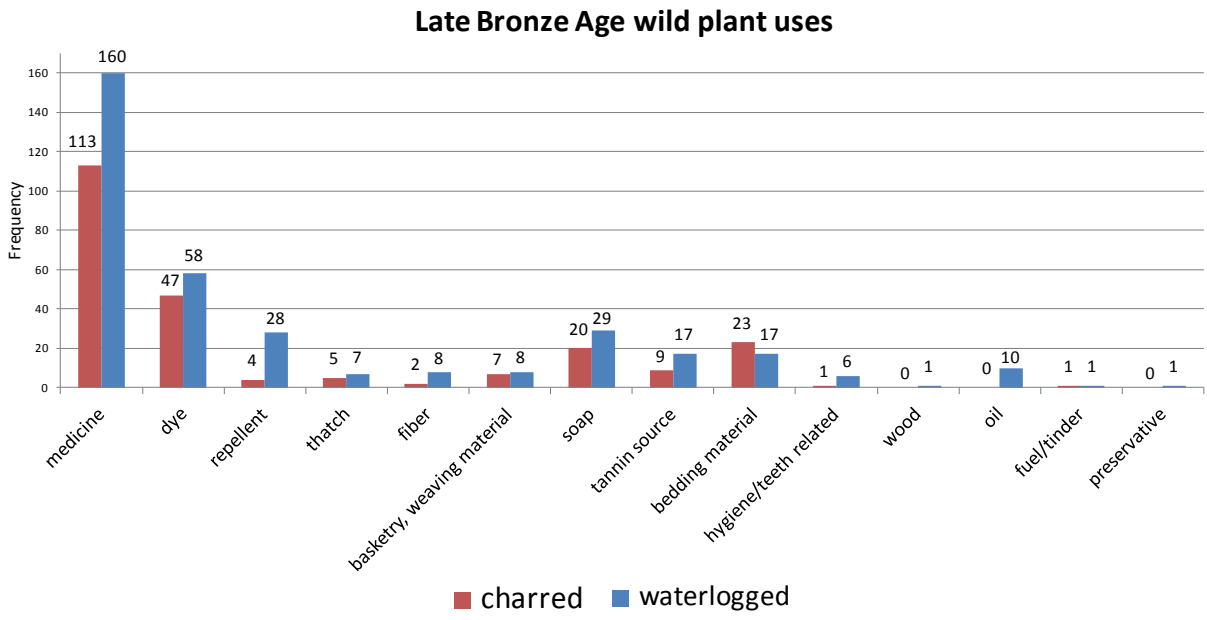


Figure 7.12. Frequencies of wild plant uses from the West Frisian Late Bronze Age ditches.

Overall, the analysis of indirect indications for different uses of wild plants has yielded a wide array of possibilities. Clearly, based on the assemblages within house contexts, activities related to the use of raw material of wild plants did exist. Direct indications for these activities are further explored below.

Direct indications for wild plant use in the Bronze Age

Direct evidence for other uses of wild plants were sought first and foremost in the West Frisian data. In some instances, examples from the Bronze Age in general were provided as well. Results are summarized in Table 7.12 and are also shortly discussed separately.

The different possible uses are based on the ethnobotanical online database (PFAF 2016) and an ethnobotanical study in Turkey (Ertuğ 2000). Only in cases where direct evidence for a use in Europe is rare, an exemplary reference is given; for West Frisia, all possible direct evidence is listed.

Medicine

It is very hard to incontestably establish the use of plants solely for medicine through analysis of archaeological evidence. However, it is assumed wild plants have been used medicinally in the Bronze Age, since medicinal plant use has been recorded in nearly every period thereafter, and even by animals such as chimpanzees and other higher primates (Sumner 2000; Engel 2002).

Fuel

All charred remains from West Frisia have of course been in contact with fire, but they were probably not all used as fuel. At Bovenkarspel, several pieces of wood have been uncovered, most of which were charred. Tree species include alder, birch, hazel, ash, pine, poplar, oak, willow, and elm (cf. Chapter 2, Figure 2.6). In the Late Bronze Age, only alder, willow, and birch wood have been found in charred form, indicating a wetter landscape than in the Middle Bronze Age, but still allowing enough wood for fuel.

Oil

Oil use has been established for the Bronze Age in general (Kučan 2007), but there were are no clear indications for the use of oil in West Frisia.

Animal fodder

Although no clear dung layers were found in West

Table 7.12. Overview of the direct indications of other uses of wild plants (excl. medicinal use) from Bronze Age Europe and West Frisia.

Use			References
Raw material	**Europe**	**West Frisia**	
Matting	yes	yes	Richmond *et al*. 2010; Besteman 1979, 218
Basketry	yes	yes	Jones et al. 2014; van Iterson Scholten 1977, 137; Bakker *et al.* 1968, 198
Rope	yes	yes	Pryor 2002, 244; van Iterson Scholten 1977, 136
Building material	yes	yes	Kooistra 2010, 138
Textile fibre	yes	no	Bergfjord *et al.* 2012
Miscellaneous	**Europe**	**West Frisia**	**References**
Fuel	yes	no, but likely	
Animal fodder	yes	no, but likely	Karg 1998
Oil	yes	no	Kučan 2007
Dye	yes	no, but Dutch Bronze Age examples exist	Hofmann-de Keijzer *et al.* 2005; Greimer, unpubl.; Joosten & van Bommel 2015

Frisia which could have provided insight into consumed plants by livestock, several plants were found that are known from historical sources to have been used as fodder (Clark & Malte 1913). These plants are summarized in Table 7.13. Besides these plants mentioned in old Canadian records, many more could undoubtedly have been used as fodder, such as prickly sow thistle (*Sonchus asper*). Therefore, Table 7.13 is only an indication of the richness of fodder plants available in West Frisia.

Although not exactly fodder, bait for hunting purposes could also have been a reason to collect certain wild plants. The species used for this purpose can however, be so general in nature, that it was not possible to identify them with certainty in West Frisia.

Raw material

Matting

The plants indicated for making mats in Turkey – reed and bulrush – have both been uncovered in West Frisia, with reed being the most common. In Medemblik Oude Haven, also a platform of alder branches was found, covered by a secondary wicker work (Besteman 1979, 218).

Basketry

At Hoogkarspel, evidence for basketry is found in the form of a basket fragment, and several remains of raw material found at the bottom of pit, suggesting a work place for practicing basketry (van Iterson Scholten 1977, 137; Bakker *et al.* 1968, 198; Figure 7.13).

Rope

Evidence for rope production is found in Hoogkarspel

Table 7.13. Potential fodder plants uncovered in West Frisia.

Taxa	English name
*Agrostis stolonifera**	creeping bent
Echinochloa crus-galli	barnyard millet
Festuca arundinacea-type	tall fescue
Lolium perenne	perennial ryegrass
Medicago lupulina	black medick
Panicum miliaceum	European millet
Phalaris arundinacea	reed canary grass
Phleum pratense	timothy
Poa palustris	swamp meadow grass
Poa pratensis	smooth meadow grass
*Poa pratensis/trivialis**	smooth/rough meadow grass
*Trifolium repens**	white clover
Vicia faba var. *minor**	tick bean
Vicia sativa ssp. *angustifolia*	narrow-leaved vetch

*=plant not uncovered specifically in house context

(van Iterson Scholten 1977, 136; Figure 7.14) in the same pit where the basketry remains were found. Wood, bast, chips, and fibres were found alongside the unfinished rope products which together measured 88 cm. This rope shows that the knowledge to construct nets for hunting purposes was present in West Frisia.

Building material

Wood and plants for thatching have been uncovered in West Frisia. In Medemblik, two rare pieces of alder wood were found in post holes of a house, indicating their use as building material (Kooistra 2010, 138). In general, remains of construction wood are very rare in West Frisia. However, it is not possible to directly reconstruct whether plants were used for thatching and which species these may have been.

Material to create tools would also have consisted mostly of wood, but no clear tools have been uncovered in West Frisia so far. The ard marks present at many sites in West Frisia (Chapter 6) however, show that ards were present, which were probably made out of wood.

Textile fibre

It has recently become clear from a find in Denmark that stinging nettle (*Urtica dioica*) was used in the Bronze Age to produce textiles from its fibre (Bergfjord *et al.* 2012). This shows that not only cultivated fibre plants were used in the production of textiles. No evidence for textile is known from West Frisia, which may be the result of it not being recognised during excavations. Although textile fibre plants have been found, such as stinging nettle and ribwort plantain, no clear indications for the production of textiles could be ascertained.

Dye

Prehistorically, various plants are known to have been used in dyeing textiles, as evidenced by the analyses on Bronze and Iron Age textiles from Hallstatt, Austria (Joosten *et al.* 2006). However, only plants cultivated for dyeing in later time periods (*i.e.* Middle Ages) are used as a reference, so the various unknown dye components visible in these textiles may have derived from previously unknown wild dye plants (pers. comm. M. van Bommel). In Drenthe, the Netherlands, the use of the blue dye plant woad (*Isatis tinctoria*) (Geimer, in prep.) as well as an unknown yellow dye plant (Joosten & van Bommel 2015) has been established on woollen textiles connected to the yarn balls and the Emmer-Erfscheidenveen bog body clothing, both dating to the Bronze Age (Appendix A1.4; Chapter 8, section 8.3.2). Surely, similar dying plants would also have been available to the West Frisian people.

Several potential dye plants have been uncovered in West Frisia. Assuming people in West Frisia also used wool to create textiles, several plant species could have been used for dyeing blue, purple, pink, red, yellow, green, brown, and black (Chapter 8, section 8.3.2).

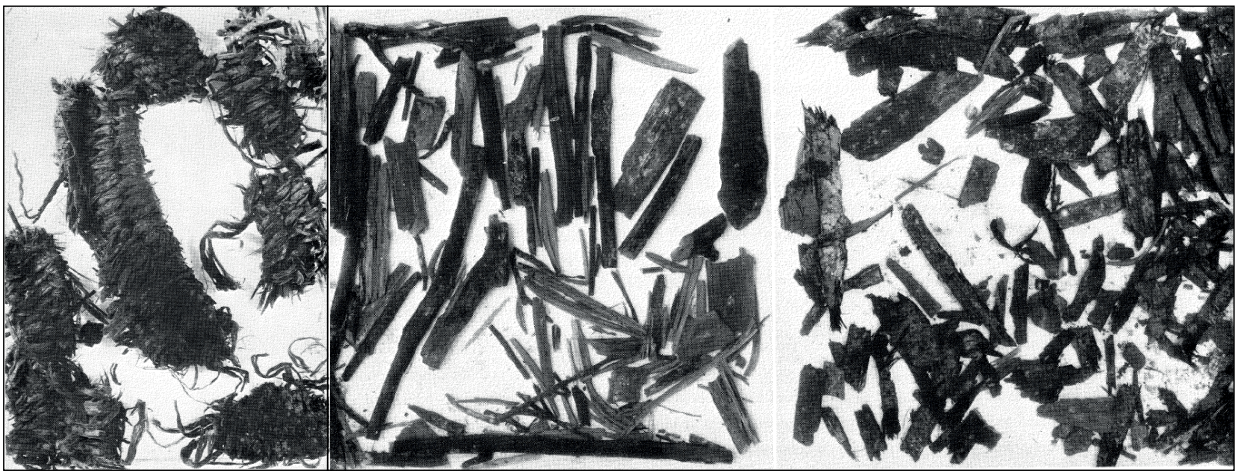


Figure 7.13. Remains of basketry (left) and raw material (right) uncovered in a deep pit at Hoogkarspel; scale 1:2 (from: van Iterson Scholten 1977, 38).

Social/ritual

No clear indications for these uses were identified in West Frisia.

Miscellaneous uses

Besides the uses indicated above, plants used as insect repellent have also been found. These plants could have been used to repel insects from domestic animals, people, and stored food, which is still common practice in many small farm holdings today (*e.g.* Payne 2002).

Edible plants rejected for consumption

The plants which did not follow the expected pattern for consumption, were assessed for their other uses. Goosegrass (*Galium aparine*) has uses such as fuel/tinder, or dye; water/wild mint (*Mentha aquatica*/*arvensis*) can be used as repellent; and self-heal (*Prunella vulgaris*) can also be used asdye. Common marestail (*Hippuris vulgaris*) and floating manna grass (*Glyceria fluitans*) however, have no apparent other uses. Upon closer inspection, it has become apparent that common marestail is best harvested for consumption from autumn to spring, even though the vegetative parts are consumed either cooked or raw (PFAF 2016). This means that seeds may have arrived with the harvested plant and become charred in that manner. Alternatively, this plant has mild medicinal properties which may have been the reason for collection. Floating manna grass surprisingly has no known other uses (PFAF 2016). The presence of many uncharred seeds in house

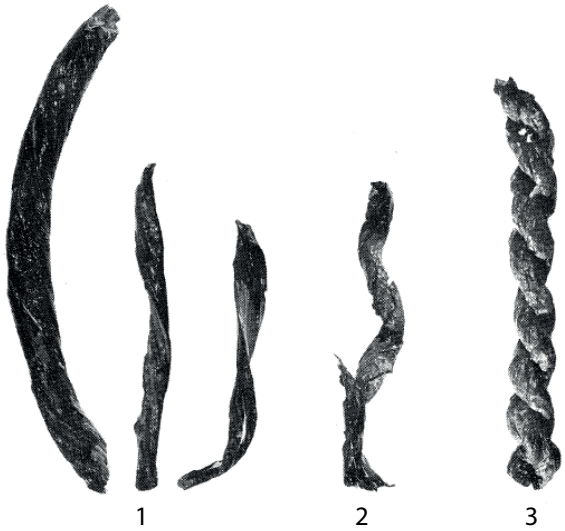


Figure 7.14. Remains of rope making uncovered in a deep pit at Hoogkarspel; 1: unfinished rope pieces; 2: single-ply rope; 3: two ply rope; scale: 1:2 (from: van Iterson Scholten 1977, 136).

contexts may therefore be explained by the fact that this plant may have grown locally in the Late Bronze Age ditches, releasing its seeds into the water, where they are ultimately preserved in uncharred form.

7.5 RECONSTRUCTION OF WILD PLANT GATHERING

7.5.1 Individual proxy contributions to the reconstruction of wild plant gathering

Every chapter so far has greatly benefitted from the application of ethnographical studies and this chapter is no exception. This research field has enabled the recognition of the contribution of wild plant gathering to the subsistence of small-scale mixed subsistence farmers, regardless of geographical location or climate. Ethnobotany has enabled a more detailed understanding and expectation of the gathering and use of wild plants, both for consumption purposes, as well as other reasons. These other purposes of wild plants, including fuel, oil, animal fodder, and raw material for the production of various tools and equipment, have firmly established the importance of wild plants for the fulfilment of basic needs that surpass consumption. Based on an online ethnobotanical database, it was possible to establish these possible uses of the different plants found in West Frisia as well. Ecological information on the preferred growing locations of edible wild plants uncovered from house contexts has provided insight into the places visited by Bronze Age people to collect plants for consumption. Archaeology finally, has both provided an overview of expected edible species present in prehistory, as well as direct indications in West Frisia for the use of plants for consumption and raw material.

The approach of this chapter was to view wild plant gathering from multiple perspectives with the use of several disciplines. The combination and integration of these proxies has once again produced new results and a more detailed understanding of the role and praxis of wild plant gathering in mixed farming subsistence. Moreover, the approach has resulted in the recognition of the different processes affecting the visibility of gathering as a practice. By taking these effects into account during interpretation, gathering of wild plant species has been revealed as a probable, and even integral part of life in the Bronze Age, which would not have become apparent when considering only one discipline.

7.5.2 Assessing previous main components

It is apparent from the previous section that the approach applied in this chapter has yielded many new results. Both the role and praxis of wild plant gathering in Bronze Age West Frisia has been established. In this section, the validity of the main components of the previous model are evaluated through a comparison with the new results.

Main component 1 was formulated as follows:

(1) People started to live with their backs towards nature in the Bronze Age.

Based on the analyses of the different activities related to wild plant gathering, including preparation, gathering itself, and processing, is has become clear that people must have possessed a vast knowledge of their surroundings and the different plants available in it. The different growing locations of plants, the knowledge of their availability throughout the year, and their different uses further attests to the fact that people knew what they were doing. Similar results were obtained in Chapter 4 on hunting, which means that main component 1 is in need of reformulation:

(N1) People lived together with nature in the Bronze Age, exploiting it for what they required to aid their subsistence.

Main components 2 was formulated as follows:

(2) Bio-resources play a very restricted role in Bronze Age subsistence.

Based on the analysis of the uses of wild plants (but also wild animals, see chapter 4) it has become clear that the collection of wild plants most likely complemented Bronze Age subsistence by providing people with material which was not produced by farmers during this time: vegetative plant matter including leaves, green stems, roots, flowers,

fruits, and nuts. These plant parts would have aided subsistence both as an addition to the diet, and as a source of raw material to produce an array of products required on the settlement. Since the new results clearly do not match main component 2, a new main component 2 is formulated:

(N2) Bio-resources play an elaborate role in Bronze Age subsistence, both as an addition to the diet, as well as a source of raw material to create other products.

Main component 3 was formulated as follows:

(3) Wild plant remains which are not considered to have been collected, such as nuts, fruits, or berries, belong to plants which can be described as weeds.

Based on the analysis of possible plant uses with the help of ethnobotanical studies, it has become clear that wild plants have many virtues and are often especially collected for parts other than fruits or nuts. Besides their use as food, vegetative parts can also be used, as stated, as a source of raw material. In effect, these plant parts have more uses than nuts and fruits, and are often available for a longer period of time. Again it seems that the current main component and the new results are not compatible and main component 3 is therefore newly formulated:

(N3) Wild plant remains which are not known collected nuts, fruits, or berries often belong to species which have many more uses than consumption only, potentially have more uses, are available during longer periods of time, and should therefore be considered as potential valuable additions to subsistence, not weeds.

Main component 4 was formulated as follows:

(4) Collection of edible wild plants is almost abandoned during the Bronze Age, evidenced by the near-absence of remains of nuts, fruits, and berries.

Based on a re-analysis of plant remains the extensive effects of taphonomy on assemblages and subsequent interpretation have become apparent. When plants are collected for their seeds, they are likely to come in contact with fire. Therefore, their prevailing preservation will be in charred state, and frequencies will be relatively high. However, it has become clear that no large amounts of nuts are required during the Bronze Age in comparison to the Neolithic, since staple food now consists of cereals. Berries can be consumed raw, and may therefore also be preserved in uncharred form rather than charred form.

When plants are not specifically collected for their seed or fruit, the resulting frequencies of seeds will be low in general. Processing of these plant parts often does not involve the use of fire, and therefore, their main preservation will occur in uncharred form. The frequencies of charred seeds from plants collected for their vegetative parts will thus be low regardless of the soil in which they are preserved. Since most assemblages consist of only charred material, plants collected for parts other than seeds will either be absent or severely under-represented.

The role of collecting seeds, fruits, and nuts as staple food has most likely shifted in comparison with previous periods, since cereals form the main staple food. Such (charred) remains of collected fruits and nuts will thus be less frequent than before. Remaining edible plant species are collected for their vegetative plant parts, of which seeds are also logically present at low frequencies. The near-absence of remains of edible wild plants in general, and of nuts, fruits, and berries in particular, can therefore not be directly interpreted as an unimportance of edible wild plants during the Bronze Age.

Main component 4 is no longer valid and is therefore newly formulated as well:

(N4) Edible wild plants are not abandoned during the Bronze Age, but the reflection of their remains is restricted by the shift in use in comparison with previous periods; less wild plant species are collected for staple food, since cereals form the staple food source: species collected for their other parts, which complement subsistence during this time, are nearly invisible due to the absence of seeds and poor preservation of vegetative matter.

Main component 5 was formulated as follows:

(5) The few finds of berries and nuts indicate only occasional collection of wild plants during autumn.

Based on the results highlighted under main component 4, few remains of wild plants do not directly relate to the actual extent of collecting being practiced. Since these plants were no longer required as the main staple food in the Bronze Age, their reflection in the archaeobotanical record is greatly overshadowed by the daily processing of cereals. Many direct and indirect indications which were presented in this chapter have shown that wild plants must have been collected on a regular basis throughout the year, for a multitude of reasons and parts. The results suggest that main component 5 should also be reformulated:

(N5) The few finds of berries and nuts only represent the visible tip of the iceberg, which in its totality will have consisted of a wide array of wild plant species collected throughout the year, for various reasons and parts.

Main component 6 was formulated as follows:

(6) All confidence was placed in agricultural production in the Bronze Age, eliminating the need for the collection of wild plants.

The range of edible plant species found in house contexts as well as the other uses for which these wild plants may have been used, indicate that apparently the yields of agricultural production were not sufficient for Bronze Age subsistence. The properties and uses of plants that were perhaps missing in the cultivated plants would have encouraged wild plant gathering, and this will be explored in more detail in Chapter 8. Based on this chapter however, it is clear that main component 6 is not in concurrence with the results and it is therefore reformulated as follows:

(N6) All confidence was placed in agricultural production in the Bronze Age to provide people with staple food in the form of cereals, and raw material in the form of crop residue; the collection of wild plants was needed to aid this part of subsistence by providing farmers with additional plant parts which were not or could not be produced by themselves.

Main components 7, 7a and 7b were formulated as follows:

(7) Seeds of plants are preserved differently depending on which plant part is used for consumption.
(7a) Seeds of plants collected for their vegetative parts will always be present in relatively lower frequencies than seeds of plants collected specifically for their seeds, regardless of preservation condition.
(7b) Under wet preservation conditions, seeds of plants collected for their vegetative parts will be relatively better represented in uncharred form than in charred form, whereas the opposite is true for plants collected for their seeds.

Based on the comparison of the expectations of the different preservation states and frequencies of plants collected for different purposes along with the known uses of these plants based on ethnobotanical information, it could be concluded that there was a clear consistency in results. Almost all plants collected for vegetative parts followed the expected pattern for this use and the same was observed for plants mainly collected for seed. Main components 7, 7a, and 7b therefore do not require reformulation.

Almost none of the main components of the current model were able to describe the role and praxis of wild plant gathering to an extent where they were compatible with the new results. Thus, the new main components outlined above are combined and integrated to form a new model for wild plant gathering in Bronze Age West Frisia.

7.5.3 New model for wild plant gathering

Although wild plant gathering leaves few recognisable traces in the archaeobotanical record, this food strategy formed an integral part of subsistence in the Bronze Age. West Frisian people exploited many different habitats surrounding their settlement in order to obtain wanted plants. Gathering

will have occurred on a near-weekly basis and would have been consistently practiced throughout the year to collect plants which complemented the available staple cereal diet. Different plant parts will have been exploited each season: young shoots, stems, and flower buds would be collected in spring; flowers and leaves in summer; fruits, seeds, and nuts in autumn; roots and tubers in late autumn, winter, and early spring. Most plants will have been collected for their vegetative parts, to provide people with food, which was unavailable as a cultivated variety during this time, and raw material. Depending on the use of the plant, processing could have varied from rinsing, to cooking, to drying (with or without the use of fire). Although drying plants would ensure use at a later time, long-term preservation of wild plant remains is not assumed. This assumption is based on the fact that vegetative parts lose their nutritive properties during drying, and spoilage would have been difficult to prevent under the conditions in West Frisian houses during the Bronze Age. Therefore, wild plants for consumption were probably collected for immediate processing, although wild plants for other use may have been preserved until time was available for the creation of products.

In the Bronze Age, nearly everything needed to be constructed by farmers themselves. It can therefore be assumed that the collection and processing of wild plants contributed even more to subsistence in the Bronze Age than in more recent farming communities. By being fully aware of the potential of the environment surrounding their settlements, Bronze Age farmers were able to combine exploitation and production of plants to match their requirements. Without the use of wild plants, both the diet of people, as well as life at the settlement would be incomplete. Wild plants should therefore not be regarded as weeds, but rather as plants whose virtues have not yet been discovered (Ralph Waldo Emerson).

8. Bronze Age farming in West Frisia

8.1 INTRODUCTION

The four subsistence strategies related to West Frisian farming have been investigated separately in the previous four chapters, including the analysis of hunting, animal husbandry, crop husbandry, and wild plant gathering. Through these investigations, the potential role and praxis of each separate component has become clear in a more detailed manner, merited by the application of multiple disciplines. However, as introduced in Chapter 1, it is not the analysis of the separate aspects that provide insight into the complex system of farming. The different parts which constitute a farming system can in reality not be viewed as separate entities due to their balanced interconnectedness with other parts of the system. Therefore, the four analysed subsistence strategies need to be integrated to create a better understanding of farming as a whole.

In order to understand subsistence farming in a larger context, in this chapter, these four strategies are synthesized into three main themes. These themes were chosen based on the analysis results of the previous Chapters 2-7, which were rooted in the approach that basic subsistence includes the basic needs food, fire, shelter, and water (Chapter 3, section 3.1). The analyses in Chapter 2 were mainly focused on the reconstruction of the environment in which activities related to the fulfilment of the basic needs occurred. This chapter was therefore concerned with the composition and distribution of flora and fauna in West Frisia. Chapters 4-7 were mainly focused on the analysis of the role and praxis of each subsistence strategy in the procurement of food, as well as shelter (housing and clothing). These four chapters thus investigated how the different subsistence strategies contributed to the overall diet, range of clothing, and shelter options in West Frisia. In addition, these chapters have enabled the identification of the different activities required to accomplish the fulfilment of the basic needs. The three overarching themes of the previous chapters can be summarized as (1) The reconstruction of the landscape (section 8.2); (2) Reconstruction of subsistence (section 8.3); and (3) Reconstruction of activities related to subsistence (section 8.4).

These themes will form the foundation of the integration of data, focusing on the most basic and universal aspects related to farming. In each theme, the aim is to arrive at a still more detailed understanding of the balanced manner in which each subsistence strategy is part of the larger system of Bronze Age farming. The combined analysis of all available data from one settlement (Bovenkarspel Het Valkje; section 8.5) is the culminating analysis which shows the added value of a holistic approach, which even revealed differences in subsistence on a household-level scale. It is only through this horizontal comparison between the different strategies that the relative contribution of each subsistence strategy to small-scale mixed farming systems can truly be evaluated. Concluding this chapter therefore, is a reconstruction of Bronze Age farming in West Frisia, in which the relative role of crop and animal husbandry, and hunting and gathering is discussed. Following this reconstruction, a new model for Bronze Age farming in West Frisia is presented, as well as an assessment of the role of West Frisia as a case-study for coastal communities in the Bronze Age.

Finally, based on the new model, several main subjects are chosen which will be used for comparative purposes with other areas in the Netherlands and north-western Europe in Chapter 9.

8.2 RECONSTRUCTION OF THE LANDSCAPE

In this section, the landscape is reconstructed on a detailed level by integrating the data of the composition and distribution of the flora and fauna in West Frisia (Chapter 2) with the data on farming practice (Chapter 5 and 6). By taking into account the potential impact of the animals and humans living in

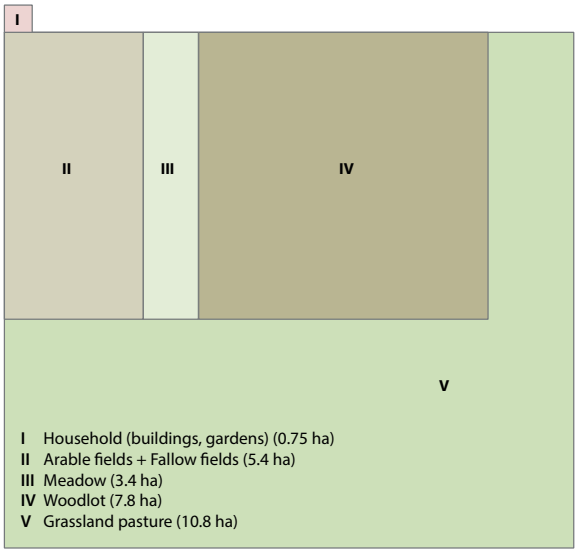


Figure 8.1. Hypothesized maximum total area required per household (0.28 km^2), grassland pasture only.

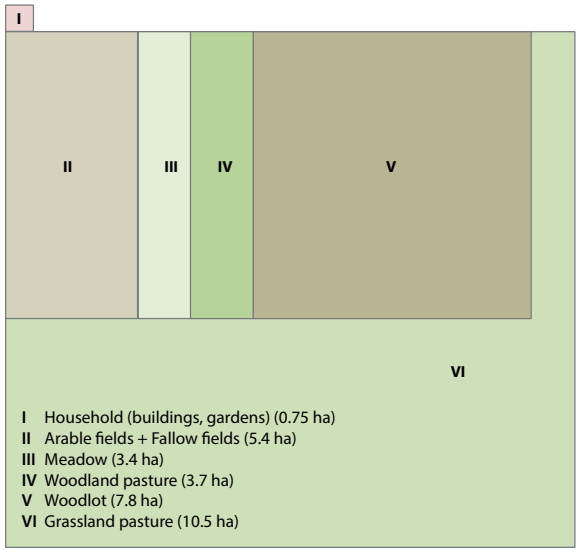


Figure 8.2. Hypothesized maximum total area required per household (0.31 km^2), grassland pasture for all animals, and additional woodland pasture for goat.

West Frisia in the Bronze Age, this integration allows for an assessment of the possibilities of types and extent of vegetation present around the settlements. To accomplish this, both the areas required by households and their livestock and crops, as well as the area required by the wild animals living in Middle Bronze Age West Frisia were investigated. Both types of required area are first discussed individually, followed by a map showing the total impact on the maximum possible vegetation of West Frisia in the Middle Bronze Age. This final map includes the relative distribution of vegetation, animals, and humans present in the environment, as well as the potential impact on it. For the Late Bronze Age, such a detailed reconstruction was not made, but a general discussion is provided instead.

8.2.1 Area required by households and their livestock and crops

Area per household

The total area required by households and their livestock was calculated by combining area sizes required for the settlement, the arable and fallow fields, the meadow, the pasture, and the woodlot (*i.e.* required area of the forest that serves as a source of wood for the settlement). The information on the areas required for animal and crop husbandry were obtained from Chapter 5 and 6, respectively. The other areas, including the area of the settlement, the meadow, and the woodlot were obtained from the archaeological study of requirements for prehistoric farmers by Gregg (1988; see section 8.3.1.2). Two total impact areas were constructed (Figure 8.1 and Figure 8.2), which only differ in their pasture types. The first considers only grassland pasture usage, whereas the second considers both grassland and woodland pasture for the species goat and cattle (cf. Chapter 6). Furthermore, the values for required pasture as well as arable and fallow fields in general reflect maximum values, meaning that a maximum of 2 years fallow is included (*i.e.* three times the hypothesized value of 1.8 ha of arable fields per household), as well as the maximum herd sizes hypothesized in Chapter 5. The values employed from the work of Gregg have been divided by six to arrive at values per household, since she reconstructs an average of six contemporaneous households at a settlement (see section 8.3.1.2). The resulting total maximum area of the household in Figure 8.1 is 0.28 km^2, and that of the household in Figure 8.2 0.31 km^2 (Appendix A1.13).

Estimated possible number of contemporary houses in West Frisia

The total impact of humans in West Frisia was calculated as follows for both the grassland pasture only and mixed grassland/woodland pasture situations.

Table 8.1. Average number of contemporary houses and inhabitants (both humans and domestic animals) during the Middle and Late Bronze Age based on the available exploitable land in West Frisia (from: van Zijverden forthcoming).

	Middle Bronze Age			Late Bronze Age		
	total nr. houses	total nr. humans	total nr. domestic animals	total nr. houses	total nr. humans	total nr. domestic animals
Pasture type						
Grassland only	1,003	7,018	6,516 cattle 7,519 sheep 2,506 goats 1,003 horses	370	2,589	2,404 cattle 2,774 sheep 925 goats 370 horses
Grassland mainly, with additional woodland pasture for goat	929	6,501	6,036 cattle 6,965 sheep 2,322 goat 929 horses	343	2,398	2,227 cattle 2,569 sheep 856 goats 343 horses

Table 8.2. Average number of contemporary houses and inhabitants (both humans and domestic animals) during the Middle and Late Bronze Age based on uncovered concentrations of Bronze Age remains during field surveys in West Frisia (from: van Zijverden forthcoming).

Middle Bronze Age			Late Bronze Age		
total nr. houses	total nr. humans	total nr. domestic animals	total nr. houses	total nr. humans	total nr. domestic animals
832	5,824	5,408 cattle 6,240 sheep 2,080 goats 832 horses	175	1,222	1,135 cattle 1,310 sheep 437 goats 175 horses

The total area which was exploitable in both the Middle and Late Bronze Age was employed based on the research of Van Zijverden (forthcoming). These values were divided by the total average area required by one household (see previous section) to arrive at the average number of contemporary houses which could be sustained by the exploitable land in West Frisia, as well as the inhabitants of these houses in terms of humans and domestic animals. This situation was reconstructed for both the Middle and Late Bronze Age (cf. van Zijverden forthcoming) and the results are shown in Table 8.1.

The results of the calculations presented in Table 8.1 indicate that West Frisia could have been very densely populated throughout the Bronze Age, and that people and their livestock will no doubt have had a large impact on their surroundings in both periods. In the Late Bronze Age, fewer numbers of houses, people and domestic animals could be sustained, due to a decrease in the total size of exploitable land (van Zijverden forthcoming; Chapter 2).

Besides the calculations made above on the average possible number of households based on the available exploitable land in each of the Bronze Age periods, estimations on the households actually present in West Frisia were also made (van Zijverden forthcoming). These estimations are made based on the retrieved remains during field surveys of West Frisia. When it is assumed that each concentration of retrieved Bronze Age remains represents a household, the average total numbers of actually present households could be estimated (Table 8.2).

From the comparison of Table 8.1 with Table 8.2, it is clear that in the Middle Bronze Age, the estimated number of households in West Frisia is approaching the total potential area exploitable by humans during this time. The Middle Bronze Age in West Frisia can therefore be regarded as densely populated. In the Late Bronze Age however, the estimated number of households covers less than half of the potentially exploitable area. Apparently, during this time, there was a severe reduction in the total populations of humans and their livestock in West Frisia.

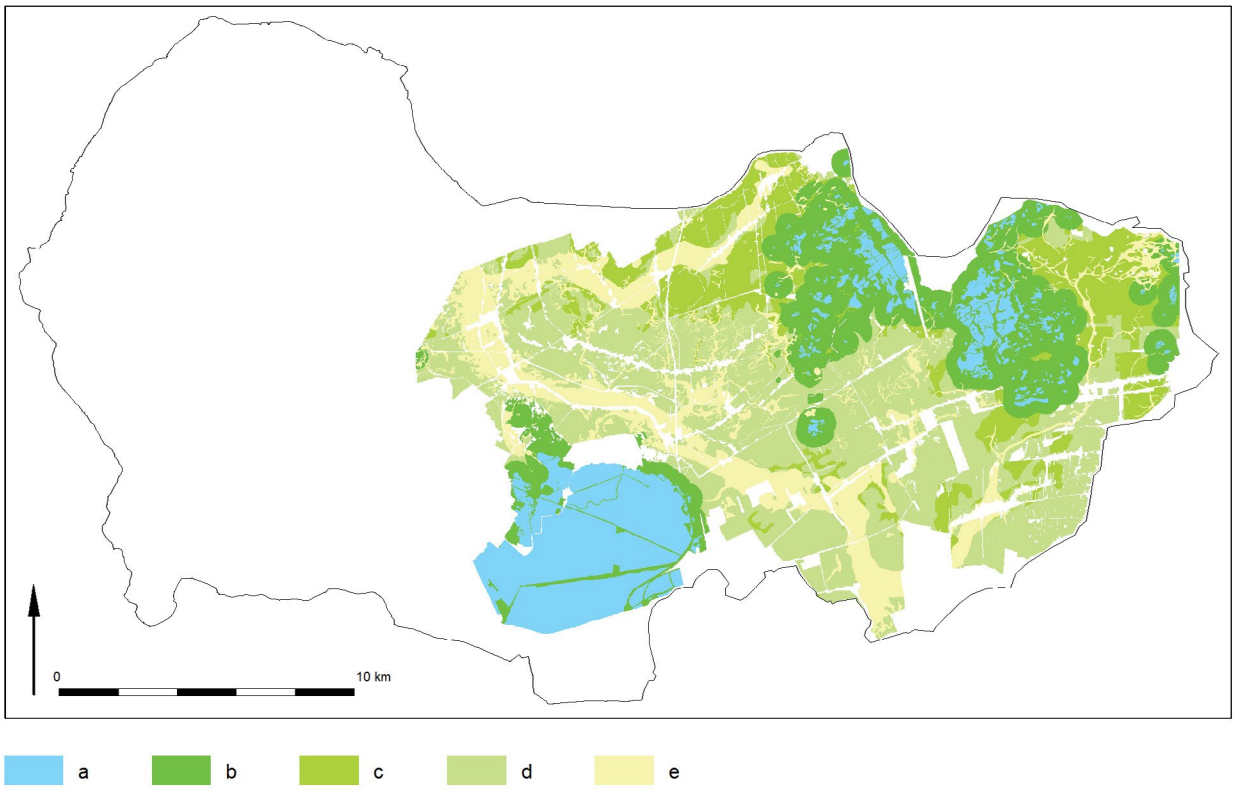


Figure 8.3. The forested situation map of eastern West Frisia; a:water; b: *Alnetea-Glutinosae* and *Artemisio-Salicetum albae* carr forests; c: *Fraxino-Ulmetum* forest; d: *Viola odorata-Ulmetum* forest; e: *Querco-Fagetea* forest (from: Cronau 2016).

8.2.2 Area required by wild animals

The impact of wild animals on the environment, or the area required for their survival, was researched based on the uncovered large wild mammal species in eastern West Frisia (including red deer, roe deer, moose, wild boar, and beaver; Cronau 2016). In this research, the presence of the same large mammals throughout the Bronze Age is interpreted as evidence that healthy populations of these species existed in West Frisia during both the Middle and Late Bronze Age. Only large mammal species are researched, since it is expected that their impact on the environment will have been greatest. Two extreme situations were considered for eastern West Frisia: a maximum vegetation cover, or forested situation (Figure 8.3), and a minimum vegetation cover, or deforested situation (Figure 8.4).

In order to study the impact of large mammals on these two types of vegetation cover, several aspects of their behaviour were researched (Cronau 2016). First, the approximate density of each large mammal species in the vegetation was researched, except beaver, since this species only affects some trees around water bodies (Cronau 2016; Table 8.3; Figure 8.5 e). However, since density alone is not an adequate measure of impact on vegetation, the animal densities were subsequently translated into total weights of the populations of each animal species, to account for differences in volume of matter consumed. In turn, this total weight was converted to the total consumption of vegetative matter of each species (Cronau 2016; Table 8.3). Other types of animal behaviour which were researched include food preference, interaction with individuals of the same and other species, habitat preference, home range, and migration (Cronau 2016). The resulting information from all these behavioural aspects combined was used to predict the total impact of wild animals on the vegetation.

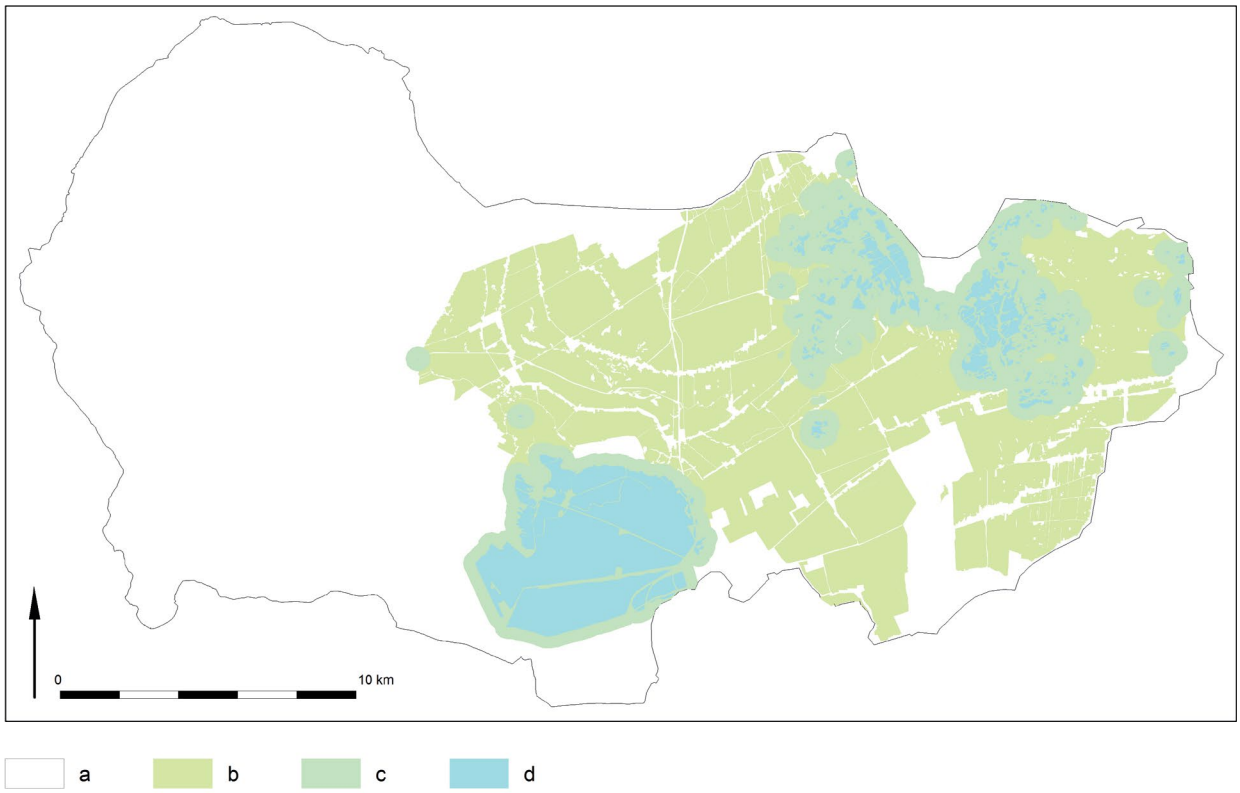


Figure 8.4. The deforested situation map of eastern West Frisia. a: Arrhenatheretum elatoris grassland; b: Phragmiton australis reed swamp; c: water (from Cronau 2016).

8.2.3 Distribution of plants, animals, and humans in the West Frisian landscape

Middle Bronze Age

The impact based on humans and their livestock, wild animals, and the interaction between them was combined to assess the composition of the landscape of eastern West Frisia in the Middle Bronze Age (Cronau 2016). In Figure 8.5, the resulting map is shown. From this figure, it becomes clear that the impact of humans and livestock in the Middle Bronze Age was indeed extensive (Figure 8.5 e, f and g; cf. section 8.2.1), amounting to around 16 km^2 of the landscape being treeless because of direct human impact. It must be noted that the impact radii of humans (Figure 8.5 g) are an idealized situation, representing a circle around the settlement. In reality, these areas will have been more distributed over the surroundings, according to for example each of the pasture categories observed in Figure 8.1 and 8.2, although the total impact of humans on the environment will remain the same, regardless of location.

The further surroundings of the settlements must, however, still have been covered by a variety of vegetation types, since the pressure here is lower (Figure 8.5 a-d). Water and different vegetation types which may thus still be expected to be part of the landscape are, grassland, shrub land, and large areas of forest of different types. These types form a combination of Figure 8.3 and Figure 8.4 depending on the pressure from Figure 8.5: the lowest pressure is observed for the wetter vegetation types (Figure 8.3 b; Figure 8.4 a), which may also be related to their ability for fast regeneration. The drier forest types surrounding the wetter vegetation (Figure 8.3 c and d) will have had an open canopy, due to the combined distributed and concentrated pressure of wild animals, and would have alternated with open grassland (Figure 8.4 b). Around the water bodies (Figure 8.3 a; Figure 8.4 c), the impact was medium high, mostly because of

Table 8.3. Density of animal species and their total consumption per km² (Cronau 2016).

Ungulate species	1) Forested situation of West Frisia		2) Deforested situation of West Frisia	
	Density (individuals/km²)	Total consumption (average kg dry matter/km²/yr)	Density (individuals/km²)	Total consumption (average kg dry matter/km²/yr)
Moose	1.42	3,834	0.26	702
Roe deer	18.15	2,015	0.15	17
Wild boar	5.75	5,313	2.29	2,116
Red deer	10.34	9,208	6.42	5,717
Total	35.66	20,370	9.12	8,552

beavers, creating a treeless boundary. The highest pressure will have been exerted on the driest forest type (Figure 8.3 e), where both livestock and wild animals grazed, restricting the growth of these already slow regenerating forests to a climax vegetation (Cronau 2016).

Livestock will most likely have grazed wherever adequate grassland was available (Figure 8.5 c, d, and f). Sheep in particular will have grazed the driest parts of the grassland (Figure 8.5 c, d, and f) in both summer and winter, and was probably restricted to the driest grassland in winter (Figure 8.5 f), due to wet conditions being present in the other vegetation types during this time of the year. To reach these dry areas, people from some of the settlements would have had to travel somewhat further from the settlement, but every settlement lies within a 5 km range from these locations. Therefore, the action radius of farmers postulated in Chapter 3 remains valid for animal husbandry practices as well. The different activities related to the movement of livestock across the land are further explored in section 8.4.

The overall resulting habitat types are in concurrence with those observed in Chapter 2, but this analysis has enabled a more detailed understanding of the location of the different landscape elements around the West Frisian settlements and the impact on them by people and livestock.

A final result from this impact analysis is that the reconstruction of the Middle Bronze Age landscape of eastern West Frisia has provided an extra indication that Bronze Age subsistence must have indeed consisted of small-scale farms: farms of larger size than those observed in Figure 8.5 would never have been able to be supported by the available suitable land for habitation.

A science-based artist impression of the Middle Bronze Age West Frisian landscape can be found in Appendix A1.14.

Late Bronze Age

The pressure of humans and (wild) animals on the Late Bronze Age environment, although not reconstructed here in detail, would have been largely comparable to the pressure reconstructed for the Middle Bronze Age. This is considering the lower amount of available suitable land for habitation during this time (Chapter 2, section 2.5.3), but also the lower number of people inhabiting this land (section 8.2.1). However, local pressure on certain vegetation types will probably have been higher due to the different suitable vegetation types suitable for grazing being condensed into smaller areas (Chapter 2, section 2.5.3).

8.3 RECONSTRUCTION OF SUBSISTENCE

This section researches in detail how basic needs may have been met in West Frisia. The potential for dietary addition in each of the different subsistence

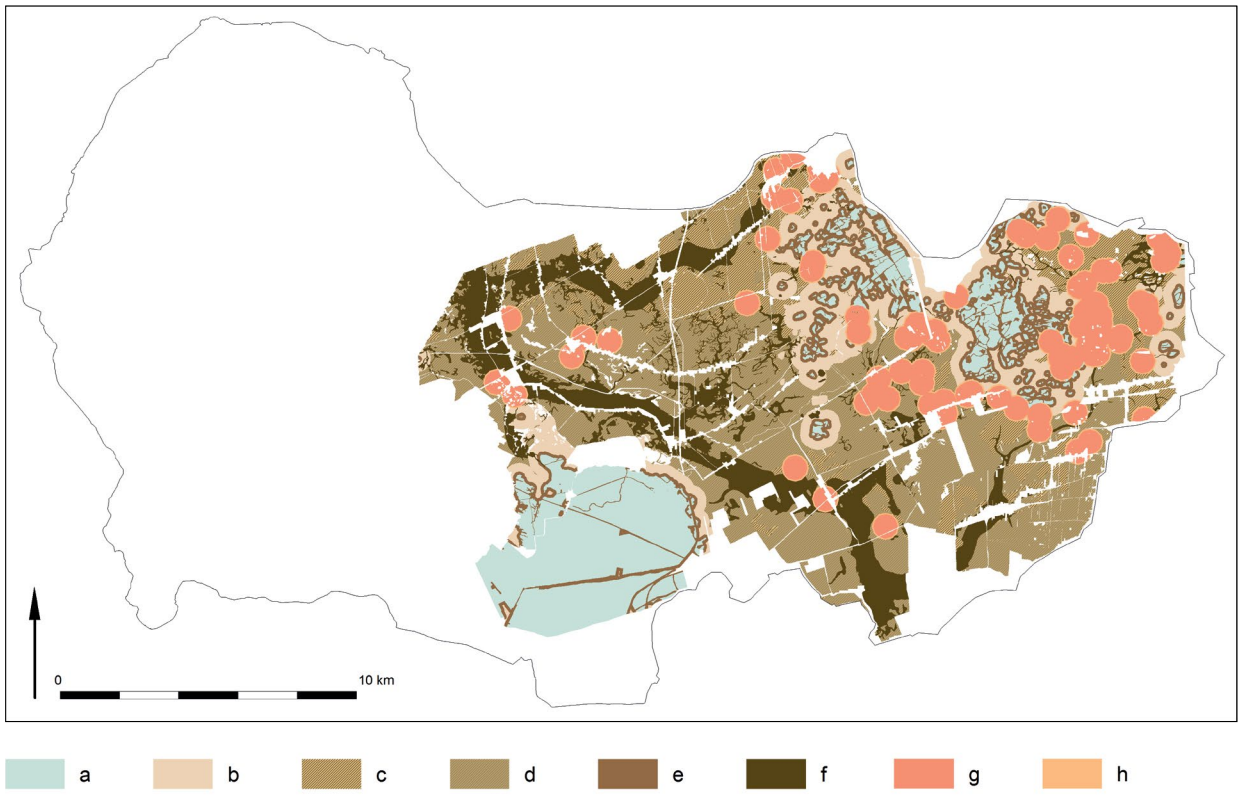


Figure 8.5. Reconstruction of the Middle Bronze Age vegetation in eastern West Frisia, including the impact of humans, livestock, and wild animals. Pressure is exerted on the landscape by the settlement and its domestic and wild resource exploitation, or by grazing of wild and domestic animals, which can be distributed or concentrated for different vegetation types. a: water/reed swamp; b: low pressure; c: low to medium distributed pressure, and medium concentrated pressure; d: medium distributed pressure, and low to medium concentrated pressure; e: high overall pressure; f: very high overall pressure; g: human settlement and livestock impact area (two houses are considered here as a settlement); h: transitional zone from cultural to natural landscape (from: Cronau 2016).

strategies has become clear from Chapter 4-7, but their actual role and interconnectedness in the farming system is not apparent based on these separate analyses. Also, the ability of each of these strategies to provide for the other basic needs of housing and clothing has not been synthesized yet. Therefore, in this part of the chapter, diet, clothing and the house form three sub-themes which are explored based on the results from Chapter 4-7. The analyses in each of these sub-themes will reveal the need for all four strategies in each part of subsistence, and especially the continuing and even vital importance of wild resources in Bronze Age farming.

8.3.1 Diet

Indications for the diet of small-scale mixed farming communities have been obtained from different sources, namely ethnography, archaeology, nutritional studies, and physical anthropology. Each of these approaches is discussed separately below.

8.3.1.1 Ethnography

Indications for the role of different subsistence strategies in small-scale mixed farming communities were already discussed separately in Chapters 4-7, based on selections on the work by Murdock (1981). Figure 8.6 shows the average values of the different food strategies observed in the selected cultures (Appendix A1.4).

What becomes clear from Figure 8.6 is that, in communities practicing mixed farming, people always depend more on agriculture (cf. crop husbandry) for their diet than on any other food strategy, including

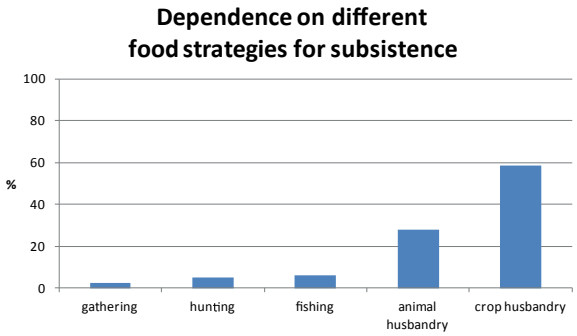


Figure 8.6. Average values of the different food strategies in small-scale farming communities based on the selected cultures of the ethnographical work by Murdock (1981).

animal husbandry, since cereals form the staple food of the selected communities. In addition, Figure 8.6 shows that the use of wild resources comprises 13% of subsistence, divided between gathering of plants, hunting (incl. trapping and fowling), and fishing). Also interesting to note is that the exploitation of wild resources seems to occur regardless of the size of the community (*i.e.* neighbourhoods, hamlets, villages; Appendix A1.4), although the relative dependence on each of the wild resources is different. For example, in villages, people depend significantly less on hunting than in neighbourhoods or hamlets (Appendix A1.4).

These results show the dependence of present-day mixed farming communities on the different food strategies for their subsistence. However, since Murdock is so vague about their specific contribution to the diet, and his research does not necessarily apply directly to prehistoric societies, more detailed research is needed, which is discussed next.

8.3.1.2 Archaeology

One of the major studies on prehistoric diet, and the role of each of the food strategies in the total diet, is the work of Gregg (1988). She has researched the addition of each of the food strategies to the diet of a (Neolithic) farmer, as well as the monthly fluctuations in the availability of each available food resource. Her work is based on existing optimal foraging models (Jochim 1976; Keene 1981). By including farming practices, Gregg adapted these models into an optimal farming model (Gregg 1988, 16). Through calculations based on several assumptions, she sought to acquire knowledge about the amount of wild and domestic resources in the diet of Neolithic farmers, and the extent of land required to support a settlement. Although this model is out-dated in some respects, and farming can by no means be regarded as optimal, her study does allow for an insight into annual and monthly resource availability and requirement in a farming context.

Below, Gregg's main assumptions of are presented and it is clarified why her study can form an example and a basis of comparison for West Frisia.

Gregg: assumptions and model input

The research area chosen by Gregg is southern Germany in the sixth millennium B.C. She states that most Neolithic settlements in the research area were small, dispersed settlements of 4-10 contemporaneous houses spaced approx. 100 meters apart (Gregg 1988, 4 and references therein). Some of the settlements were occupied continuously for up to 400 years, with a 25 year cycle of house construction, occupation, and abandonment. The main assumptions of this model are summarized in Table 8.4. The table indicates that most assumptions agree very well with the results from the analysis of West Frisian crops and livestock (Chapters 5 and 6). Crop husbandry results are comparable to Gregg's model except for minor differences including the fact that cultivated crops in West Frisia include both wheat and barley, although in the Late Bronze Age, mostly wheat is present; the average field size of arable fields per individual is 0.3 ha (1.8 ha/6 persons); and postulated crop yields are higher at 2000-2700 kg/yr after detraction of harvest losses. Animal husbandry results are also in concurrence: all aspects are similar, with only slightly higher reconstructed numbers of sheep/goat kept per household. Due to the large overlap of assumptions made by Gregg with the results for West Frisia, her model is employed and adapted to create an understanding of the Bronze Age subsistence in West Frisia.

Table 8.4. Overview of the main assumption of the model of Gregg for the south-west German Neolithic, compared with the results for West Frisia from Chapter 5 and 6.

	Neolithic southwest Germany	West Frisia
Settlement characteristics		
Settlement type	permanent	permanent
Settlement pattern	small, dispersed settlements	small, dispersed settlements
Nr. of contemporaneous houses	4-10 (av. 6)	at least 4 (Bovenkarspel Het Valkje; Roessingh in prep.)
Crop husbandry		
Crops	wheat	wheat and barley
Fields	ley fallow*	no fallow-short fallow
Average field size per individual	0.35-0.45 ha	0.3 ha (1.8 ha/6 persons)
Sowing time	spring or autumn-spring	spring
Soil fertility	high	high
Harvest yield wheat	1000 kg/yr	2000-2400 kg/yr
Animal husbandry		
Animals	cattle, sheep, goat, pig	cattle, sheep, goat, pig, dog, horse
Housing	yes, four months (winter)	possible
Feed	forest browse, pasture, fodder, crop stubble, fallow plots	forest browse, pasture, fodder, crop stubble, fallow plots
Average herd size per house	5-8 cattle, 2-5 sheep, 2-4 goats, 0-2 pigs	5-8 cattle, 5-15 sheep/goats, 0-3 pigs
Herd dynamics	stable/no growth	stable/minor growth
Birth season	spring	spring
Milk consumption	yes	yes (cf. Chapter 5, section 5.4.3)

*Ley fallow is a special type of fallow in which livestock is grazed on the emerging grass and shrub land after a fallow period. The length of such fallow can be short-, medium-, or long-term (after: Ruthenberg 1980, 14-5).

With the abovementioned assumptions, Gregg has developed a hypothetical settlement for her modelling (Gregg 1988, 128). The settlement consisted of six houses, with, randomly generated, four to eight household members (Gregg 1988, Table 32), and owned livestock (Gregg 1988, Table 40). Using these variables as the input for her model, she calculates that this settlement would require around 13 ha for arable fields, 4.5 ha for houses, outbuildings, and garden plots, 53 ha for the woodlot (for fuel and wood for construction), 18 ha for pastureland, 20 ha for natural meadows, and 2.6

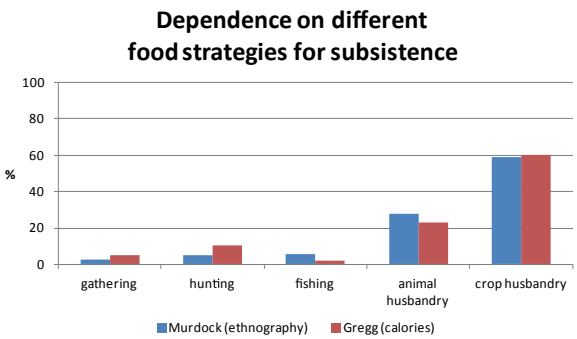


Figure 8.7. Average values of the different food strategies in small-scale farming communities based on the selected cultures of the ethnographical work by Murdock (1981) and the archaeological work by Gregg (1988).

ha for forest browse. Her reference settlement would thus require a minimum of 6 km^2 for their domestic resources (including 40 cattle, and 40 sheep/goat), which is around 1 km^2 per household (Gregg 1988, 165-7). The total amount of land required by farmers in West Frisia amounts to around 0.3 km^2 per household (cf. section 8.2.1). This difference is most likely related to the amount of woodland required by Gregg's model in comparison with the West Frisian situation. Woodland browse contains much less nutrients than pasture, and so, a much larger area is needed to meet domestic animal demands.

Gregg: implementation and adaptation

Gregg's model is based on the work of Jochim (1976), who examined the structure of wild resource exploitation of the Mesolithic. His model investigates the monthly use of each wild resource as part of the total annual diet based on caloric intake. Additional (domestic) resources were added by Gregg to mimic Neolithic farming subsistence. Her model allows for a month-by-month comparison of resource use and changes resulting from different relative proportions of domestic and wild resources in the diet throughout the year can therefore be identified. Four main large wild animals were included in the model (*i.e.* red deer, roe deer, boar, and beaver) since they occurred most often at the Neolithic sites. Furthermore, fish, birds, small game, and wild plant foods were grouped by Gregg into collective classes. She also researched their seasonal availability and density near the settlement. In the case of farmers practicing animal husbandry, Gregg argues that the density of red deer will be low, since red deer and

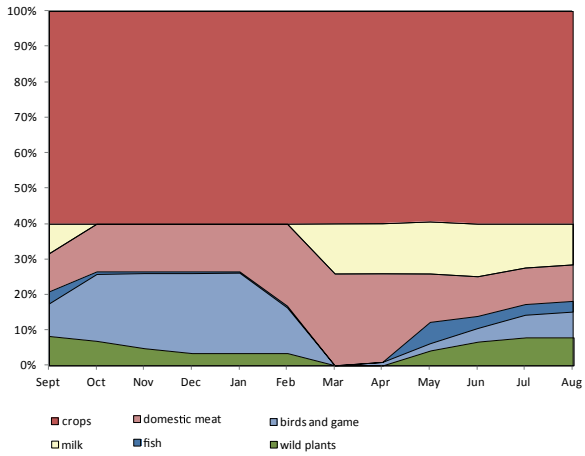


Figure 8.8. Monthly fluctuations in the available food groups in the Bronze Age diet based on calories (adapted from: Gregg 1988).

cattle compete for the same resources. Therefore, for this study, the low density of red deer indicated by Gregg is used.

As discussed above, many of the assumptions made by Gregg are considered comparable to the Bronze Age West Frisian situation (cf. Table 8.4). However, an adaptation was made to her model (Appendix A1.15): Gregg assumes a contribution of pulses/legumes to the diet of the Neolithic farmer. However, very few to no remains of this food group have been identified in Bronze Age West Frisia, and the North Sea coast/ southern Scandinavia in general (Chapter 6, Table 6.4 and Table 6.5). Therefore, the calories allotted by Gregg to this food group were placed under the wild plant category, since these would have formed a substitute for the nutrients otherwise obtained from domestic pulses/ legumes (cf. Chapter 7, section 7.4.2.1). With this new information included, the monthly diet values of table E (Gregg 1988, 240) by Gregg were recalculated and used for the West Frisian situation (Appendix A1.15). The results from the recalculations are summarized in Figure 8.7 and Figure 8.8, and are subsequently divided into the main food categories used by Murdock (1981). The figures show the average annual addition of each resource group to the diet (based on calories), and the monthly fluctuations in availability of each resource, respectively.

As it is unsure what Murdock meant by the relative dependence on the different food categories, it is hard to compare differences directly, but it can be seen in Figure 8.7 that the general trend of Murdock's observations is matched by the calculations made by Gregg. The latter does however seem to imply a stronger dependence on the consumption of wild animals at the expense of domestic animals, which may reflect a difference between more recent and prehistoric farming communities.

In Figure 8.8, the monthly contribution of each food category to the diet based on calories is shown. From this figure, it is apparent that the combination of crop and animal husbandry contributes most calories to the diet throughout most of the year. Similar values have been proposed by Buurman for West Frisia (Buurman 1996, 31). In winter months, the reduced amount of calories from domestic animals (both meat and milk) are buffered by small and large game meat. Some additional calories are obtained from fish and wild plants, especially in summer months, although their overall contribution to the caloric diet is low. According to Gregg (1988, 186), wild resources are not required at all for additional calories in March and April, because domestic food sources are highly abundant during this time. They are therefore (mostly) absent in Figure 8.8 during those months.

The above graphs provide an interesting insight into the fluctuations of food resource use by prehistoric farmers throughout the year. The variety of food resources employed by these farmers indicates the importance of nature in their lives, not only for crop and animal husbandry practices, but also for wild resource exploitation. Various available resources will have been used to complete the diet, differing in relative composition on a monthly basis. Gregg's calculations furthermore provide insight into the quantitative contribution of each of the food categories based on calories. An aspect missing from her elaborate work however, is the qualitative contribution of each of the food categories for obtaining a healthy diet. A diet solely based on obtaining the required amount of daily caloric intake might not necessarily be sufficient in providing a person with essential macro- and micronutrients required to maintain a good health. Therefore, the importance and possible implications of these (missing) nutrients is discussed next.

8.3.1.3 Nutritional studies

Quantitative data required for establishing a healthy diet rather than a calorie-sufficient diet was obtained from a report on human vitamin and mineral requirements released by the World Health Organisation (WHO) and the Food and Agriculture Organisation of the United Nations (FAO) (WHO & FAO 2002). In this report, it is outlined that dietary guidelines should ensure that 97% of the population meets their daily nutrient requirements. The dietary prerequisites are expressed as the Recommended Nutrient Intake (RNI). However, instead of listing individual RNI values, the report provides food-based dietary guidelines (FBDGs), which provide a list of food combinations which ensure adequate nutrient intake. These FBDGs mainly aim at the acquisition of critical micronutrients. The critical micronutrients, which are most difficult to obtain for people consuming a staple diet of cereal grains or tubers, are vitamin A, vitamin C, folate, iron, and zinc (WHO & FAO 2002, 7-8). Deficiencies of these micronutrients can result in (fatal) ailments such as blindness, scurvy, anaemia, disrupted brain and muscle development, and stunted growth and higher susceptibility to infectious diseases, respectively (WHO & FAO 2002, 9-10). In order to counter or prevent these effects, it is essential that micronutrient uptake is increased by broadening and diversifying the diet.

The consumption of a combination of additional food sources has been established for people consuming, amongst others, white rice or refined couscous-based diets. These diets however, consist of cereals that have been modified from their original nutrient composition, mostly by removing the germ and bran from the grain. Since in prehistory intact (whole) grains were consumed, the diets proposed by the WHO and FAO are not directly comparable to the prehistoric situation. In order to reflect the Bronze Age situation in West Frisia more closely, information on whole grains of emmer wheat and hulled barley was applied to the dietary suggestions of the WHO/FAO report. In this manner, it could be assessed whether Bronze Age farmers consumed a

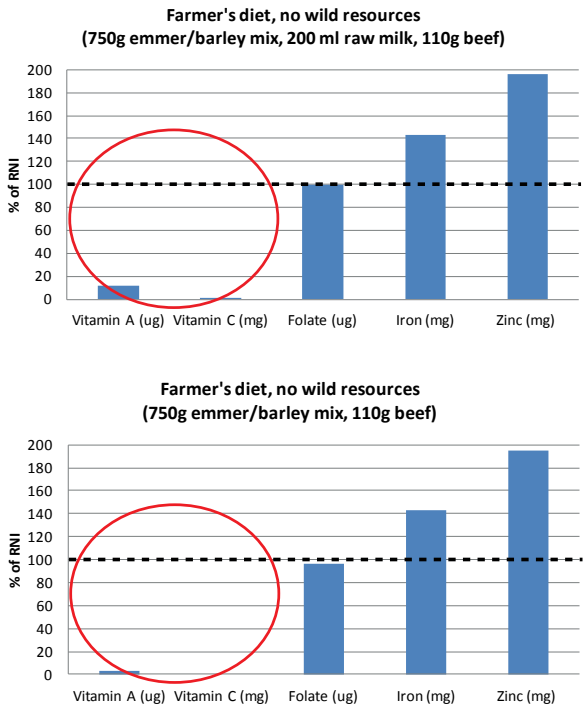


Figure 8.9. Overview of the diet of Bronze Age farmers based on cereals, red beef meat, and including milk (left) or excluding milk (right), without addition of wild resources. The dashed line indicates the recommended nutrient intake (RNI) per day of the most important micronutrients. The red circle indicates the obvious lack of essential vitamins in this type of diet.

diet with sufficient critical micronutrients, or whether there was a shortage of these importance elements.

Bronze Age West Frisia

First, an overview of the micronutrients available in a Bronze Age farmer's diet was constructed based on domestic resources (*i.e.* without addition of wild resources) and with the aid of the calculations from WHO & FAO (2002, 21-4). Two types of diet were constructed, which both include a mix of emmer and barley (because they were usually present in a 50/50 frequency ratio in Bronze Age contexts in West Frisia), and beef meat (*i.e.* the most frequently encountered domestic animal in the zoological remains). In the second diet, also raw milk was included, since this domestic resource will also have been available to farmers during several months of the year, and indications for its use are found in Bronze Age Enkhuizen Kadijken, England, and Scotland (Chapter 5, section 5.4.3; Copley *et al.* 2005; Craig *et al.* 2005; Roessingh & Lohof 2011). Micronutrient information has been compiled from several sources (WHO & FAO 2002; Piironen *et al.* 2008; Chatzav 2009; Raw milk 2016; USDA 2016), and calculations were made to assess the nutritional contents of the diet (Appendix A1.15). Nutritional content is, in this case, defined as the amount of (micro)nutrients in a given diet composition, in which each of the most difficult to obtain micronutrients should reach 100% or more. When all critical micronutrients reach over 100% in a diet, nutrient demands are met.

What can be seen from Figure 8.9 is that in both Bronze Age "domestic" diets the micronutrient content of the critical vitamins A and C is far below the recommended daily levels. Figure 8.9 thus shows that farmers could not solely rely on their produced crops and animals to ensure their health. Such low levels of vitamins would ultimately result in scurvy (lethal) or blindness, and it is not assumed that entire settlements would succumb to these ailments: habitation lasted for several centuries. Therefore, is important to identify possible sources of these vitamins in other food groups, which Bronze Age West Frisians could have consumed to ensure adequate vitamin intake.

Domestic animal vitamin A and C sources

Liver meat can form a potential source of vitamin C, since many animals (excluding humans) can produce their own vitamin C and store it in this organ. The concentration of this vitamin in liver meat is not very high however (Bender 1992; USDA 2016) so that considerable amounts of liver would need to be consumed by each person on a daily basis (*i.e.* 200g on average) in order to assure adequate levels of vitamin C in the diet. Vitamin A is available at reasonable levels in organ meat as well, especially liver, and can thus have aided vitamin A intake when a slaughtered animal was consumed.

A problem with organ meat is, however, that levels of vitamins decrease during heating (Bender 1992), so unless organ meat was consumed raw, processing the meat would have decreased the levels of vitamin A and C considerably. Furthermore, the availability

of vitamins from organ meats fluctuates throughout the year, since these organs logically only become available after slaughter. Furthermore, when a liver becomes available after slaughter, it must be consumed within a short period of time, since organ meat spoils easily and preservation is difficult (*e.g.* Mays 2004, 85). Therefore, a more consistent source of these vitamins is required to complete the diet on a daily basis.

Plant vitamin A and C sources

Wild plants can be valuable sources of micronutrients. Plants especially, such as pulses or legumes, (leafy green) vegetables, and fruits, have a high micronutrient density and are the preferred way of obtaining critical micronutrients (WHO & FAO 2002, 8).

Where possible, the nutrient profile of the edible wild plants from house contexts (Chapter 7, Table 7.7) has been identified in order to assess the vitamin A and C potential of wild plants in West Frisia. These wild plants were postulated to have been collected for their seeds and/or vegetative parts based on their prevailing preservation state and relative frequency in houses contexts (Chapter 7, section 7.3.3 and section 7.4.2.1).

The information on the critical micronutrients of these plants was obtained from research on the edible wild plant use by Canadian indigenous people (Kuhnlein & Turner 1991, Chapter 6). It may be argued that Canada is not comparable to north-western Europe with respect to plant nutrient composition. However, although general micronutrient content may vary depending on the environmental conditions in which a plant grows, this mainly affects the mineral content, since these are absorbed from the surroundings. Vitamins on the other hand, are produced by the plant itself and are only influenced by available sunlight, location, and seasonality (Bernstein 1945, 570; United States 1948,9). Since Canada has a relatively similar latitude to north-western Europe, and therefore has mostly comparable sunlight hours and seasons, conditions which might affect vitamin content of wild plants are deemed largely comparable to West Frisia. In addition, many wild plant species are present in both areas.

The vitamin content of the West Frisian edible wild plant species on which data was available is summarized in Table 8.5. In this table, the energy is shown which can be obtained from each species, as well as the actual vitamin content of the plant species, its nutrient density, the daily intake value based on 100 g of raw material, and the amount of grams required to be consumed of each species in order to obtain the required levels of vitamin A and C.

As can be seen, many of the wild plants are naturally rich in vitamin content, especially when it is considered that modern-day apples or carrots contain around 5 mg/100g vitamin C and 3-800 µg/100 g vitamin A (USDA 2016). Most of the wild plants from Table 8.5 exceed these values.

Vitamin A and C content is highest in greens and leaves, although roots of wild carrot (*Daucus carota*) also contain levels of vitamin C. Limited data is available on the vitamin content of these plant seeds, however they generally contain much less vitamins than young green parts of the plant. This would be an explanation for the fact that many present-day cultures collect plants mainly for their vegetative parts. The seeds of wild plants probably have comparable characteristics to the crops produced by farmers. From the plants of which greens and leaves are consumed, only 35-150g of raw material needs to be eaten daily to meet vitamin C requirements. Especially greens of turnip (*Brassica rapa*), fat hen (*Chenopodium album*), stinging nettle (*Urtica dioica*), and curly dock (*Rumex crispus*) are highly nutritious. Both turnip and stinging nettle have probably been collected in West Frisia solely for their green parts (Chapter 7, Table 7.7). These species also grow on locations which are easily accessible to the farmers, such as on the settlement or on nearby arable fields. Common plantain (*Plantago major*) leaves on the other hand, have relatively low vitamin C levels, so that more than 600g needs to be consumed to meet demands.

As stated, vitamin C can also be obtained from roots of wild carrot, of which 200g provide daily required vitamin C levels. This plant could provide vitamin C during winter. People would have to travel somewhat further from the settlement to obtain it, as it grows on

Table 8.5. Nutrient composition per 100 g of the wild plants uncovered from house ditches in West Frisia.

			Vitamin C			Vitamin A		
Taxa	Part Used	Energy (kcal)	mg	% ND	100% DV (g)	RE (µg)	% ND	100% DV (g)
Brassica rapa	greens	22	130	433	42	990	198	86
Capsella bursa pastoris	greens	33	64	212	87	327	65	260
Chenopodium album (cooked)	greens	32	37	123	149	970	194	88
Chenopodium album (raw)	greens	34	98	328	56	1,277	256	67
Montia fontana	young greens	31	34	115	160	-	-	-
Plantago major	greens	-	33	111	165	-	-	-
Polygonum aviculare	greens	-	78	260	71	-	-	-
Rumex acetosella	greens	43	34	112	164	560	112	152
Rumex crispus	greens	24	88	294	62	1,014	203	84
Sonchus asper	greens	26	63	209	88	-	-	-
Urtica dioica	greens	-	90	299	61	-	-	-
Mentha spec.	leaves	39	64	213	86	1,334	267	64
Plantago major	leaves	61	8	27	688	252	51	337
Stellaria media	leaves	-	35	116	158	613	123	139
Urtica dioica	leaves	38	75	250	73	2,248	450	38
Daucus carota	roots	-	24	80	229	-		
Chenopodium album	seeds	414	-	-	-	-	-	-
Echinochloa crus-galli	seeds	417	-	-	-	-	-	-
Polygonum lapathifolium	seeds	425	-	-	-	-	-	-

All information is derived from Kuhnlein and Turner 2009, except for Sonchus asper (Guil-Gerrero et al. 1998), and Montia fontana (Tardio et al. 2011). ND: nutrient density; DV: daily intake value; RE: retinol equivalent.

nitrogen-rich grasslands. Alternatively, people may have cultivated these plants in a vegetable garden, but the presence of such gardens in West Frisia is unclear. Vitamin A is supplied by less species in Table 8.5, but still, consumption of 50-150g (average 100g) of plant material is usually sufficient to reach demands (Figure 8.10). However, roots of wild carrot, which are available during winter, do not contain vitamin A, and this absence may form a problem during that time. Another interesting fact of wild greens/leaves, which

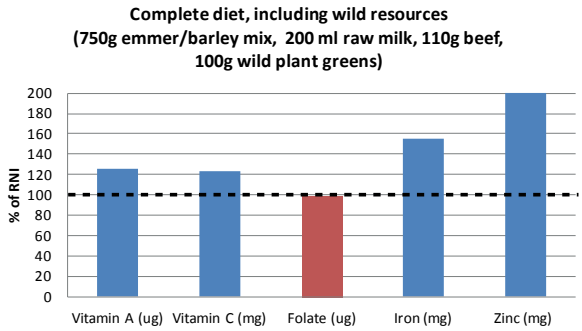


Figure 8.10. Overview of the diet of Bronze Age farmers based on cereals, red beef meat, and milk, including 100g of wild plant greens (average values of greens and leaves from Table 8.5). The dashed line indicates the recommended nutrient intake (RNI) per day of the most important micronutrients. Folate is indicated in red, because the exact folate content measurements were not available for the researched wild plants, even though this micro-nutrient is present in wild plants. The actual amount of folate will thus be even higher than shown here.

can be seen in Table 8.5, is that they contain very few calories/100g. This means that calorie-wise, wild plants indeed are not a considerable addition to the diet, which is in concurrence with Gregg's model (Figure 8.7 and Figure 8.8). Gregg also implies that in March-April there is an absence of wild plants in the diet because domestic resources are abundant. During this same period of the year however, most plants provide young shoots and leaves with high levels of vitamin A and C, which would be required to form a healthy diet. It is therefore clear from the above results that calories alone are not an appropriate measure to assess diets: critical micronutrients also need to be present in sufficient quantities to maintain health. These could be obtained from wild plants throughout the year, also during times of domestic resource abundance.

Wild animal vitamin A and C sources

Another wild resource which is rich in vitamins, besides wild plants, is fish. Especially eel meat contains high levels of vitamin A, and less than 150 g of eel (raw or processed) provides enough of this vitamin for daily requirements (Nutritiondata 2014a). Fish can therefore form a valuable addition to the diet, especially when wild plants rich in vitamin A are less available, such as during winter months.

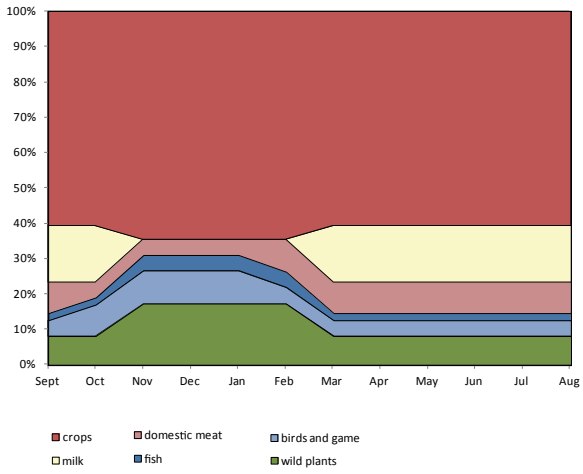


Figure 8.11. Monthly fluctuations in the available food groups in the Bronze Age diet based on a healthy, balanced dietary composition.

Vitamin C levels in freshwater fish vary widely, and only pike provides reasonable levels. Still, 200 g of raw pike can only provide around 13% of the recommended daily vitamin C intake (Nutritiondata 2014b), and is on its own not enough to acquire daily demands. Therefore, additional sources of vitamin C are still required to complete the diet.

Gregg's model revisited

As it is now clear that a diet based solely on calories does not necessarily reflect a healthy diet, the results of the adapted model presented by Gregg from Figure 8.8 were adjusted to incorporate the importance of each of her major available food groups to the diet based on health/well-being (Figure 8.11; Appendix A1.15).

In Figure 8.11, it is clear that wild plants, in combination with crops, meat, and sometimes milk, can be the main constant nutrient sources throughout the year. Important to note is that the collection of only nuts and fruits in autumn will not have been sufficient to provide people with their daily requirement of vitamin A and C. In periods of the year in which wild plant greens or fruits are lacking, roots can be consumed (although more grams are requires) in combination with (smoked) fish, to meet vitamin demands.

Summarizing, the use of wild plants and animals (especially fish) will have been essential to the diet and well-being of Bronze Age farmers. Relying solely on what can be produced by the settlement will have resulted in severe deficiencies, ultimately leading to death. Of course, people will not have been aware of micronutrient levels in their diets in the manner that is possible today. However, through a combination of cause-and-effect reasoning and thousands of years of knowledge of wild plant use in their ancestry, they will have realised the importance of a varied diet, which included wild resources.

Ultimately, rather than using the term "optimal farming" for the farming practices described by Gregg, the Bronze Age subsistence should be seen as adaptable farming, with people adapting to the availability and abundance of necessary resources, both domestic and wild.

8.3.1.4 Physical anthropology

Bronze Age West Frisian farmers had access to a wide variety of food resources which could have ensured their health based on both calories and micro-nutrients. However, it is still unknown whether people were actually capable of doing so during this time. Therefore, with the aid of physical anthropology, the general health level of Bronze Age people was researched, including possible evidence for nutritional deficiencies.

Prehistoric nutrition: deficiencies

One of the assumptions made in the FAO/WHO report is that people are able to meet their nutritional demand, if, and when they have access to sufficient quantity and variety of resources. If this is not possible, for whatever reason, deficiencies might still arise and leave marks on bones of people. Examples of micronutrient deficiencies in the north-west European Bronze Age were sought in the literature, to assess the probability of a deficient diet during this time period. In addition, several West Frisian skeletons were analysed to assess the local situation.

General health in Bronze Age north-western Europe

General health of past people can be identified by several types of marks on the skeleton. These include porous bone in the top of the eye sockets (*i.e. cribra orbitalia*), growth arrest lines in femur or tibia (*i.e.* Harris lines), enamel formation arrest lines (*i.e.* enamel hypoplasia), dental caries, and stature (*i.e.* length of an individual) (Tornberg 2013, 9 and references therein). Only a few studies on general health of late prehistoric people exist for the area of north-western Europe. A study in Sweden (Tornberg 2013) includes remains from the Nordic Late Neolithic/Early Bronze Age (2300-1100 BC), and one other study was performed in Denmark (Bennike 1985), encompassing only the Nordic Late Neolithic (2300-1700 BC). Finally, in Northern Germany, Bronze Age/pre-Roman Iron Age cremation burials (500 BC-100 BC) have been analysed for indications for general health as well (Hermanussen & Kühl 2006). Although the cultural time periods researched in Sweden and Denmark differ from the Dutch periods, these times in prehistory are roughly comparable to the Early Bronze Age and Middle Bronze Age in the northern Netherlands (cf. Chapter 9, section 9.4.1). The German study falls outside the Dutch Bronze Age, but will give indications for general health in the following period. Therefore, the data from these investigations into past health is used as an expectation for general health conditions during the Bronze Age in West Frisia.

In Sweden, the skeletal remains of 18 individuals could be analysed for direct and indirect indications for general health. Four different methods for examining general health were included in the study: dental health, nutritional deficiency, stature, and trauma (Tornberg 2013, 9). The results of the study seem to indicate a good general health pattern. Prevalence of dental caries indicate a high consumption of cereal, which can be seen as evidence for a stable diet. Furthermore, the prevalence of bone deformations which can be linked to nutritional deficiencies is low, both in adults and children (Tornberg 2013, 13). The adult values of nutritional deficiency in Sweden are comparable to the values found in Danish skeletal remains from the Late Neolithic (Bennike 1985). Deficiencies in the child skeletal material are represented less in the Swedish material, however, indicating either lower prevalence of such conditions, or death before recognisable aberrant bone deformation can occur. The reconstructed stature of both Swedish and Danish skeletal material yielded heights comparable to present day populations, which

are abnormally high for prehistory (Tornberg 2013: 14, Table III, and references therein). Especially the stature of the Swedish material (1.77 m for males and 1.66 m for females) seems to indicate very good living conditions and general health during the Late Neolithic (which is during the same time horizon as the West Frisian Early Bronze Age). Finally, there were few traumas recorded in the Swedish material, and they generally showed signs of healing, meaning that general health, in combination with care by others, must have been sufficient enough to survive the trauma for a considerable period of time. So, the general health of people living in these farming communities was good enough to limit the chance at deficiencies, and to heal adequately after suffering trauma.

Another research into general health was, as said performed by Hermanussen and Kühl (2006). In this study, 11 adolescent individuals from a Bronze Age and pre-Roman Iron Age cremation site from Northern Germany were examined for growth characteristics. Evenly spaced growth arrest lines (*i.e.* Harris lines) indicate a probability of an annual growth stop in these individuals, possibly linked to environmental conditions (Hermanussen & Kühl 2006, 22), which may include diet (Gunnell *et al.* 1998). It is interesting to postulate whether this growth arrest may have been the result of nutrient or calorie deficiency during winter months.

General health in Bronze Age the Netherlands

A few Dutch examples of general health in the Bronze Age also exist. In Wassenaar, a mass grave was uncovered (Smits &Maat 1993), which provided some information on health in the Early-Middle Bronze Age in the Netherlands. The average adult male stature was 1.75 m, with one 18 year old person even measuring 1.82 m (Smits & Maat 1993, 23). At Meteren-De Bogen, one person's stature was also reconstructed to 1.74 m (Robb 2002, 680). These statures are very high and indicate good general health (Smits & Maat 1993, 24). Female dental information showed that their teeth had a higher attrition rate than those of males, possibly linked to female activity involving the teeth, or grittier food consumed (Smits & Maat 1993, 24).

Specific evidence for nutrient deficiencies

Not all micronutrient deficiencies common in cereal based staple diets are reflected in skeletal material. Of the critical micronutrients, only vitamin C and iron deficiency can be recognized. Vitamin C deficiency can cause internal lesions which can provoke a response in bone tissue when haemorrhaging occurs close to the skeleton. Iron deficiency causes anaemia, which in turn causes porous lesions in the upper part of the eye-sockets. However, it must be kept in mind that anaemia can also be the result of the body's defence against pathogens, so that it can also signify infection rather than iron deficiency. Evidence for both conditions are found in the Early Bronze Age.

Vitamin C deficiency (scurvy)

In Britain, an Early Bronze Age round barrow (2200-1970 cal BC) yielded, amongst others, a child which portrayed likely signs of vitamin C deficiency, or scurvy (Mays 2008). The combination of pathological indications present in this child led to the postulation that scurvy was the most likely cause, making this the earliest example from Britain. Overall however, scurvy seems to be a rare condition in prehistoric in north-western Europe, based on a survey of 123 skeletons of sub-adults from early Britain (Mays 2008, 185). This means that generally, people were able to obtain enough vitamin C in their diet during this time period.

Iron deficiency

Evidence of wide-spread iron deficiency exists in Ireland in the Early Bronze Age (Mount 2012). Here, skeletal material of all age categories from a dozen Early Bronze Age cemeteries all seem to reflect either poor adaptation to the environment or nutritional stress. However, Mount states that these possible explanations are unlikely in this area, since archaeological evidence indicates well-adapted societies that did not over-exploit their surroundings. Instead, he postulates that people were suffering *en masse* from infection. During infection, iron is stored in the liver, which can also result in anaemia. Mount suggests that a disease such as malaria may have been the cause of the wide-spread anaemia, forming the main threat to the Irish population during this time. Both the location (near water) and climate (1-2°C warmer than today) in Ireland in the Early Bronze Age were very accommodating to malaria mosquitoes, which were also still recorded in Ireland up until the 19th century.

What has become apparent from the above examples is that Bronze Age people will surely have experienced times of nutrient scarcity in their diet, possibly annually. However, overall, they seem to have possessed a good enough general health standard without major deficiencies in vitamin C and iron in their diet. It can therefore be assumed that people were usually able to obtain enough critical micronutrients, which is most easily achieved by consuming wild plants.

General health in Bronze Age West Frisia

Zwaagdijk

The site Zwaagdijk yielded three Bronze Age skeletons (Modderman 1964) from which general health information could be obtained (Veselka 2015). The stature of West Frisian people could be calculated based on two of these skeletons (skeleton 1 and 2) from Zwaagdijk: the female adult size was 1.60 cm and the adult male size was 1.68m, which in general indicates healthy growth unhindered by malnourishment or disease, both of which may have occurred periodically (Veselka 2015, 26-7).

Both skeleton 1 and 2 also showed conditions, including amongst others several dental pathologies, and indications for hard labour based on pronounced muscle attachments on bones.

The pronounced muscle attachments of the arms of the female skeleton (skeleton 1) indicate repetitive heavy labour with the arms such as sewing, weaving, washing (Veselka 2015, 26). Although an exact activity could not be linked to this pathology, it can be expected that perhaps grinding grain may be a possible cause as well, since this is a very laborious task consisting of similar arm movements (pers. comm. B. Veselka).

The skeleton belonging to a male (skeleton 2) showed healed double fractures of both of the underarms, indicating that general health and care was good (Veselka 2015). The muscle attachments in this individual were also very pronounced, but at different locations than in the female skeleton 1. The combination of his muscle attachment pathologies indicates heavy and powerful labour with the arms and legs probably in the form of frequently moving or lifting heavy objects. In addition, multiple joints showed signs of osteoarthritis, indicating that they were worn by performance of heavy labour as well (Veselka 2015, 26).

The difference in bones and muscle attachment pathologies between these two individuals of opposite sex could, even though the sample is very small, possibly be linked to different activities being performed by men and women at the settlement (Veselka 2015, 36).

The third skeleton, skeleton 5, belonged to a child, which suffered from several conditions. This child experienced periods of malnutrition which resulted in growth retardation; maxillary sinusitis possibly due to bad ventilation indoors, exposure to smoke, or pneumonia; and rickets, due to vitamin D deficiency (Veselka 2105, 26). All these pathologies may have been interrelated or reinforced by each other.

Two of the three skeletons finally (skeleton 1 and 3), showed healed porotic lesions of the eye-socket or skull: *cribra orbitalia* and *cribra cranii*, respectively. In northern European mixed farming populations, these pathologies can be related to general absence of certain nutrients or to chronic infection (Walker *et al.* 2009, 120). The fact that the lesions healed does however show that periods of nutrient deficiencies or infection were overcome, again indicating good general health.

Drechterland N23

In Drechterland, recent rescue excavations prior to the construction of new road, (N23), several Bronze Age skeletons were uncovered. First, a skeleton belonging to a female was found, which was researched on general health characteristics (Pijpelink 2015a). The reconstructed stature of this individual was 1.61 m, indicating a good health standard. The only pathological indication found in this individual was *cribra orbitalia*, again indicating periods of insufficient nutrient intake, or exposure to chronic infection.

A further four skeletons were uncovered in the remains of a barrow mound, which had been disturbed in the past by building activities. These

four individuals (an adult man, two adult women, and a child) were also investigated on general health characteristics (Pijpelink 2015b). The height of the adult individuals ranged from 1.65 m-1.76 m, with the former height belonging to the two women, and the latter to the man. These heights, especially that of the male individual, indicate good general health. However, all individuals exhibited signs of osteoarthritis in the neck and back, related to the loss of cartilage between joints due to hard labour. Further pathological indications are the loss of dental elements, and severe wear on the teeth. Only the child exhibited *cribra orbitalia*, which may be related to specific nutrient deficiency or prolonged exposure to infection.

Markerwaardweg N23

Another Bronze Age skeleton was found at a different location during the rescue excavations related to the construction of the N23 road (see above). This skeleton was found face-down in a pit, and belonged to a male (van Spelde 2015). The individual had a height of around 1.70 m and possessed healed fractures, both again indicating that the general health standard was good. The bones did, however, show several signs of disease and trauma. The teeth were worn, and *dental hypoplasia* was established, which indicates periodic exposure to disease or malnutrition during early childhood. Osteoarthritis was also present, indicating worn joints due to hard labour. Mild signs of *cribra orbitalia* finally, indicate that this individual suffered from either nutrient deficiency or chronic infection in his life.

Overall, (specific) elaborate dietary deficiencies were not observed in West Frisian skeletons, and the general health of people was good. The child from Zwaagdijk had vitamin D deficiency, but this vitamin is best obtained through exposure to direct sunlight, and only to a lesser degree by consuming fatty fish such as eel or salmon. The fact that this child had multiple health conditions may have resulted in the child being kept inside, resulting in the vitamin D deficiency from lack of sunlight, not necessarily from lack of an appropriate diet.

The presence of cribria orbitalia or *cribra cranii* in many skeletons indicates that either nutritional deficiencies of vitamin C in the diet or chronic infection may have formed a serious problem during the Bronze Age. However, because the overall health of people was good based on stature and ability to heal from trauma, and no clear consistent malnourishment could be established, severe vitamin C deficiency is unlikely. Therefore, chronic infection may very well have been the main cause of the observed lesions. Similar to the EBA in Ireland, malaria may have formed a major threat to Bronze Age West Frisians, since the environment in West Frisia was equally suitable for the prevalence of this disease as in Ireland during this time. Further research is required to confirm this possibility, for example by identification of either the parasite (*Plasmodium*) or the host (*Anopheles* mosquitoes) causing malaria (Morgan-Forster 2010).

8.3.2 Clothing

Clothing is another basic necessity, and indications for potential sources of raw material for clothing have already been briefly discussed in Chapter 4-7. These results are summarized here to provide an overview of the clothing possibilities of Bronze Age West Frisians.

Sources of raw material for clothing in West Frisia

Several types of raw material would have been available to Bronze Age people in West Frisia, of both plant and animal origin. In Chapter 4, it became clear that a range of wild mammals was hunted, among which were many fur-bearing animals, or animals providing good hides (Chapter 4, Table 4.6). Observations of skinning marks on bones (Chapter 4, section 4.4.5.4) indicate that skins of animals were, at least in some cases, carefully removed to process them further, possibly also into clothing.

Chapter 5 showed that domestic animal species were exploited for multiple purposes (Chapter 5, sections 5.4.3 and 5.4.4). Domestic animal remains were frequently uncovered with slaughter marks,

indicating that the animals were fully processed after death. After slaughter, the hide of the cattle and pig would be available to process into sturdy leather, whereas sheep and goat skin would turn into a more supple form. Sheep could also have been exploited for their wool in West Frisia, even though no specific preference for this use could be observed (Chapter 5, section 5.4.4). The type of sheep kept in West Frisia (Appendix A1.5) does, however, have the potential to produce very fine wool, an example of which was observed in the province of Drenthe, in north-eastern the Netherlands, where these sheep possibly originate from. Here, balls of yarn and woollen garments were found, with high fibre quality (Appendix A1.5).

Examples for both domestic and wild animal skin use, as well as woollen garments in the Bronze Age, some of which are presented here, derive from several locations in Europe, and even from the Netherlands. For instance, in Hallstatt, Austria, several Bronze Age skins of domestic and wild animal species including cattle, goat and sheep, chamois (*i.e.* wild goat-antelope), ibex, dog or other small fur-bearing animals were uncovered in the salt mines (Ryder 1993: 107), as well as many intricate Bronze Age woven woollen textiles (Grömer *et al.* 2013); in Denmark, cattle skins have been uncovered as wrappings of the dead in grave contexts, as well as woollen garments, such as in the case of the Egtved girl (Hvass 2000); and in the province of Drenthe, in the north-east of the Netherlands, the Emmer-Erfscheiden bog body wore clothing consisting of a combination of domestic sheep and cattle hides, but also deerskin, and a woven woollen garment (Vons-Comis 1990). Apparently, a combination of wild and domestic animal skins as well as wool formed the major animal sources of raw material for the construction of clothing in the Bronze Age (Nyegaard 1983, 102).

Chapter 6 provided a possible source of raw material for creating clothing, which may have been cultivated specifically for this reason. The seeds of flax (*Linum usitatissimum*) uncovered at Bovenkarspel, Enkhuizen, Westwoud, and Hoogkarspel Watertoren, although few in number due to being possibly highly affected by taphonomical processes (Chapter 6, section 6.4.8.2) suggest that this plant may have been cultivated, possibly also for the production of fibres for the construction of linen clothing.
Finally, Chapter 7 yielded indirect information on the wild plants which may have been used as raw material for clothing (Chapter 7, section 7.4.6.4), including stinging nettle and ribwort plantain (*Plantago lanceolata*). Furthermore, tannin-containing trees and plants were found and this substance would have been used to process animal skins into leather.

Examples of Bronze Age textile finds constructed from plant fibres are scarce, because preservation and recognition of these remains are rare and difficult. However, the Bronze Age nettle textile uncovered in Denmark exemplifies the use of plant fibres for textile production during this time (Bergfjord *et al.* 2012).

To summarize, a wide variety of skins and fibres were available during the Bronze Age for the production of clothing, and many different types of hides and textiles appear to have been used alongside each other to complete sets of garments. Unfortunately, the differential preservation conditions of garments constructed from either animal or plant origin (*i.e.* plant remains under alkaline conditions, animal remains under slightly acidic conditions: Good 2001, 211), means that combinations of garments constructed from these two types of fibre are rarely uncovered together.

Indications for clothing manufacture in West Frisia

Direct finds related to the processing of fibres, presumably for the production of textile, were found at several sites in West Frisia, including spindle whorls (*e.g.* Roessingh & Lohof 2011, 182). Loom weights however, have not been uncovered. Other direct finds, which can be related to the processing of animal skins include scrapers, awls, and needles (*e.g.* IJzereef 1981: 132, 140; Groot 2010a, 96; Veldhuis 2010, 76; Roessingh & Lohof 2011, 235; Zeiler & Brinkhuizen 2011, 212-4).

Figure 8.12. Clothing types in the Bronze Age of north-western Europe; Emmer-Erfscheiden bog body (left; from: van der Sanden 1996, 148, Fig. 205, ©Kevin Wilson); Egtved girl (right; adapted from: Anthropark 2009).

Clothing in West Frisia

Although no direct finds of textiles have (yet) been uncovered in West Frisia, the above examples of raw material types for clothing available here shows that a range of clothing types must have been present. Contemporary Bronze Age garments from the north-eastern part of the Netherlands and Denmark are shown in Figure 8.11 to give an impression of the possible range of clothing types present in West Frisia. However, since clothing is one of the most direct manners to convey identity (Valentijn in prep.), the actual West Frisian clothes will most likely have not been identical to those shown in Figure 8.12.

In order to attempt to identify the possible local appearance of clothing in West Frisia, the available colour palette for dyeing was summarized in Figure 8.13 based on the wild plant species known to have been used to dye textiles uncovered in West Frisian house contexts.

It becomes apparent from Figure 8.13 that many different colours were available for dyeing textiles in the Bronze Age. In turn, many colours could be obtained from multiple plant species, and no doubt a range of different hues could be created of each colour. Whether all colours were actually lightfast (*i.e.* resistant to change in colour when exposed to

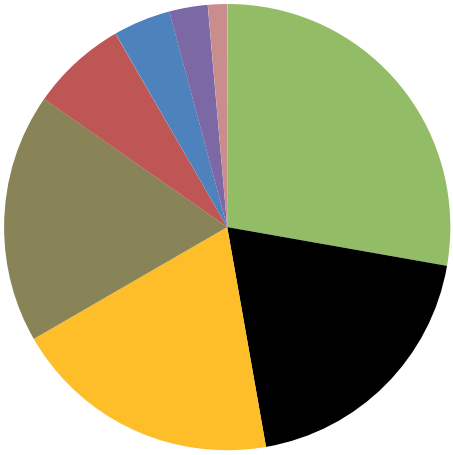


Figure 8.13. Colour palette available to Bronze Age West Frisians based on the frequency of uncovered wild dye plant species from house contexts.

light) and/or colourfast (*i.e.* resistant to change in colour when washed or exposed to weather conditions) is unknown, but repeated dyeing would have ensured coloured fabrics nonetheless. Dyed textiles are known from contemporary areas including the north-eastern Netherlands (Geimer in prep.; Joosten & van Bommel 2015) and Hallstatt (Joosten *et al.* 2006), reinforcing the idea that dyeing of textiles may very well have occurred in West Frisia as well.

8.3.3 Shelter

The third basic necessity of life which is discussed here is shelter. In the Bronze Age in general, shelter is of course provided by the house, which is no different for Bronze Age West Frisia. Scale models and actual reconstructions of West Frisian Middle Bronze Age houses have been made (*e.g.* Figure 8.14 and Figure 8.15), which provide an idea of the (relative) dimensions and possible appearance of such buildings. What is lacking from these reconstructions, and of countless many more prehistoric dwellings, however, is that the inside of the house is always portrayed as being empty. It is unclear why this is the case, since numerous finds of furniture, household supplies, tools, and equipment have been discovered which provide an insight into prehistoric life. Perhaps not every individual site has directly yielded all the objects related to daily life, but information on what must at least have been present in and around the house can be reconstructed nonetheless. This reconstruction can be based on several lines of evidence, including creating an expectation of required objects based on known activities taking place around the house and the settlement, and by researching finds from other sites to prove that the knowledge for their construction existed during this time. By extrapolating finds from other, contemporary sites to the site discussed, the inside of the house can be tentatively decorated. Of course, many aspects of the house will still remain unknown, but by at least attempting to investigate the objects which may have been present, new ideas about daily life in prehistory can be generated, simultaneously alleviating the negative or degenerative thinking about prehistoric people. When these people were able to construct everything required for their subsistence out of raw material, why would furniture and decoration be an obstacle? Surely, people will not have sat on the floor in an open-plan house with nothing but a few pots and beams to hold and secure their belongings?

In the following few sections, an attempt is made to find evidence for what the inside of a Middle Bronze Age West Frisian house may have looked like, based on expected objects, objects from other Bronze Age sites, and finds from West Frisia. These three sources of information are employed and combined to ultimately show a science-based artist impression of the inside of the West Frisian Bronze Age house.

Expectation of required objects for daily life

The expectation of required objects was created by first summarizing the basic activities occurring in and around the settlement. For each of these activities, it was established which tools would be required to accomplish the task. Although the resulting list may be far from complete, it shows many tools which could be expected on the settlement, and in and around the house (Table 8.6).

Finds known from other Bronze Age sites

Many objects which were expected to be necessary for daily life were also uncovered at many Bronze Age sites throughout the Netherlands and north-western Europe. Some examples of these finds were indicated in Table 8.6 in bold and are presented here. For each aspect related to subsistence, pictures are shown of the finds, as well as where they were uncovered.

Figure 8.14. Scale model of a West Frisian Bronze Age house.

Figure 8.15. Life-size reconstruction of a West Frisian Bronze Age house (from: Bronstijdboerderij 2013).

Table 8.6. List of required basic tools for daily life in prehistory

	Tools	Equipment	Furniture
1. Diet			
1.1 Hunting	knife stick	net, **weir, trap,** spear, sling, **bow and arrow,** hook, etc.	
1.2 Animal husbandry	knife **cheese strainer** shearing tool?	**rope halter** **bit and bridle** milking container (bucket?)	
1.3 Crop husbandry	**sickle** digging stick, **hoe** pestle/mortar pounding tool sieves, winnows, **baskets** quern	**plough/ard** **yoke**	
1.4 Wild plant gathering	**basket** digging stick knife		
1.5 Consumption	**pot** **whisk** **plate, cup, ladle, bowl**		hearth
2. Clothing	carding/combing tool **spindle whorl** **needle** **awl** scraper	**loom and related objects**	loom stool
3. Shelter	**axe** chisel hammer		benches/**chairs** beds (and bedding) stools shelves hearth hooks
4. General	**rope** **containers (wood, ceramic, baskets)** fire making tools **shovel** **boat** **cart** sweep/besom **ladder**		

Objects in bold were found during the excavation of various Bronze Age settlements throughout the Netherlands and Europe and are discussed below. Other objects, not indicated in bold, may also have been found, but are not further included in the discussion.

1. DIET

1.1 Hunting

Figure 8.16. Fish weir from Must Farm, Peterborough, England (from: Must Farm n.d.).

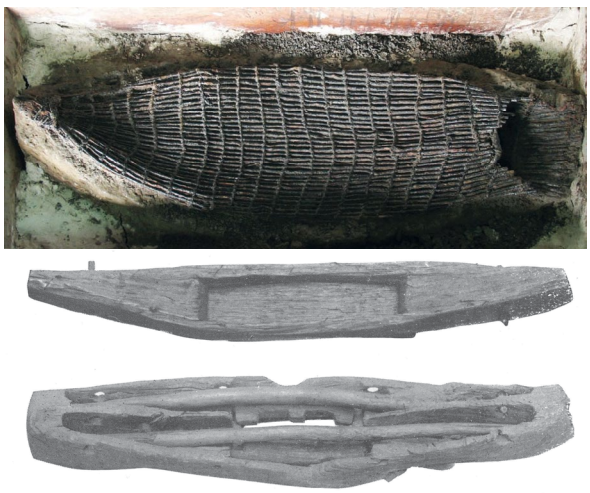


Figure 8.17. Traps. Above: fish fyke from Enkhuizen Kadijken, West Frisia, the Netherlands (from: Roessingh & Lohof 2011); below: tread traps from Hinge and Nisset Nørremose, Jutland, Denmark (from: Clark 1966, plate I).

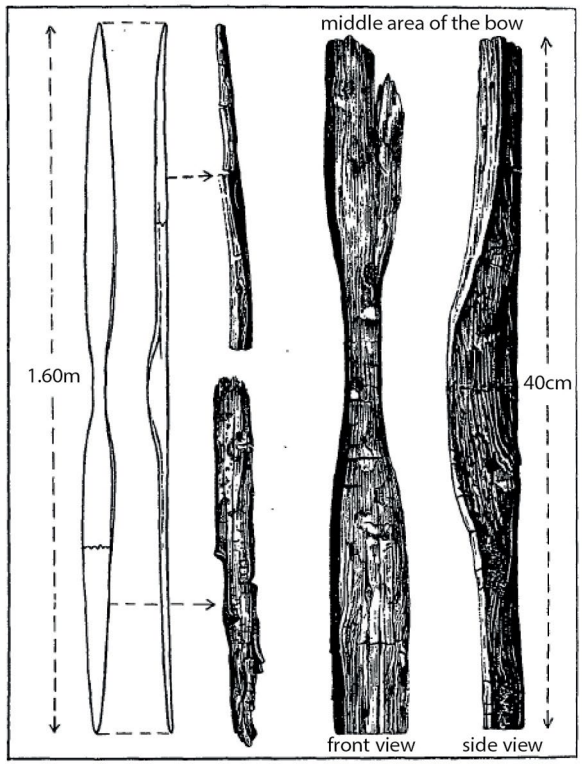


Figure 8.18. Bow from Noordwijkerhout – De Zilk, Noordwijk, the Netherlands (adapted from: van der Wal 1952) and arrowheads from West Frisia.

1.2 Animal husbandry

Figure 8.19. Cheese strainer from Zwaagdijk-Oost, West Frisia, the Netherlands.

Figure 8.21. Horse bridle-bit from Sigmaringen, Badem-Württemberg, Germany (from: British Museum 2016a).

1.3 and 1.4 Crop husbandry and wild plant gathering

Figure 8.20. Halter made from rope to restrain cattle from Siggård, Jutland, Denmark (from: Kveiborg 2009).

Figure 8.22. Bronze and flint sickles from Heiloo, the Netherlands; sickle handle made from wood from Hauterive-Champréveyres, Switzerland (from: Pillonel 2007).

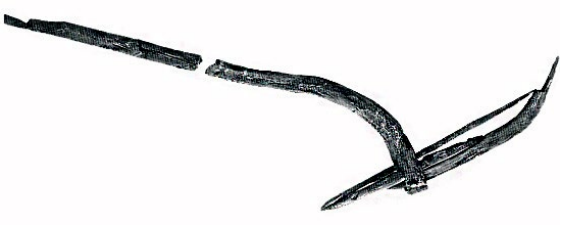
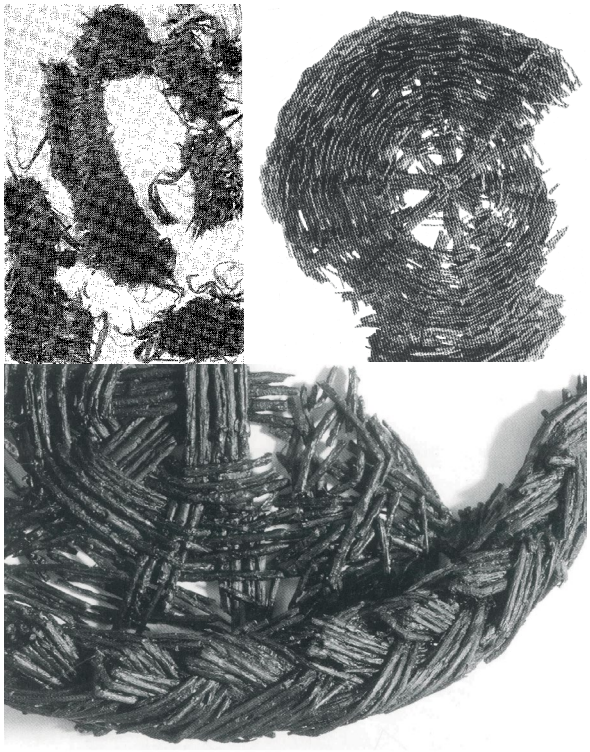


Figure 8.23. Ard found in Donneruplund, Velje, Denmark (from: Denmark's history 2014).

Figure 8.24. Simple yoke found at Flag Fen, Peterborough, England (from: British Museum 2016c).



To the left: Figure 8.25. Remains of basketry from Hoogkarspel, West Frisia, the Netherlands (top left; from: van Iterson Scholten 1977) and Hauterive Champréveyres, Switzerland (top right and below; adapted from: Pillonel 2007).

Figure 8.26. Hoe from Hauterive-Champréveyres, Switzerland (from: Pillonel 2007).

1.5 Consumption

Figure 8.27. Examples of Bronze Age pots from Enkhuizen Kadijken, West Frisia, the Netherlands (adapted from: Roessingh & Lohof 2011: 164, 167).

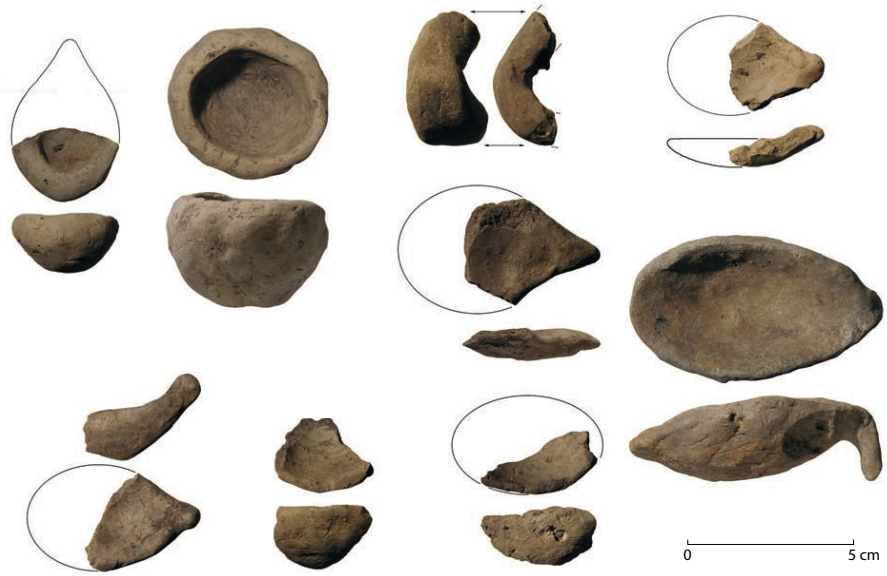


Figure 8.28. Small bowls and spoons from Enkhuizen Kadijken, West Frisia, the Netherlands (adapted from: Roessingh & Lohof 2011, 166).

Figure 8.29. Bowls from Enkhuizen Kadijken (adapted from: Roessingh & Lohof 2011: 165, 185).

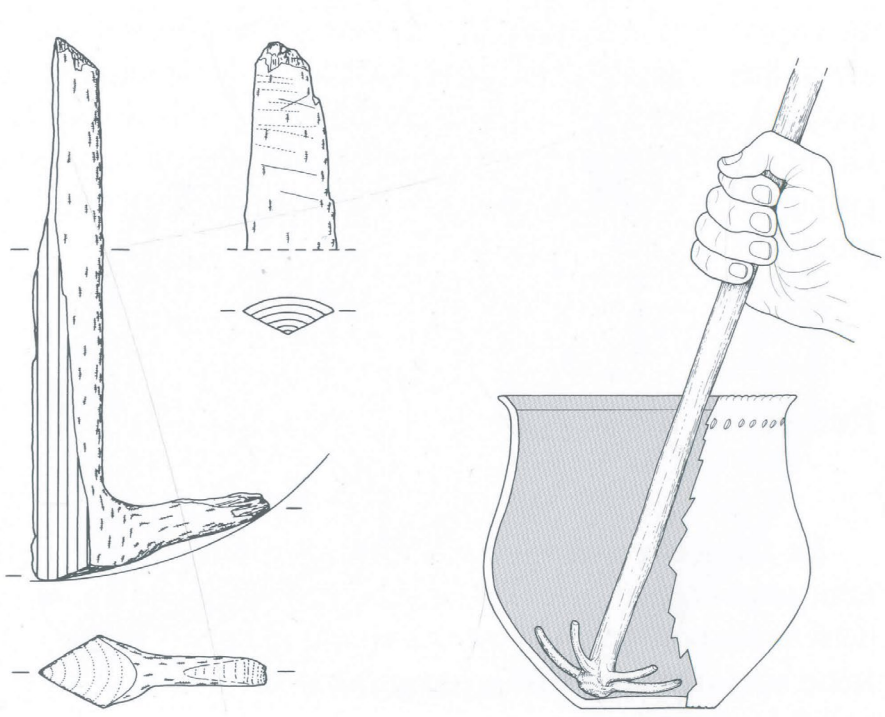


Figure 8.30. Remains of a whisk from Hauterive-Champréveyres, Switzerland (from: Pillonel 2007).

Figure 8.31. Plate from Hauterive-Champréveyres, Switzerland (from: Pillonel 2007).

2. CLOTHING

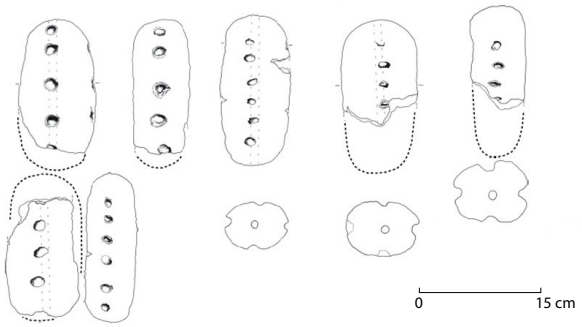


Figure 8.32. Loom weights made from loam from Zutphen Loöerenk, the Netherlands (from: Fermin 2008, 232-33).

Figure 8.33. Awl and needle from Enkhuizen Kadijken (from: Roessingh & Lohof 2011, 213).

Figure 8.34. Spindle from Hauterive-Champréveyres, Switzerland (from: Pillonel 2007) and spindle whorls from Enkhuizen Kadijken, West Frisia, the Netherlands (from: Roessingh & Lohof 2011, 163).

3. SHELTER

Figure 8.35. Wooden axe handle from Hauterive-Champréveyres, Switzerland (from: Pillonel 2007) and bronze chisel from Westwoud, West Frisia, the Netherlands.

Figure 8.36. Wooden folding chairs. Left: folding chair from Guldhøj barrow, southern Jutland, Denmark (adapted from: Bullenwächter 2008); right: folding chair from northern Germany (from: Klapphocker 1950).

4. GENERAL

Figure 8.37. Pieces of rope found at Hoogkarspel (from: van Iterson Scholten 1977, 136).

Figure 8.38. Wooden container, lid, decorated rim of a container, and decorated containers from antler with wooden base from Hauterive-Champréveyres, Switzerland (from: Pillonel 2007).

Figure 8.39. Boat from Must Farm, England, United Kingdom (from: History blog 2012). Paddle probably used for maritime travel from Westwoud, West Frisia, the Netherlands (from: Ons West-Friesland 2015).

Figure 8.40. Shovel head made from moose antlers from Hoogkarspel Tolhuis, West Frisia, the Netherlands.

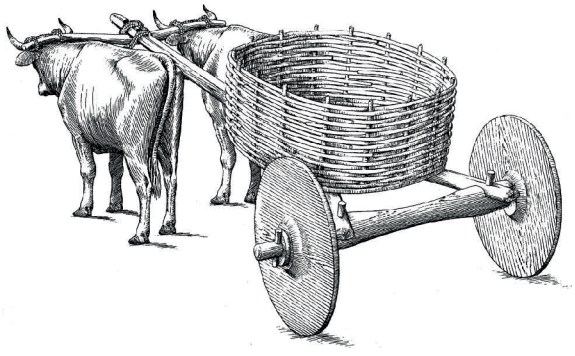


Figure 8.41. Two-wheeled cart from Bølling Sø, central Jutland, Denmark (Schovsbo 1987, 131).

Figure 8.42. Ladders. Left: ladder from Tiel-Medel, the Netherlands (van Hoof & Jongste 2005, 67); right: possible ladder from Enkhuizen Kadijken, West Frisia, the Netherlands (Roessingh & Lohof 2011, 252).

Figure 8.43. Decorated bone comb from Bovenkarspel Het Valkje, West Frisia, the Netherlands. Top left: photo of the actual uncovered part of the comb; bottom left: photo of the actual uncovered part of the comb with scratches highlighted by author; right: reconstruction of the complete comb (adapted from: IJzereef 1981, 139, fig. 86).

Science based artist impression of the inside of the West Frisian Middle Bronze Age house

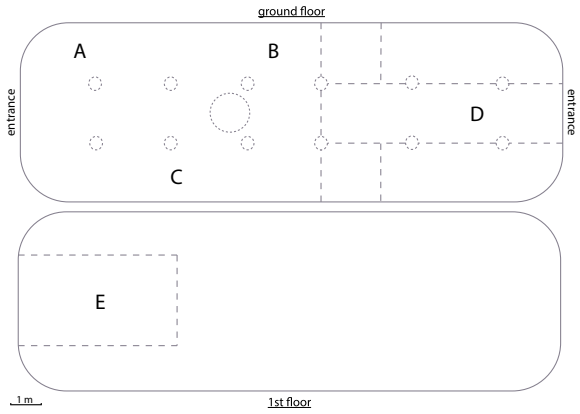


Figure 8.44. Top view of the inside of a West Frisian Middle Bronze Age house with first floor (above) and second floor, consisting of an attic (below). A: textile production area, due to favourable light conditions; B: cheese making area and storage of consumption related material due to cool conditions for cheese production in the northern part of the house; C: tool storage area and beds; D: barn, due to differences in house lay-out (Roessingh in prep.); E: attic with food storage, only in western side due to incompatibility with barn.

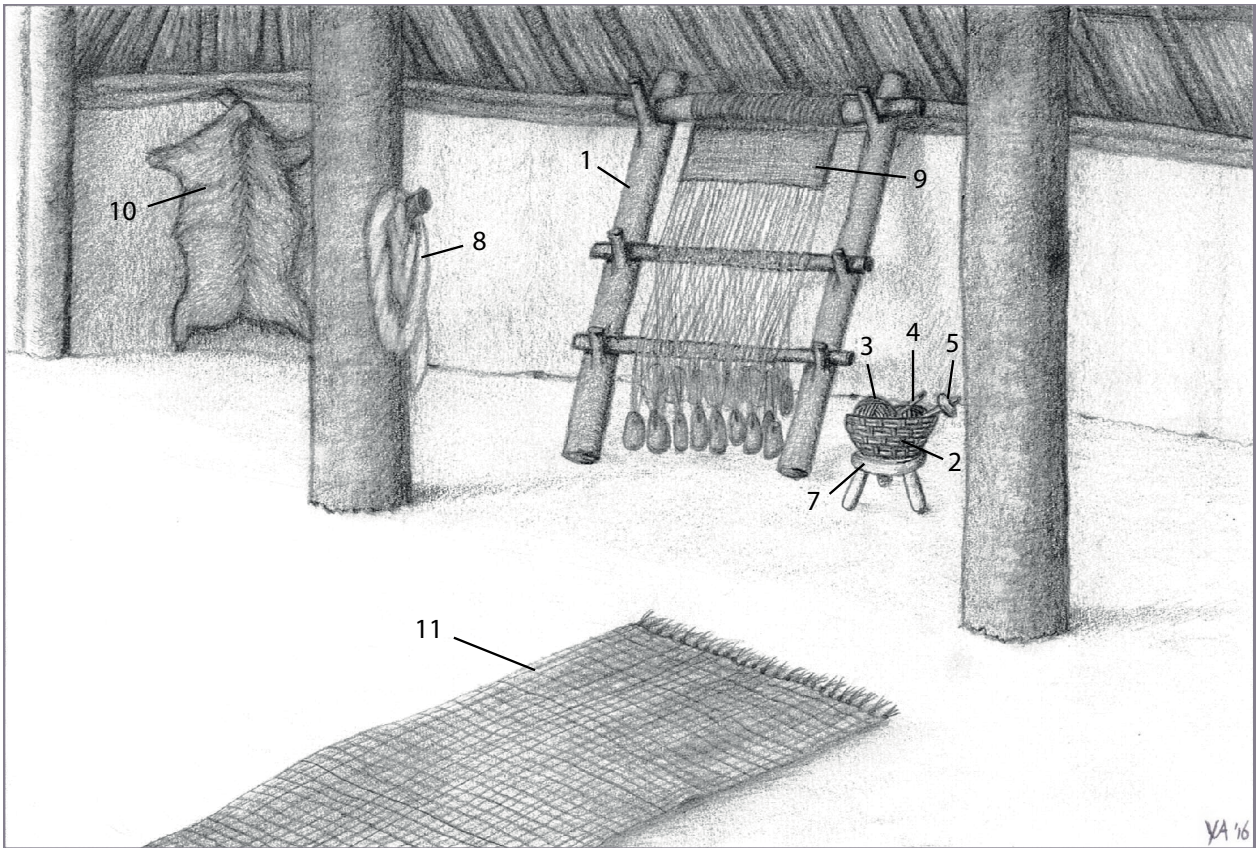


Figure 8.45. Textile production area. 1: warp-weighted loom; 2: basket; 3: ball of yarn; 4: needle; 5: spindle whorl; 6: loom weight; 7: stool; 8: carded wool; 9: linen; 10: hide; 11: mat.

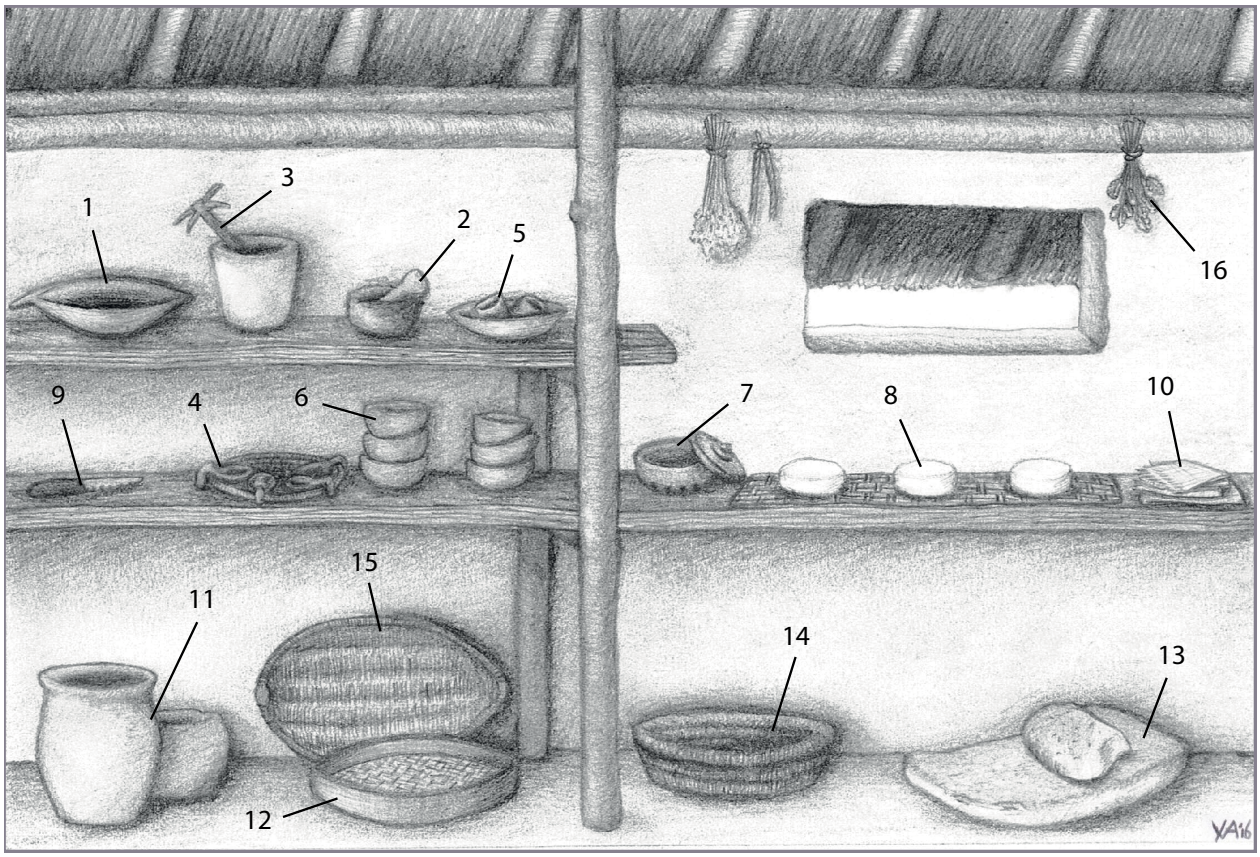


Figure 8.46. Cheese making area and storage of consumption related material. 1: bowl; 2: bone pestle; 3: whisk; 4: spoon; 5: miniature bowl; 6: ceramic container; 7: cheese strainer with lid; 8: cheese; 9: knife; 10: cheese cloth; 11: pot; 12: sieve; 13: quern; 14: basket; 15: winnowing basket; 16: dried herb.

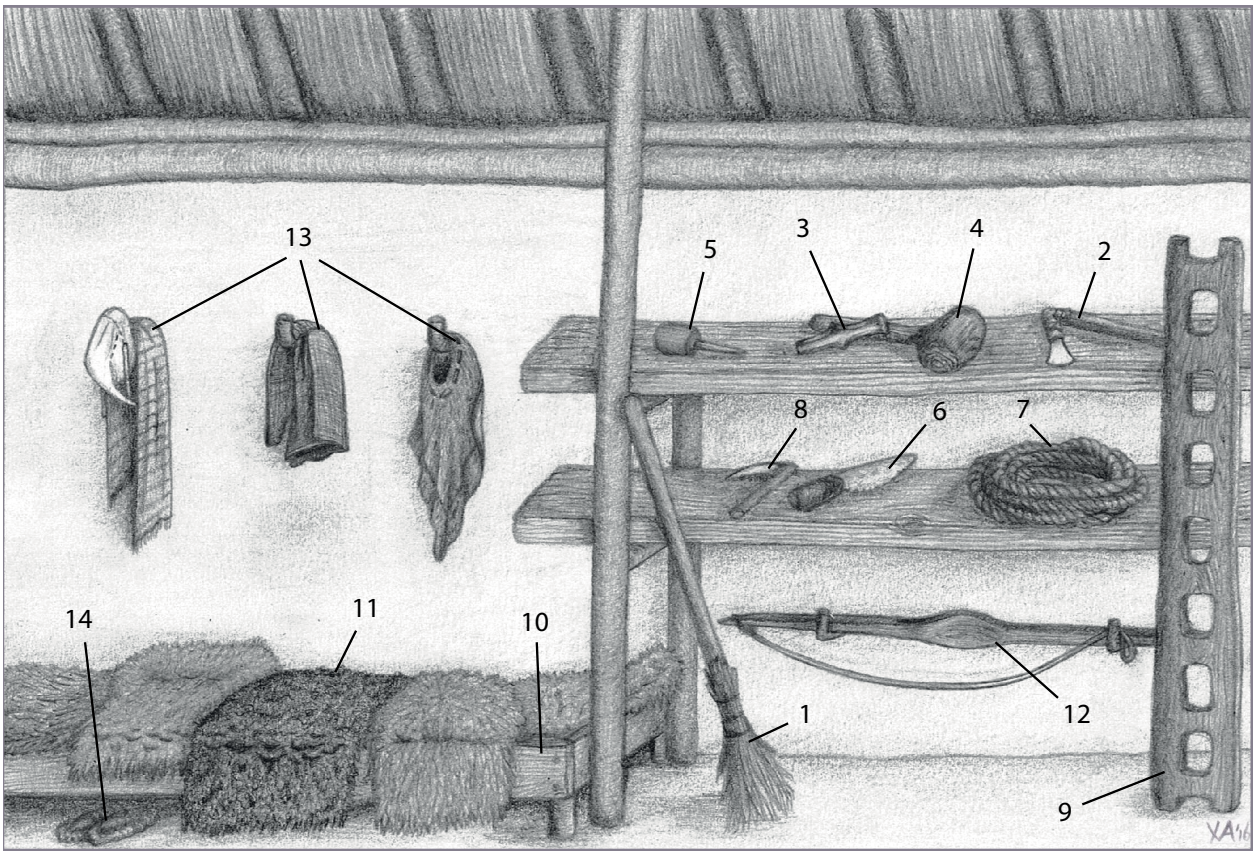


Figure 8.47. Tool storage area and beds. 1: broom; 2: axe; 3: chisel; 4: wooden hammer; 5: awl; 6: slaughter knife; 7: rope; 8: sickle; 9: ladder; 10: bed; 11: sheep skin; 12: wooden bow; 13: clothing; 14: shoes.

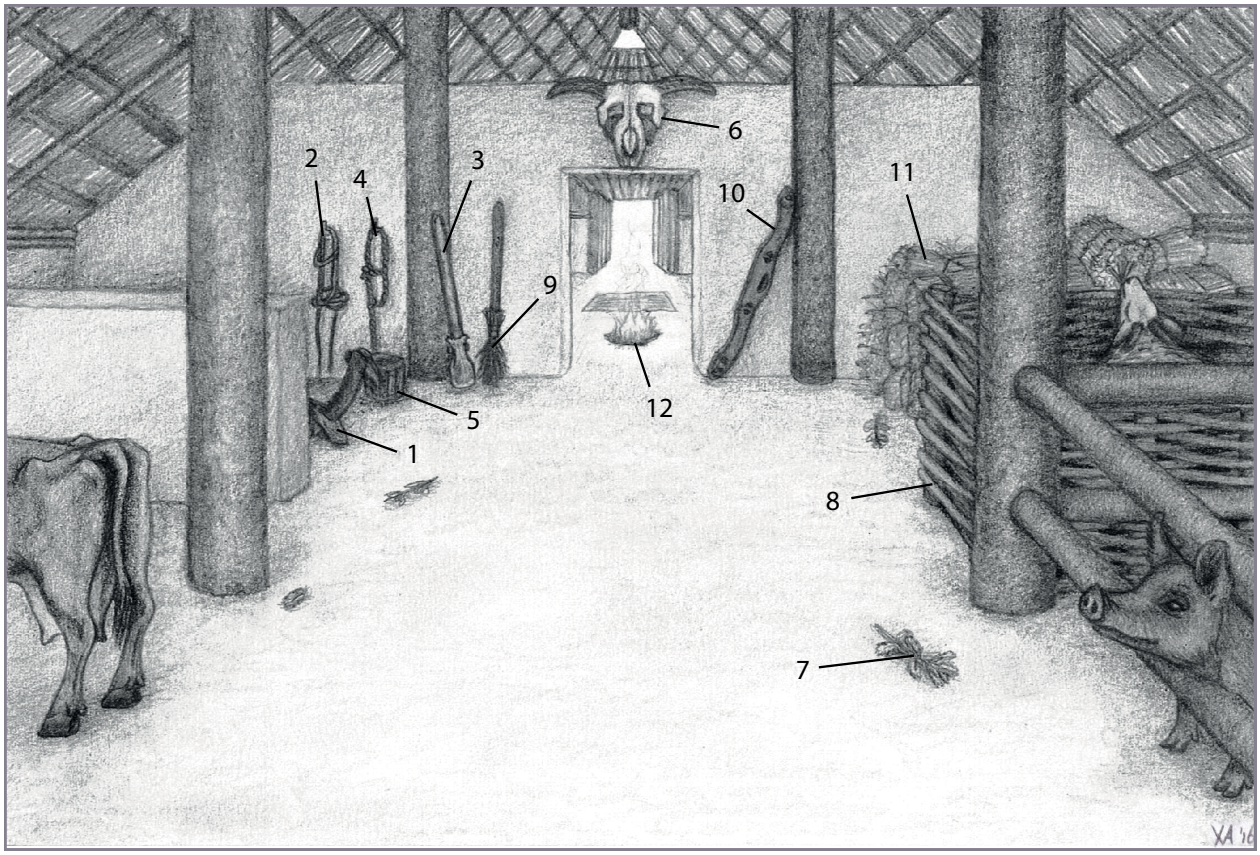


Figure 8.48. Barn. 1: ard; 2: bit and bridle; 3: shovel; 4: rope head gear 5: milking bucket; 6: cattle skull hung from leather straps (found in Tiel-Medel; Cavallo & van Groenesteijn 2005, 139); 7: repellent (see Chapter 7); 8: wattle pen; 9: broom; 10: yoke; 11: fodder; 12: hearth.

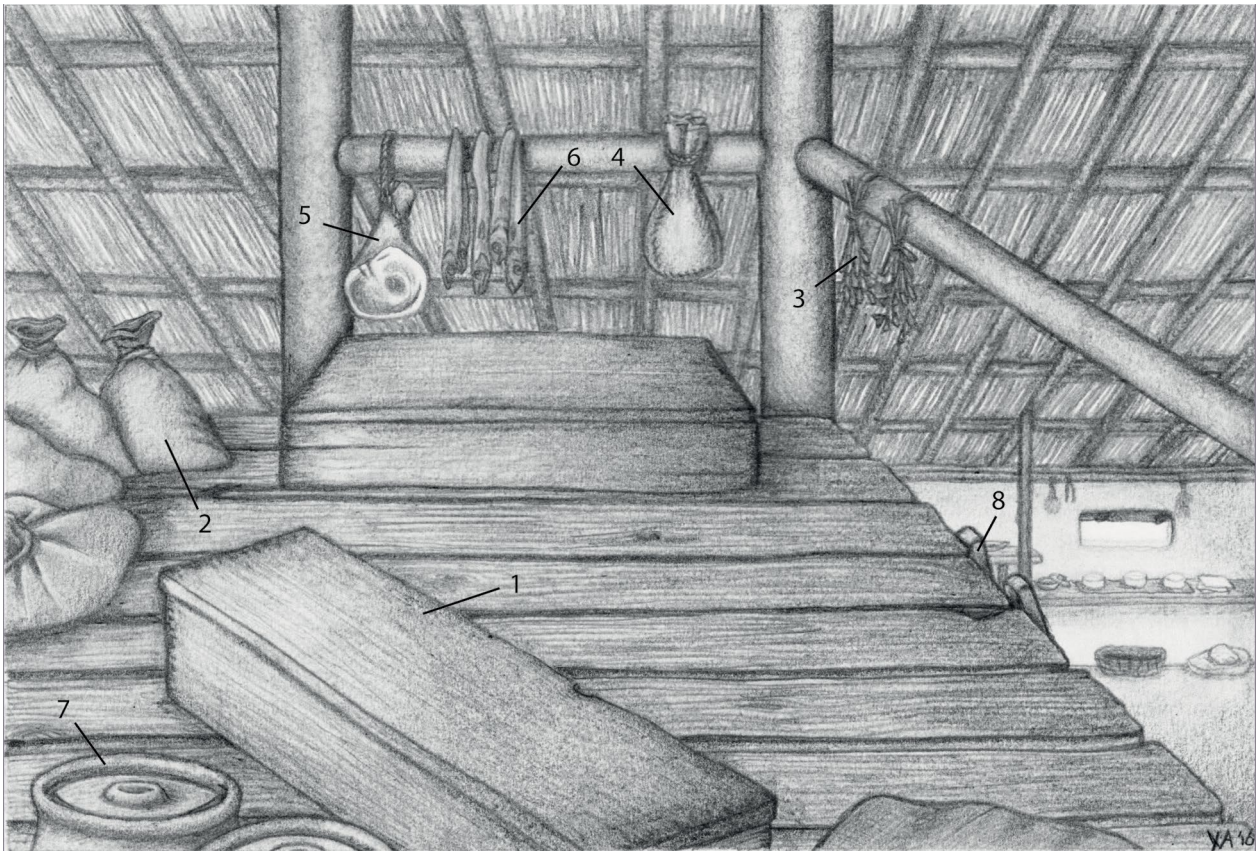


Figure 8.49. Attic with food storage. 1: wooden container; 2: linen sack; 3: dried herb; 4: leather bag; 5: dried meat; 6: dried fish; 7: ceramic container; 8: ladder.

8.4 RECONSTRUCTION OF ACTIVITIES RELATED TO SUBSISTENCE

In this third section, the research is focused on how the different activities related to subsistence were practiced throughout the year. Furthermore, besides synthesizing the seasonalitydata from Chapters 4-7, the relation of activities to the distance from the settlement is assessed (cf. Chapter 2 and this chapter, section 8.2.3), as well as the influence of a (changing) environment through time (cf. Chapter 2). The characterization of these activities includes both farming activities and activities related to wild resource exploitation, and both types of activities are researched for the Middle and the Late Bronze Age. This differentiation in two time periods is chosen to attempt to identify possible changes in activity related to the environmental changes that occur in the Late Bronze Age (cf. Chapter 2).

The resulting activity diagrams, or year cycles, provide clear insight into the work required in a farming system on an annual basis, the adaptability to environmental change, as well as the interconnectedness and complexity of a farming system that includes wild resource exploitation.

The year cycles produced in this chapter are comparable to the work of Clarke (1972; Figure 8.50). In his research, Clarke included activity, distance, landscape type, and climatic influence, thus capturing complex concepts related to subsistence in one image.

Activity practices in West Frisia are similarly summarized by combining the influence of the environment and the distance from the settlement with human activity, based on the conclusions of the previous chapters. A total of four cycles is constructed (Figures 8.51-8.54): one for each time period (MBA and LBA), for both domestic (crop and animal husbandry) and wild (hunting and gathering) resource exploitation.

In each of the circles for the MBA and LBA, the centre of the circle represents the settlement; the inner circle the arable fields; the middle circle the dry land areas (dry grasslands, dry forest); and the outer circle the wetland areas (wet grasslands, wet

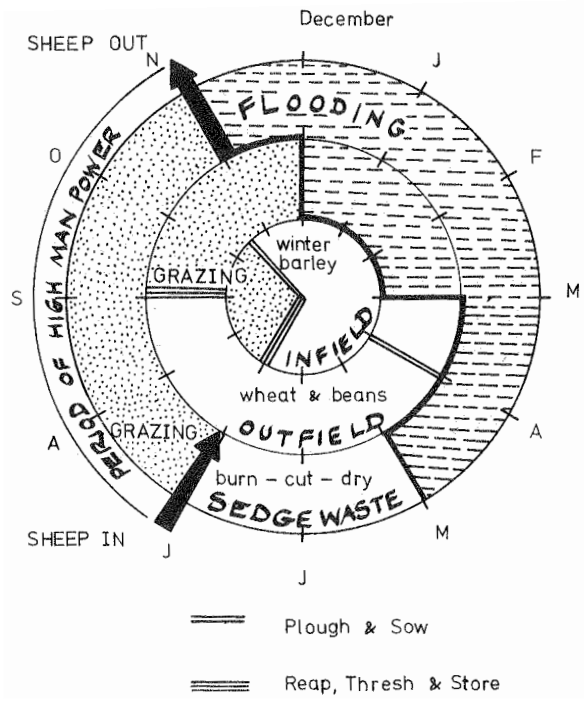


Figure 8.50. Year cycle of Iron Age subsistence (from: Clarke 1972, 856, fig. 21.10).

forest, waterside vegetation, cf. Appendix A1.2). In the overall cycles, arrows denote movement of livestock from areas where the arrow originates to the area where the arrowhead ends. Dashed lines are employed to indicate activities such as harvesting, manuring/ploughing, and sowing. Starting the year in September, the beginning of autumn, the year cycle is discussed separately for each period and resource exploitation type.

8.4.1 Middle Bronze Age

Autumn: domestic resources

In September, sheep, having grazed on both wet and dry land areas in the summer, would have been transferred to only dry land areas. In autumn, wetland areas would have become increasingly wet and an increasing risk for infectious diseases for the already susceptible sheep. Cattle, being more resilient to wet conditions, would have continued to graze on both dry and wet areas throughout autumn.

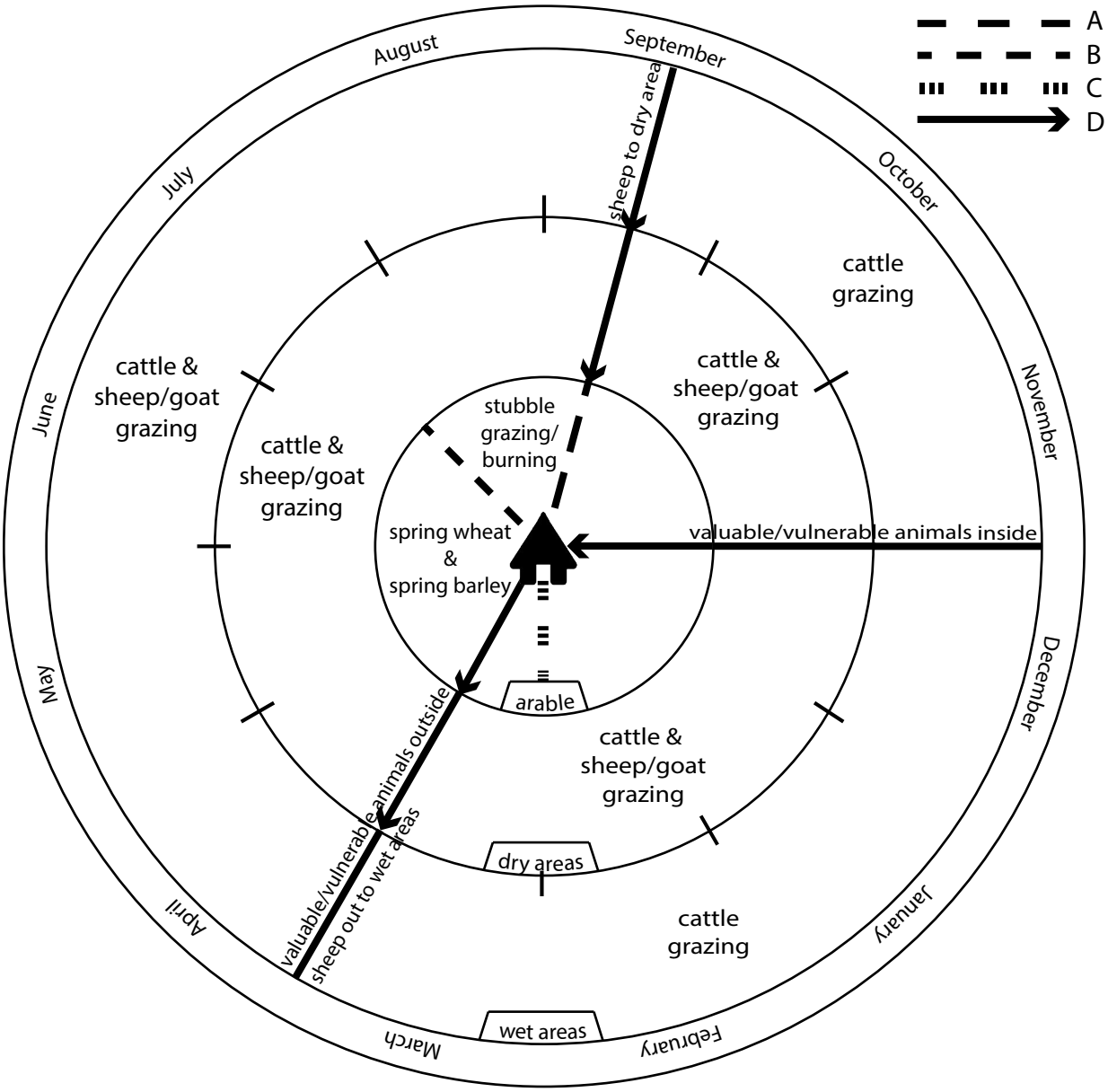


Figure 8.51. Middle Bronze activity year cycle for domestic resources (including crop and animal husbandry). A: harvesting; B: manuring/ploughing; C: ploughing/sowing; D: movement direction of livestock.

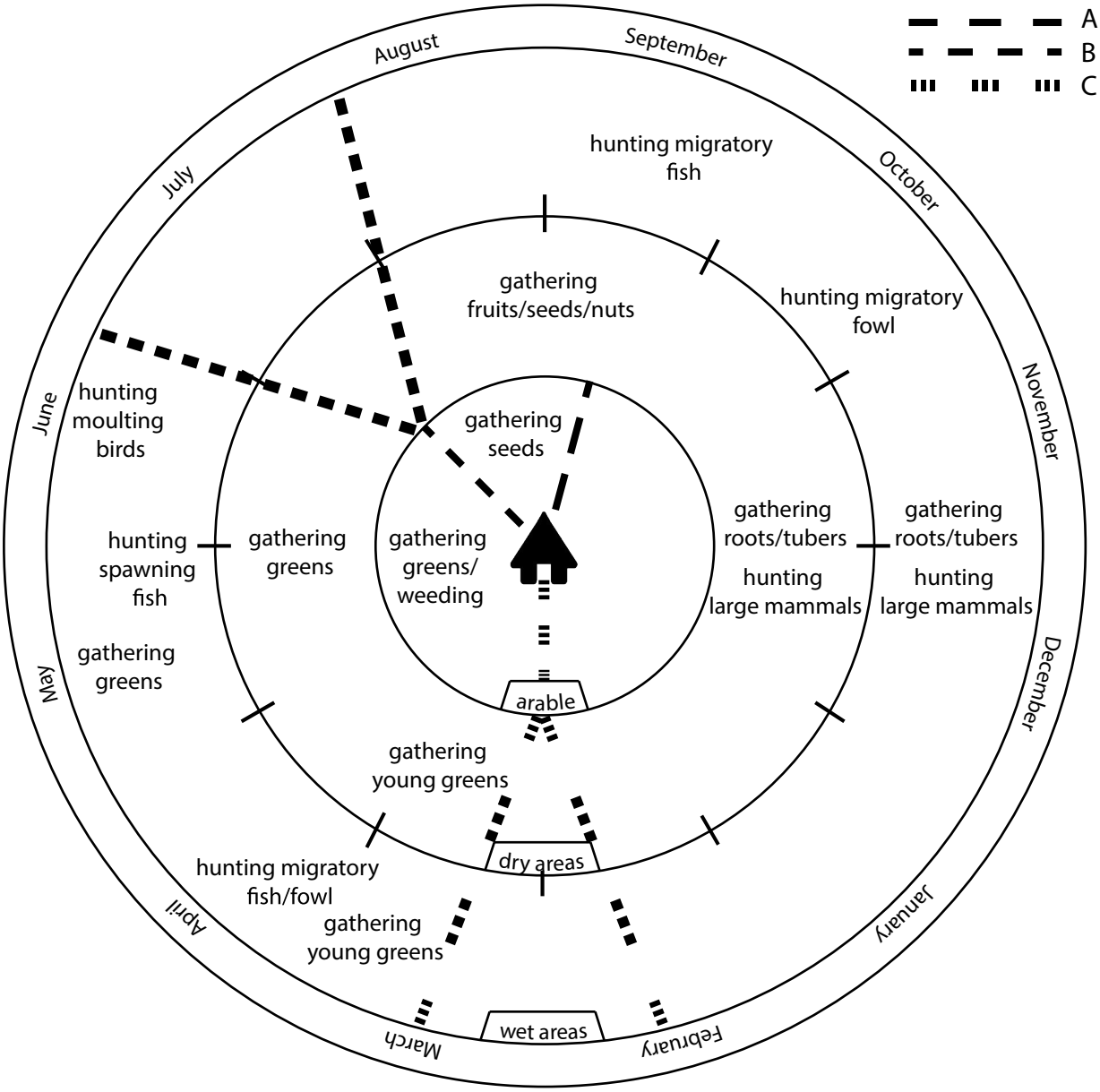


Figure 8.52. Middle Bronze activity year cycle for wild resources (including hunting and gathering). A: harvesting; B: manuring/ploughing; C: ploughing/sowing.

Breeding of cattle, sheep, and goat would also have occurred during this time.

On the arable fields, manuring and ploughing would have taken place in order to prepare the fields for the sowing of new crops in the spring.

Autumn: wild resources
During this time, domestic resources such as meat and milk would have been running out. Therefore, towards the end of autumn, the importance of hunting wild animals would have increased.

Most of the fruits, seeds, and nuts would have been available during most of autumn, but would have decreased in number towards the end of this season. In November, however, roots of wild plants would have become available as a viable food source.

Winter: domestic resources
Winter, being the harshest of seasons in terms of weather conditions, would have prompted people to bring valuable and vulnerable animals, such as horses or pregnant and old animals, inside their houses. In this manner, animals could be more easily protected and cared for. Remaining livestock would have been kept outside, with the possibility of foddering them when winter was extremely harsh. During this time, pigs would have been breeding.

Arable fields were left alone for most of the winter. Second ploughing, weeding, and sowing of fields, however, might possibly have started as early as February, weather permitting. Still, most of winter would have been a quiet period for animal and crop husbandry practices, leaving room for other activities such as repairing, making tools/equipment, etc.

Winter: wild resources
Winter would have been the most active game hunting time in the farmer's year. Fur animals were most valuable in this period because of their thick furs, and large game would have been a nice addition to both the diet as well as an extra source of protein and raw material. Towards the end of winter, fish and fowl became more available, as migration started. Smoked fish and meat may have been consumed during this time as well.

Throughout winter, roots and tubers would have been the main wild plant resource available to people.

Spring: domestic resources
As soon as weather conditions became more favourable, the animals which were kept inside during winter, would have been transferred to their grazing areas in March/April. During this time, vegetation would have begun to grow, providing fresh food for livestock. Most animal species would have been giving birth during this season, starting with sheep and goat, followed by pig, and cattle. Animals dying either during or after birth would have been processed to become the meat supply for the year ahead. Milk supply would have been highest in this period, and would have decreased steadily during summer and autumn.

If weather conditions were unfavourable in February, second ploughing, weeding, and sowing would have taken place at this time instead.

Spring: wild resources
The very high supply of domestic meat in spring would have reduced the need for hunting for subsistence in this season. However, eggs of wildfowl would have been available at this time, forming an extra food source, and most fish would have been spawning during this time, making them easy targets for capture.

Wild plants, similar to pasture, would have been growing, meaning young shoots and leaves rich in vitamins would have been widely available.

Summer: domestic resources
Summer would have meant grazing of livestock in different areas. Wetland areas would have been dry enough in summer for sheep to also graze here. After harvest, the arable fields may have become available for stubble grazing as well. At the start of summer, cattle may still have been producing offspring, but cattle that had already given birth in spring could have been used for breeding purposes again at the end of the summer.

Depending on the time of sowing and the growing conditions for the crops, weeding would have taken place in early summer, and harvest in July/August.

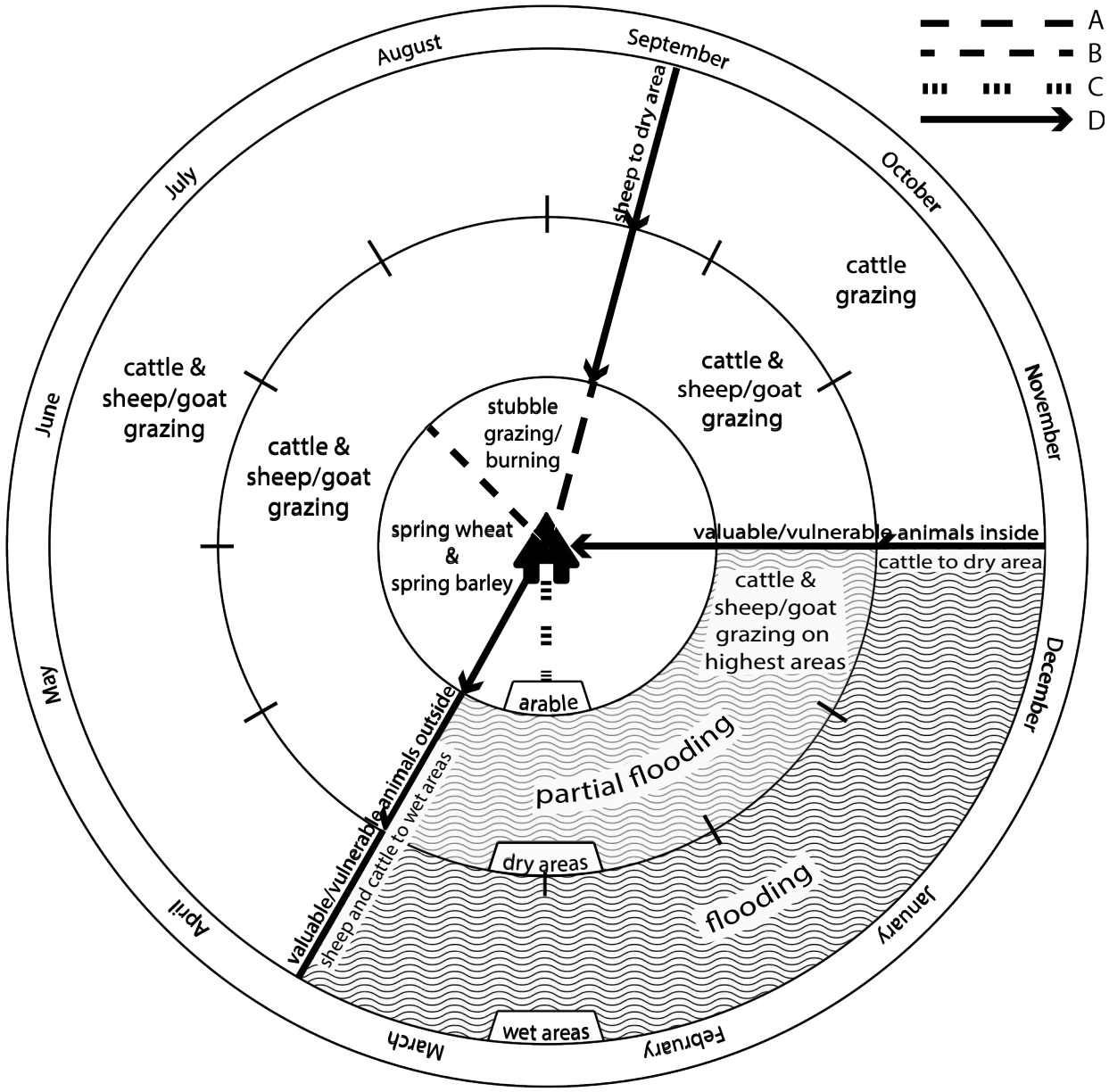


Figure 8.53. Late Bronze activity year cycle for domestic resources (including crop and animal husbandry). A: harvesting; B: manuring/ploughing; C: sowing; D: movement direction of livestock.

After harvest, the stubbles would have been either available to livestock for grazing, or burned. After grazing, manuring and ploughing can start, weather permitting. After burning, rain would have helped to transport nutrients released through burning into the soil.

Summer: wild resources
Eggs would have been less available during summer, but due to moult, (aquatic) birds themselves would have become a new resource. Fish would also have been available still, with the availability of eel increasing in the late summer, when migration started.

Wild plants would still have provided greens, although edibility would have decreased throughout summer, when seed- and fruit-bearing stages started. Seeds, nuts and fruits would therefore have become the new resources at the end of summer.

8.4.2 Late Bronze Age

Domestic resources
The main difference between the Middle and Late Bronze Age was the increasing wetness. During autumn and winter periods, wetland areas are became more inhospitable to livestock because of flooding. This aspect of the Late Bronze Age environment would have caused the transfer of cattle to dry areas in winter during this time, whereas it would not have been necessary in the Middle Bronze Age. Both sheep and cattle would have been kept on the highest and driest areas in the landscape, as most areas would have been (partially) flooded in winter and early spring. In summer however, the areas previously flooded would have been dry enough for grazing both sheep and cattle.

This flooding phenomenon would have created a large impact on other farmer's activities during autumn and winter as well. Although crop and animal husbandry were still practiced during this time, the area available, especially for grazing, would have been much smaller in comparison with the Middle Bronze Age (cf. Chapter 2, section 2.5.3). Transport or travel routes would also have become restricted during this time, unless transportation across water was occurring. The reduced amount of suitable land would not have accommodated the same amount of people as in the previous period (section 8.2.1).

Spring sowing was (still) being practiced, indicating that growing crops was possible, but only on dry enough locations. Harvesting, burning and/or ploughing might, however, have been affected by the increasingly wet environment, shortening the available time to safely process and store the harvest before autumn rains and winter floods arrive.

Wild resources
Wild resource exploitation in the Late Bronze Age would also mostly have been affected by the increasing wetness in comparison to the Middle Bronze Age. Large areas of the landscape would have been virtually inaccessible for hunting and gathering during the wet autumn and winter months. Although both were still practiced in the Late Bronze Age, the reduced amount of available hunting grounds may have restricted the potential number of people exploiting these resources.

For both the Middle and Late Bronze Age, it has become clear that people were living in harmony with their surroundings, and were not willing to evacuate an area just because of increasing wetness. Rather, they were adapting to the gradually changing environment by for example throwing up *terp* mounds and adjusting their subsistence practices according to the available resources. Once more, it is obvious that farming should never be called optimal, but rather adaptable to availability of resources, and environmental conditions.

8.5 SUBSISTENCE IN FOCUS: BOVENKARSPEL HET VALKJE

One settlement, Bovenkarspel Het Valkje, was chosen in order to investigate how the researched aspects of subsistence relate to each other within a settlement. This site has data available for analysis of all subsistence strategies, as well as information on many of the house plans. Combining the information from Chapters 4-7 on crop and animal husbandry, hunting, and gathering from multiple houses of Bovenkarspel

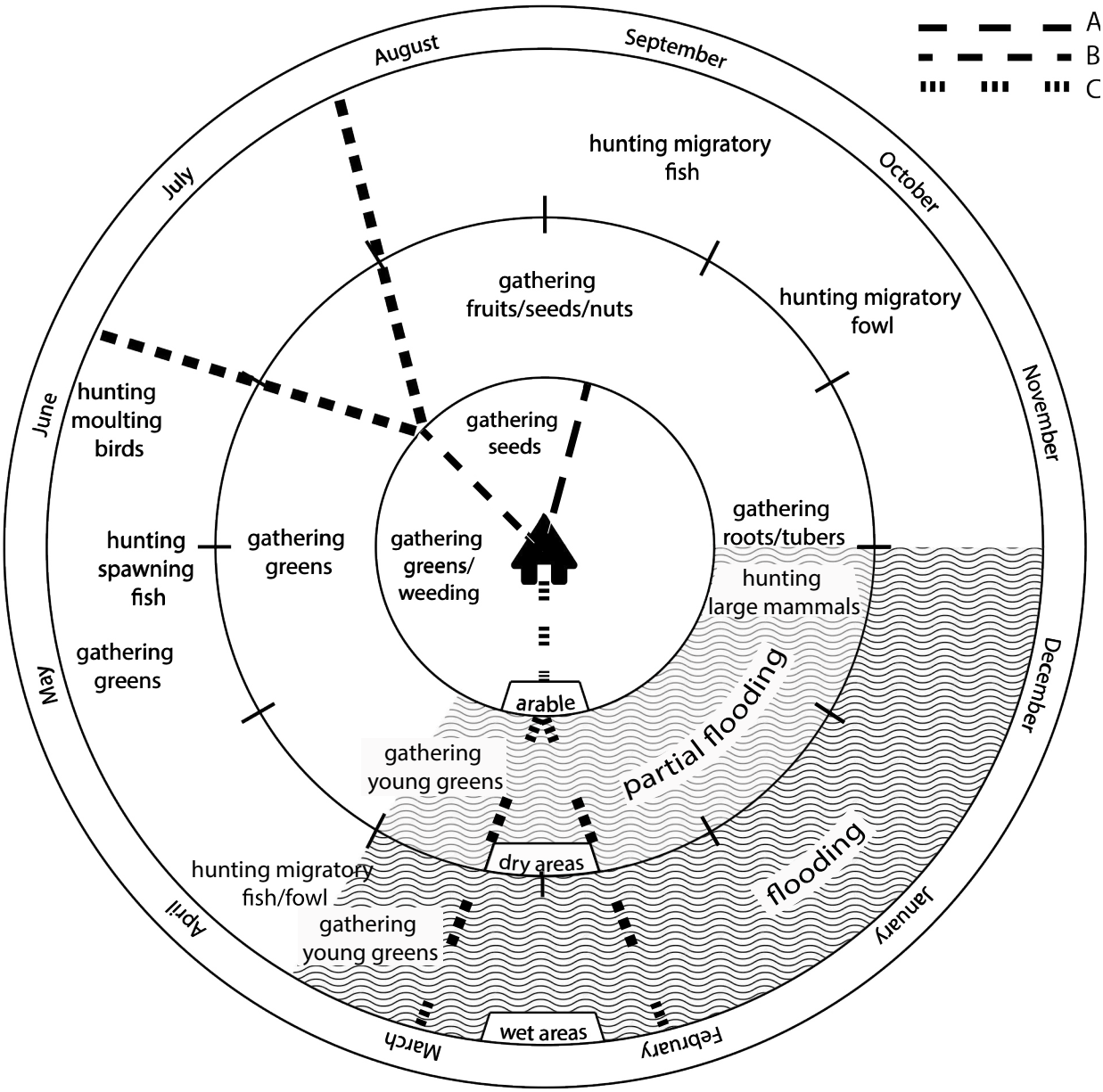


Figure 8.54. Late Bronze activity year cycle for wild resources (including hunting and gathering). A: harvesting; B: manuring/ploughing; C: sowing.

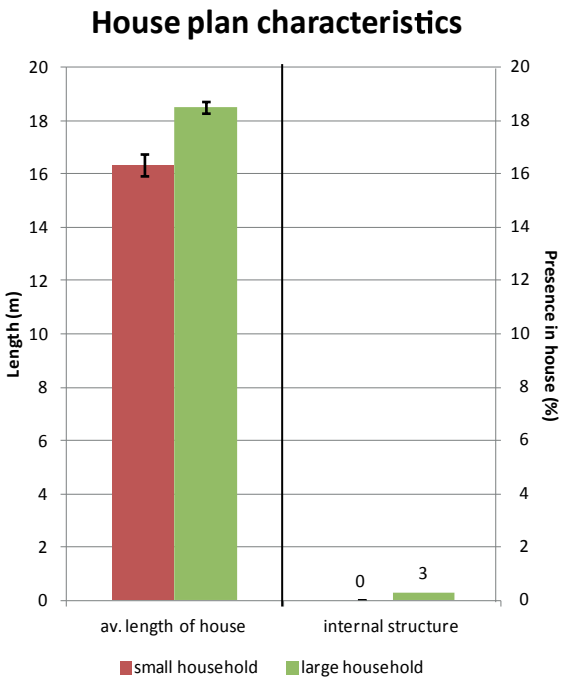


Figure 8.55. House plan characteristics of small and large households. No significant differences between households were observed.

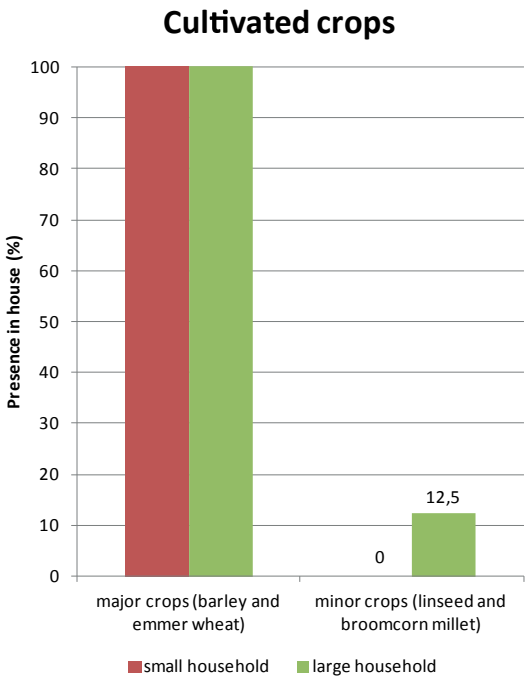


Figure 8.56. Cultivated crops present in small and large households. No significant differences between households were observed.

has enabled an inter-house comparison of subsistence practices based on remains from house ditches.

Crop husbandry harvesting practices yielded a clear division between the houses of Bovenkarspel (see Chapter 6, section 6.4.4), and this is therefore used as the main factor for comparison between small and large households. Other aspects related to crop husbandry in this comparison include the presence of other cultivated plants (linseed/flax and millet). Aspects of animal husbandry include the average number of domestic animal species kept (cattle, sheep/goat, pig, dog, horse), and presence or absence of each of these species within the household. Furthermore, the hunting-related aspect is the presence of large game. Small game could not be included due to difference in collecting and sieving practices for smaller animals at the site. Aspects related to gathering practices finally, include average number of wild plant species present, number of species of which the eco group is known, number of species from local, settlement, arable field, and off-site locations (cf. Chapter 7, section 7.4.1). The number of different uses of wild plants are also summarized, as well as the presence of specific uses. Factors which are not related to food strategy are also included in the comparison, such as the house structure. The average length of the house is taken into consideration, as well as the possible presence of an extra internal structure, which might be related to storage (Roessingh in prep.).

Of the available samples house plans, only 24 yielded enough data of each subject to be included in the comparison. Of these houses, four could be characterized as having a small household size/ limited hands available for harvest, and eight as large households/having enough time or hands during harvest (Chapter 6, section 6.4.4). The remaining twelve houses showed a mixed signal and are not included in further analyses.

The results for the MBA houses are shown in Figure 8.55-8-58. Unfortunately, the LBA contexts did not yield enough data for a detailed comparison, so only a general discussion is provided for this time period.

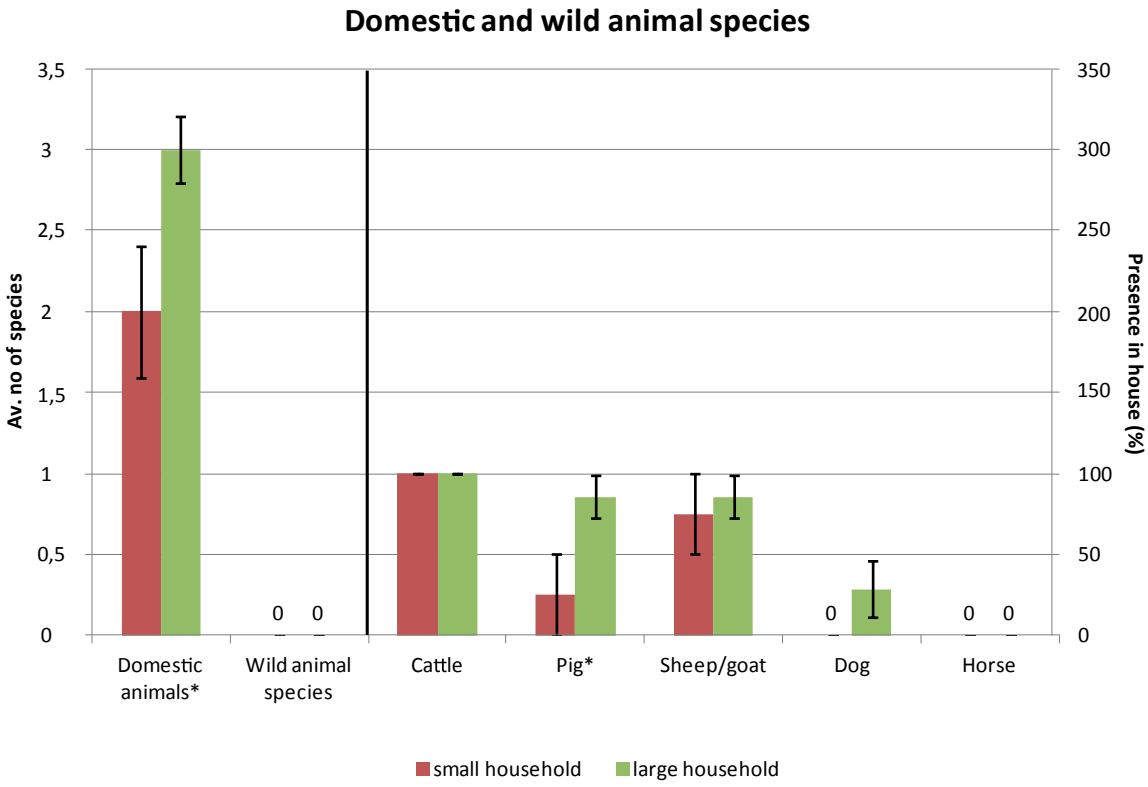


Figure 8.57. Number and type of domestic and wild animal species present in small and large households. *= significant difference between small and large households (domestic animals: two-sample t(df) = t-value, p = 0.04; pig: two-sample t(df) = t-value, p = 0.048).

8.5.1 Middle Bronze Age

Houses

The first aspect which becomes apparent from Figure 8.55 is that the average length of the house is not significantly different between small and large households. This means that throughout the Middle Bronze Age, houses were of similar size, but the size of the households within them varied. This result is consistent with the research of Roessingh (in prep.), who also concludes that there is no clear differentiation observed in house sizes through time in Bovenkarspel.

Another interesting aspect of Figure 8.54 is that internal structures are observed in large households, but not in small households. Although this may be a result of the limited number of small households present, it may also reflect an actual difference in practice. Perhaps larger households needed to store larger amounts of grain and fodder, increasing the need for a supported attic.

Crop husbandry

Cultivated plants other than barley and emmer wheat were only present in large households (Figure 8.56). This may still be due to the limited number of small households as comparison, but it may fit well with the fact that larger households would have been more capable of cultivating more than two crops than small households with limited means and people. More research is needed to further confirm this picture.

Animal husbandry

There are some differences between small and large households with regard to animal husbandry (Figure 8.57). Small households have a significantly (two-sample t(df) = t-value, p = 0.04) lower number of different domestic animal species in their house ditches. In small household ditches, cattle is the

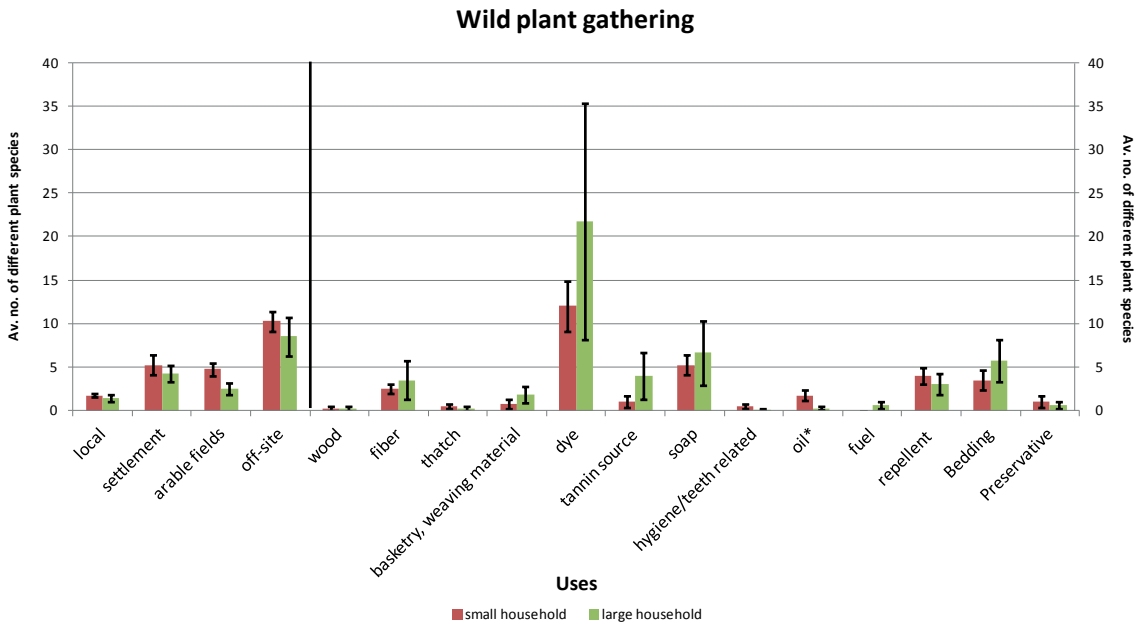


Figure 8.58. Frequency, gathering location and type of wild plant species present in small and large households. *= significant difference between small and large households (two-sample t(df) = t-value, p = 0.02).

species that is always present, followed by sheep/goat, and finally, sometimes pig. This may be related to the limited number of animal species that can be cared for with a limited amount of people in a household.

Larger households would have consisted of more people and means to keep a wider variety of animal species. Indeed, pig is nearly always present in the larger household contexts, and significantly more so (two-sample t(df) = t-value, p = 0.048) than in small households. This is consistent with the model presented by Gregg, who also places pigs in the largest households (Gregg 1988: 150, Table 40). The presumed greater potential for keeping a variety of animal species in large households is further supported by the fact that dogs are never present in the small households, whereas they are present in the larger households. Horses are so rare however, with no remains of horses found in the house contexts available.

The fact that cattle is so common, even in small households, shows their importance for subsistence. Where in Africa poor/small families usually only possess ovicaprids, often seen as the poor-man's livestock, cattle seems to be the minimal species kept by small households in West Frisia. The importance of cattle to Bronze Age people was outlined by Brusgaard (2014), who postulated their role in daily life, social interaction, and burial practice. Apparently, Bovenkarspel and West Frisia in general were no exception to this "rule".

Hunting

The total absence of large game animals in house ditches of both small and large households is striking. Several remains from large game animals were found in different contexts at Bovenkarspel, however not in house ditches, so they were logically not included in this inter-house comparison. Furthermore, the bias with which the bone material of Bovenkarspel was examined by IJzereef (1981, 24) may also have resulted in a misidentification of large mammal bones as domestic rather than wild animals. Lastly, the inconsistent sieving strategy of smaller animal bones means that fish, birds, and small mammals could not be included in the comparison, limiting the assessment whether and to which extent these hunting practices were practiced by the different households in Bronze Age Bovenkarspel.

Gathering
No significant difference between households was observed with regard to the collection of wild plants (Figure 8.58). This is consistent with the observations made in the selected cultures from the ethnographical work by Murdock (1981) (Appendix A1.4), as well as the ethnobotanical work by Ertuğ (2000; 2004), where plant gathering for consumption occurs independent of the size or wealth of the community. There is also no difference between small and large households in the location from which the plants are gathered, or the average number of plant uses indicated by the content of the ditches (data not shown). Specific uses of wild plants are mostly not significantly different between households. The uses identified for the plants found most frequently in house ditches are fibre, dye, soap, repellent, and bedding, which can all be related to activities which would take place close to or inside the house. However, two uses were significantly different: plants possibly used for their oil are found more in small households (two-sample $t(df) = t\text{-value}$, $p = 0.02$), and plants possibly used for fuel are only found in large households. The reason for this difference remains elusive.

8.5.2 Late Bronze Age

Although most houses in the Middle Bronze Age reflect a large household based on the harvesting practices, the Late Bronze Age house contexts unanimously reflect small households. This would fit very well with the reconstructed landscape in the Late Bronze Age, which would be able to accommodate, and did seem to harbour far fewer people than in the Middle Bronze Age (section 8.2.1).

8.5.3 Middle and Late Bronze Age compared

The results above have given a more detailed insight into the lives of people in Bovenkarspel Het Valkje in the Middle and Late Bronze Age. It can be postulated that Bovenkarspel began as a small settlement with a few small households (cf. Chapter 6, section 6.4.4). Throughout the Bronze Age, households increased in size and number, allowing people to cultivate and breed more different species of domestic plants and animals, although houses stayed largely the same in size and layout. In the Late Bronze Age, when environmental conditions reduced the amount of available land, households, but not houses, started to diminish again in size.

In each time period however, people exploited the resources in their surroundings in a similar fashion, using both domestic and wild plant and animal resources to maintain subsistence. Small and large households show some differences in their domestic animal species and uses of wild plants, although no clear specialisation of practices between households in each group could be observed.

Household size can thus have been related to different practices, but it has become apparent that this is, at least in West Frisia, unrelated to the size of the actual house.

8.5.4 A structure layout does not necessarily immediately reflect (the function of) a house

A further indication for the fact that in West Frisia, the size of the house does not necessarily inform about what occurred on the inside, derives from an analysis of the Bovenkarspel houses based on the work by Grabowski & Linderholm (2014). In their work, Grabowski & Linderholm aim to identify areas of activity within an house, based on a range of different types of analyses. These analyses include loss-on-ignition, which can provide information on enriched soils; magnetic susceptibility, which can inform about the location of hearths; phosphate analysis, providing indications for the presence of a kitchen space, as well as animals and manure; and ratios between cereals and non-cereals, which can signify areas in the house where grains were processed or stored (Grabowski & Linderholm 2014, 331-3). Using these techniques on an Iron Age house, Grabowski & Linderholm were able to identify different areas of activity within a house, and even tentatively distinguish between different functions of neighbouring buildings (Grabowski & Linderholm 2014, 340).

Many of these techniques are not accessible for the present study, although they will be further explored by Grabowski in the near future (Grabowski in prep.). What is currently available however, is information on ratios between cereals and non-

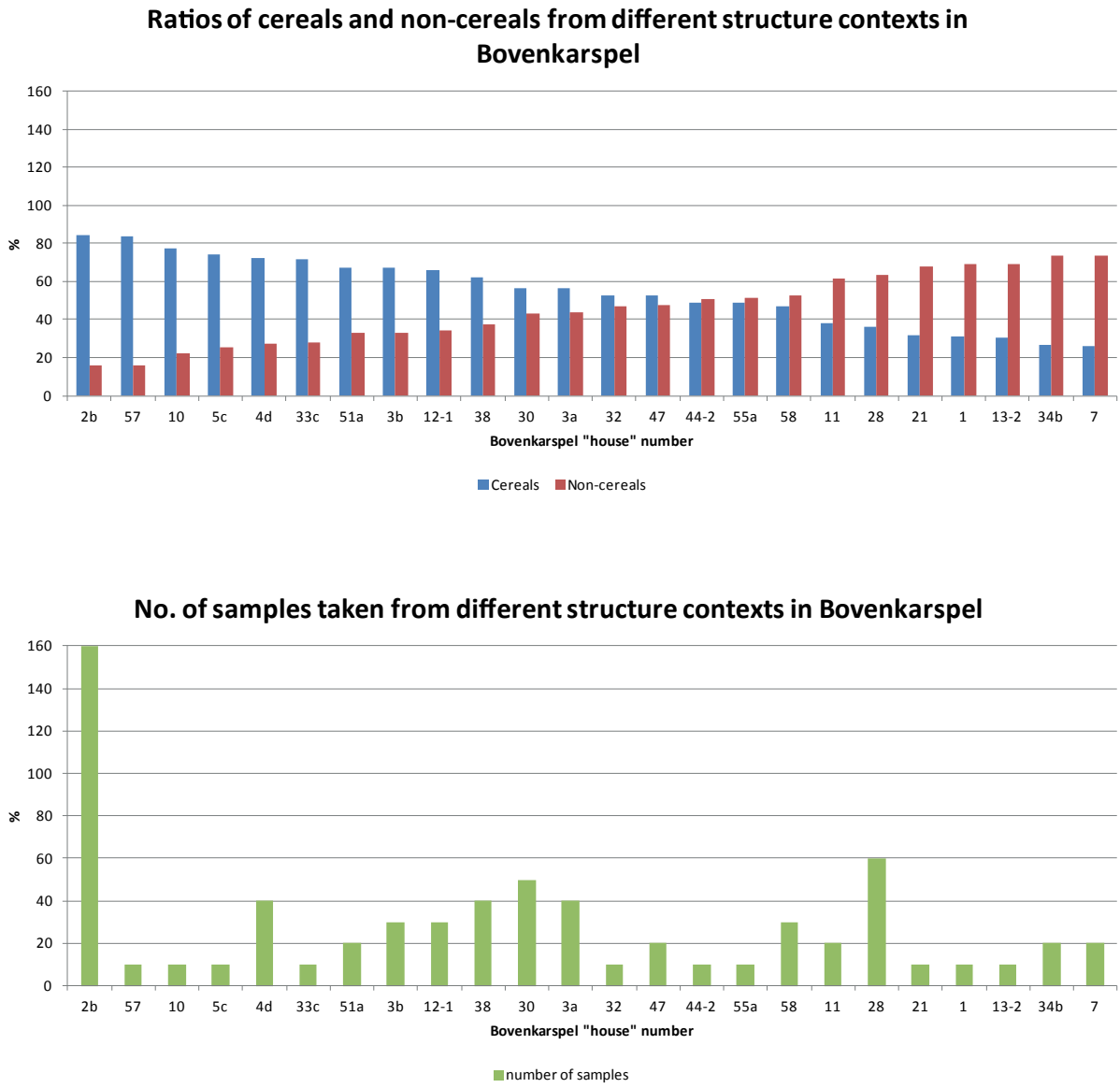


Figure 8.59. Ratios of cereals and non-cereals, and number of samples taken from several structure interpreted as houses based on lay-out from Bovenkarspel Het Valkje.

cereals, the analysis of which is presented here. Of each house from Bovenkarspel analysed in the previous section, the ratios between cereals and non-cereals were calculated according to Grabowski & Linderholm (2014). The results of these calculations can be observed in Figure 8.59. When more than one sample was available, the values of these samples were averaged. Since house contexts were not systematically sampled in Bovenkarspel, it was not possible to distinguish between different activity areas within the house. However, a general differentiation between buildings was observed.

The houses at the left of Figure 8.58 show a high ratio of cereal remains, which, according to Grabowski & Linderholm (2014, 340) should be interpreted as a farmhouse. Conversely, the buildings on the right of the graph show a high ratio of non-cereal remains, which

according to Grabowski & Linderholm may reflect a byre/barn (Grabowski &Linderholm 2014, 340). Still other houses, located in the middle of the graph, show a mixed signal of farm and byre. Interestingly, there is no correlation between the number of samples taken with and the differentiation observed.

The results from Figure 8.59 also did not correlate with any of the differentiations made in the previous section, including length of the house, or size of the household. It is therefore possible that some households, regardless of size, owned a house as well a separate outbuilding, or that communal byres for multiple households existed in Bovenkarspel. In addition, combined houses may have existed, which possessed both a living part and a barn section. These possibilities need to be confirmed however, by the study currently being performed by Grabowski (in prep).

To summarize, it is clear that when features are interpreted as a building, the function of the building cannot be directly deduced based on only the house plan. Not every plan necessarily reflects a house, and not every house need necessarily have contained both a living area and a barn part. Instead, the function of a building should be interpreted based on a combination of types of evidence including the finds from its contexts, not solely its appearance.

8.6 SUMMARY

In this chapter, all aspects related to subsistence (except fire and drinking water) have been researched for West Frisia by combining the results obtained from the previous chapters 2-7.

The impact of humans, livestock, and wild animals on the Middle Bronze Age landscape in eastern West Frisia was assessed. From this analysis, it has become clear that people (with their crops and livestock) impacted their immediate surroundings by requiring on average around 0.3 km^2 per household. Further away from these locations, however, large forests could still develop. Wild animals also impacted the environment, but not to such an extent that the succession towards forests stopped entirely. In addition, the distribution of settlements has enabled pinpointing of certain locations where forests were most likely present during this time. Finally, the number of settlements present in the landscape has reinforced the assumption that farms in West Frisia were small-scale, since larger farms could not have been supported by the available appropriate land for habitation, and crop and animal husbandry.

The diet of Bronze Age farmers in West Frisia was researched based on a multiple of disciplines, including ethnography, archaeology, nutritional studies, and physical anthropology. The resulting image was surprising, at least in comparison with older views on this subject, because Bronze Age people still required wild resources in their diet to remain healthy. A diet consisting of only cereals, meat, and milk (*i.e.* the farmers diet) has been shown to be completely lacking in essential vitamins A and C, which would eventually have led to blindness or death by scurvy, respectively. The role of wild plants (and especially their vegetative parts) in providing these critical micro-nutrients has been greatly underestimated in earlier research, which normally only considers calories as a measure for the completeness of a diet. Analyses performed on the skeletal remains of Bronze Age individuals indicate that the general health level of people was good, evidenced by their stature and ability to heal from ailments, although some periods of minor nutrient-deficiency (*e.g.* winter) will have remained present throughout this time period.

Activities related to acquiring the different types of food, including cereals, meat, milk, wild animals, fish, and wild plants have been projected into year-cycles. These images have enabled the understanding of how domestic and wild resource exploitation was combined: both activities complement each other in different seasons, or possibly even during different times of the day. During busy periods related to crop and animal husbandry, hunting and gathering seem to have been kept to a minimum as far as can be established based on seasonality. During quieter times of the year, such as during winter, these latter activities could be practiced to a larger extent. The year-cycles have indicated that all the activities related to the four subsistence strategies can be integrated without having to compromise on either domestic or wild resources.

Clothing, another important part of subsistence, was investigated for West Frisia based on both the available sources of raw material, indications for its construction, and Bronze Age finds from other areas. Although no textiles have (yet) been uncovered in West Frisia, this overview has provided indications for the possible appearance of clothing here, such as potentially used fabrics/skins, different garment types, and colour usage.

The third subsistence element researched was shelter, in particular the appearance of the inside of a West Frisian Bronze Age house. Rather than accepting an empty reconstruction, a summary of expected basic objects related to Bronze Age subsistence was presented, as well as an overview of the uncovered examples of these objects from West Frisia and other countries. This information was subsequently translated into a "science-based artist impression", which, for the first time, shows what the inside of a West Frisian Bronze Age house may have looked like. The creation of this artist impression has revealed that instead of only focussing on what is found on the excavated site, a more complete image of the past might be obtained by combining and extrapolating objects and knowledge present during the time period at other locations. At the very least, it will provide a new topic of discussion towards one of the aspects most closely related to a prehistoric household.

Finally, all aspects related to subsistence, which were available from one of the West Frisian sites, Bovenkarspel Het Valkje, were combined to investigate how the different subsistence strategies were reflected within a settlement, and between individual households. Results of this analysis have indicated that neither the size of household nor the function of a building could reliably be reconstructed based on the size of the house plan. Conversely, both household size and possible function were elucidated from the composition and frequency of botanical remains. Furthermore, several aspects related to the relative size of the household could be established. Large households possessed significantly more different domestic animal species, of which pigs are significantly more often present than in smaller households, and dogs are even exclusively found here. Gathering practices seem to target similar species and occur at similar locations regardless of household size, which is in concurrence with what is observed in ethnographic studies of small-scale farming communities today.

8.7 CONTRIBUTION OF THE DIFFERENT SUBSISTENCE STRATEGIES IN BRONZE AGE FARMING IN WEST FRISIA

This chapter has provided different types of evidence that all four subsistence strategies were in one way or another required to complete subsistence in the Bronze Age. The combination of domestic and wild resource exploitation ensured that people had access to a near-constant flow of food and raw material sources available in and around the settlement.

From section 8.3.1 in particular, it has become clear that the Bronze Age diet will have consisted of a range of different types of food from all subsistence strategies, in which cereals formed the staple diet throughout the year (around 60%), and where additional food sources may have fluctuated from season to season. The remaining part of the diet will have consisted of, on average, 15% meat, 5% fish, 10% milk, and 10% wild plants (cf. Figure 8.11). In section 8.3.1 the dietary composition was not based on caloric intake, but rather on a healthy and balanced diet consisting of adequate micro-nutrient intake.

Raw material was required for the construction of all the basic needs to survive in the Bronze Age, including acquiring food, making clothing, and building houses and their interiors (sections 8.3). Especially the contribution of wild resource exploitation to the fulfilment of these basic needs should not be underestimated. Most tools and equipment for hunting, gathering, and crop and animal husbandry, as well as daily life require wild plants (including trees) for their construction (section 8.3.3); Bronze Age clothing will still have (partly) consisted of wild animal hides and pelts (section 8.3.2).

The activities related to the different subsistence strategies could be practiced in a such a manner, that none of these strategies were negatively affected

(section 8.4). The relatively flexible nature of hunting and gathering (in terms of targeted species, visited locations, and the time of the day/year at which these activities were practiced), allowed for it's combination with the relatively rigid system of farming. This ability for integration of both types of exploitation could be exemplified by a possible reduction or change in hunting and gathering during busier times of the farming year (*i.e.* during sowing and harvesting), when these activities occurred more passively or at different times of the day, whereas during quieter times of the farming year (*i.e.* winter), more intense (active) hunting could, and did occur (cf. Figures 8.52 and 8.54).

The contribution of hunting, animal and crop husbandry, and wild plant gathering is difficult to assess in detail, since it is clear from the above that each strategy has its own merits, which cannot always be expressed quantitatively. However, considering both the importance of the different subsistence strategies in the diet, as well as their contribution in providing raw material, a tentative adaptation to the graph based on the work by Murdock, and Gregg was made (Fig 8.7; Appendix A1.4 and A1.15), and is presented here (Figure 8.60). This graph is important to show, because it takes into account that food is not the only necessity of life, and simultaneously incorporates the fact that Bronze Age farmers presumably did not have the luxury to buy created objects to aid their subsistence: they needed to create everything from what was available in their surroundings. In this respect, Figure 8.60 should reflect Bronze Age life more closely than the information based on modern-day small-scale farming communities, although more research is required in the future to confirm this view.

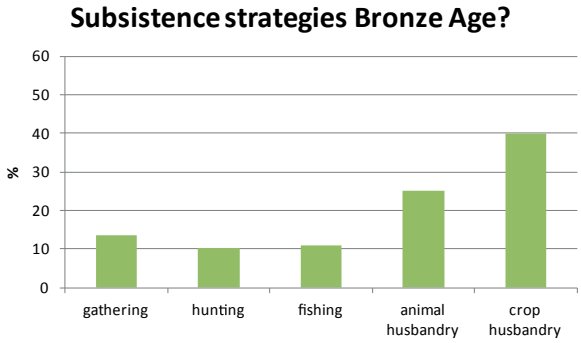


Figure 8.60. Tentative graph of the relative importance of the different subsistence strategies in Bronze Age farming, including their role in providing food, as well as raw material for the construction of products related to the other basic life necessities (clothing and shelter). For calculations and reasoning behind the construction of this graph see Appendix A1.16.

8.8 CAN WEST FRISIA BE CONSIDERED A GOOD CASE STUDY FOR BRONZE AGE COASTAL COMMUNITIES IN NORTH-WESTERN EUROPE?

The conditions of the West Frisian soils have ensured the preservation of extensive amounts of Bronze Age botanical and zoological remains. The resulting large dataset has enabled a holistic reconstruction of subsistence, which is normally not possible because of the absence of either or both types of organic remains. Subsistence practices which have been analysed based on the West Frisian data have allowed for a more detailed understanding of Bronze Age life, and the role of the different subsistence strategies in providing people with adequate food and raw material throughout the year. The inherent characteristics of the area of West Frisia, covering an area from the North Sea in the west to the freshwater lakes in the east, has furthermore provided a wide range of possible habitats and species exploited by man, which has made this area an even more valuable parallel for freshwater and saltwater coastal communities alike.

West Frisia can therefore be regarded as an excellent case study for coastal communities in the Bronze Age, especially for north-western European sites. Due to the fact that this part of Europe experiences largely similar flora and fauna, as well as mostly comparable climatic conditions, the subsistence economy can be compared on a relatively equal basis: observed local differences need not be due to differences in these variables. In addition, time periods are comparable, meaning that (long-distance) connections between regions (such as for exchange), and distribution of (domestic) plants and animals through time can be researched.

9. The Dutch and European context

9.1 INTRODUCTION

West Frisia is deemed a good case study for coastal communities in north-western Europe along the southern North Sea coast, as was hypothesized in Chapter 1, and concluded in Chapter 8. In this chapter, it is assessed whether the elements of Bronze Age farming reconstructed for West Frisia are indeed comparable to those observed in other regions in the Netherlands and Europe.

The Dutch and European regions were all chosen for their close proximity to water of varying salinity, and since West Frisia also borders both freshwater and saltwater environments. For the comparison with these other regions, the same methods are employed as those used for the analyses of the different aspects of the West Frisian subsistence economy (cf. Chapter 4-7).

The main West Frisian sites used are Bovenkarspel, Enkhuizen, Medemblik, Westwoud, Hoogwoud, and Schagen. For crop husbandry and plant gathering, in addition, data from the sites Twisk, Hoogkarspel Watertoren, and Hoogkarspel Tolhuis is employed, whereas for animal husbandry and hunting, data from the sites Andijk, Zwaagdijk-Oost, and Hoogkarspel is added.

It is assumed that the preservation of remains from the different chosen sites is comparable due to their general location on clayey soils. Results based on data from sites where soils deviate from this pattern, are interpreted with caution. Interpretation is done on a general level since sieving practices were different at every site, resulting in the fact that the quantitative differences in remains may not be comparable. If and when sieving experiments become available for these sites in the future (cf. Chapter 5), an even more detailed comparison between regions is possible. Finally, throughout this chapter, sites are mentioned by their primary location of excavation, only followed by a second, specific toponym when confusion with other locations is likely.

9.2 THE RESEARCHED AREAS: THE NETHERLANDS

In the following section 9.3, it is investigated whether Bronze Age farmers from other Dutch areas practiced subsistence in a similar manner as in West Frisia or whether they possessed their own unique practices. For this comparison, several aspects were important to consider. First, because West Frisia is considered a case study for coastal communities (Chapter 1; section 9.1), sites needed to be located in close proximity to water. The term coast usually reflects an environment close to the sea, but in this comparison, coasts of both freshwater and saltwater bodies are considered, since West Frisia is surrounded by both types (Chapter 2). Second, the preservation of remains needed to be similar or at least comparable to the West Frisian situation, which means that mostly sites located on clayey soils were considered. Sites from upland Pleistocene sandy locations were not included, since preservation of bone and waterlogged plant remains at these sites is generally very poor. Conclusions based on differences between sites of these different deposits (sand vs. clay) could not reliably be drawn since taphonomy could have had diverse effects on the archaeological record within these different soil types. More in-depth methodological research is required before such comparisons are made (Chapter 11). Third, enough botanical and zoological remains needed to be present at the sites to be able to discuss the research topics listed in section 8.8. Finally, areas which were connected to West Frisia through waterways were also considered, since water cannot only influence subsistence practices, but can also form a route via which contact between different communities may have taken place over longer distances (Valentijn in prep). In this manner, possible similarities between different areas may be explained.

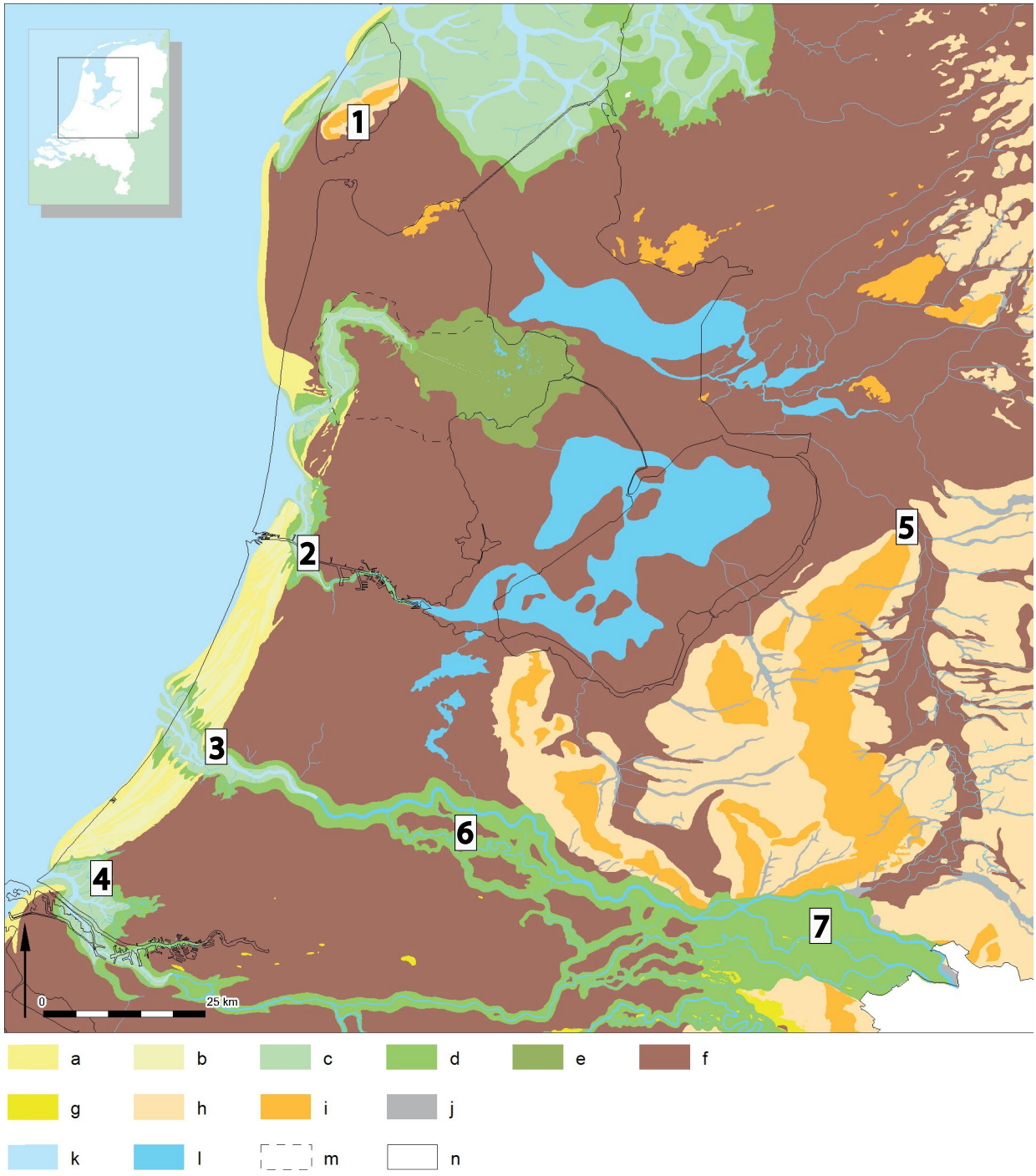


Figure 9.1. Overview of the Dutch regions researched to form a comparison with West Frisia; map according to Van Zijverden forthcoming. a: low dunes; b: beach-plain and dune valleys; c: intertidal areas: sand- and mudflats; d: fluvial flood plain and marine salt marsh areas; e: former mudflats (now freshwater environment); f: peat; g: river dunes; h: Pleistocene sand areas above 0 m –NAP; i: ice pushed moraines and drumlins; j: fluvial areas and brook valleys; k: outer water: mainly brackish and marine areas, North Sea, tidal channels and lagoons; l: inner water: mainly freshwater areas, river channels and lakes; m: outline of the recent Netherlands; n: outline of the recent area of West Frisia; 1: Texel; 2: Kennemerland, 3: Noordwijk, 4: Haaglanden, 5: Hattemerbroek, 6: River area - west, and 7: River area - east.

Table 9.1. Specific information of the sites from each researched Dutch region.

Region	Site and toponym	Date	Remains	Reference
1. Texel	Texel	MBA/LBA	Botanical, zoological	Woltering 2001; van Zeist 96/97
2. Kennemerland	Alkmaar – Canadaplein	BA	Zoological	Clason 1978
	Velsen – Hofgeesterweg	BA	Zoological	Kleijne 2014; Oversteegen unpublished
	Velserbroekpolder – VB-P63	MBA	Zoological	Kleijne 2014; Cavallo unpublished
	Velsen –Calamiteitenboog	MBA	Botanical, zoological	van Heeringen *et al.* 2014
	Heiloo – Vlooiendijk	LBA	Zoological	van Haaster, Dijk and Lange 1997
	Uitgeest – Waldijk I	LBA	Botanical, zoological	Koning *et al.* 2008
3. Noordwijk	Noordwijk – Bronsgeest	EBA	Botanical, zoological	van Heeringen *et al.* 1998
4. Haaglanden	The Hague – Bronovo	MBA (1500-1100)	Botanical, zoological	Bulten & Boonstra 2013
	Voorburg – Leeuwensteijn	MBA	Botanical, zoological	Hagers *et al.* 1992
5. Hattemerbroek	Hattemerbroek	MBA/LBA	Botanical	Hamburg *et al.* 2011
6. River area - west	Zijderveld – A2	MBA	Botanical, zoological	Knippenberg & Jongste 2005
7. River area - east	Meteren – De Bogen (28-1)	EBA/MBA	Botanical, zoological	Meijlink *et al.* 2002, Kranendonk & Bloo 2002
	Eigenblok	MBA	Botanical, zoological	Jongste & van Wijngaarden 2002
	Lienden – Woonwagenkamp	MBA	Botanical, zoological	Schoneveld *et al.* 2002
	Tiel Medel – Bredesteeg	MBA/LBA	Botanical, zoological	van Hoof & Jongste 2005

9.2.1 The sites

Figure 9.1 summarizes the location and names of the regions under review. All sites were, as said, chosen based on their location with regard to water and connection possibilities with West Frisia. Specific information on the different sites – some regions comprise multiple sites – is summarized in Table 9.1. Varying levels of presence and preservation of remains were encountered at the different sites, which resulted in a varying level of detail in the description of general Bronze Age subsistence in the different Dutch regions. In the following section 9.3, each subsistence strategy is discussed in the same order as Chapter 4-7 including data from all researched Dutch regions when enough information for a region is available. When more than one site was present in a region, sites are first discussed separately before drawing conclusions on the entire region. For each subsistence strategy, the results from the different regions are compared with the West Frisian situation.

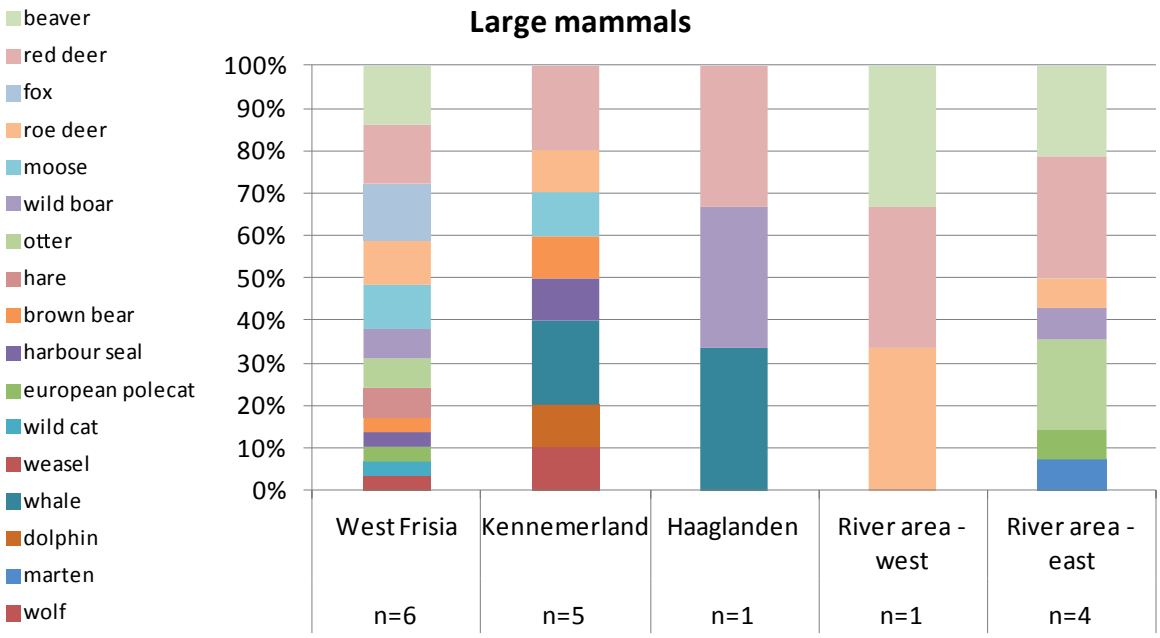


Figure 9.2. Frequencies of large mammals from different Dutch regions in comparison with West Frisia.

9.3 COMPARISON OF DUTCH SITES WITH WEST FRISIA

9.3.1 Hunting

Wild animal composition

Wild animal remains were found in fairly low numbers in most regions, except for Texel and Hattemerbroek (Figures 9.2-9.5). All the remaining sites could be compared with regard to the presence of mammal, bird, and fish species. However, a comparison between sites based on the frequency of occurrence of species was only possible for large mammals due to the different excavation techniques and unknown taphonomical processes present at the sites (*i.e.* lack of sieving experiments performed at these sites). Still, some species (*e.g.* hare, polecat, etc.) may remain under-represented. Similar to West Frisia, all sites are represented by a broad spectrum of fish, bird, and large mammal species (Figures 9.2-9.5), which means that a wide range of hunting skills and knowledge was present in every region. Hunted large mammals which appear in more than one region include, in decreasing order of frequency, red deer, roe deer, beaver, wild boar, brown bear, moose, harbour seal, otter, European polecat, and whale (Figure 9.2, 9.3). Other species (*e.g.* fox, hare, wild cat, and weasel, found in West Frisia) appear to be more restricted to one area, or perhaps represent rare finds (such as dolphin and wolf).

West Frisia stands out because of its wide range of wild animal species. However, this area is relatively large and composed of a wide range of habitat types (cf. Chapter 2) spanning an area of 40 km from the North Sea in the west to the freshwater inland lakes in the east. When this aspect is considered, it becomes clear that different parts of West Frisia might very well be comparable to the other regions. The regions close to the North Sea, such a Kennemerland and Haaglanden, contain similar species to the western sites of West Frisia (*i.e.* Hoogwoud and Schagen), whereas other elements of the West Frisian fauna list are comparable to more inland locations such as the river area.

Bird remains, although not often found, also show similarities between regions. At most sites, similar bird groups to those observed in West Frisia are exploited (Figure 9.4), even though not all species are

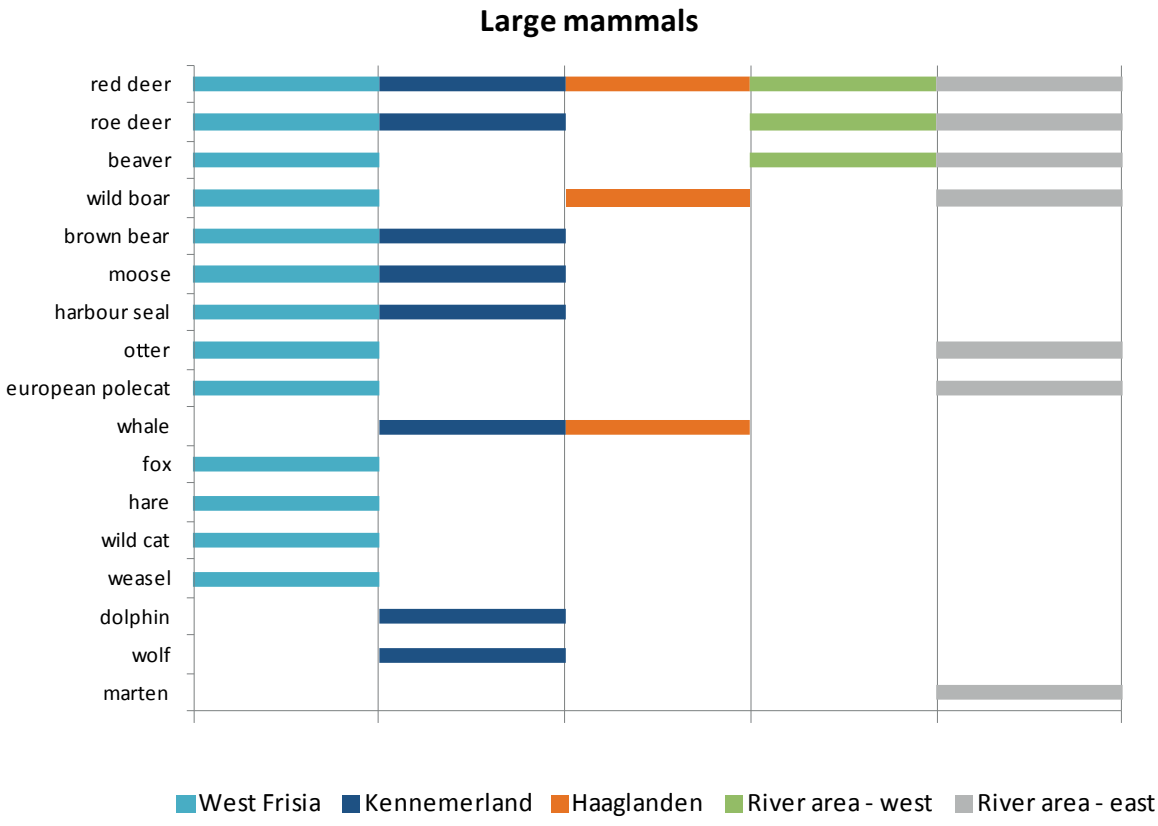


Figure 9.3. Presence/absence of large mammal species in the different Dutch regions in comparison with West Frisia.

necessarily the same; birds from other Dutch regions also include water fowl (such as geese and ducks), corvids (*i.e.* jackdaw), and owls (*i.e.* little owl). Remains from fish are equally scarce as the remains of birds, but also here, some observations can be made. The most frequently uncovered species include the freshwater fish perch, bream, catfish, common rudd, roach, pike, eel, silver bream, tench, and ide. Migratory fish, such as thinlip mullet, salmons, and sturgeon are also prevailing. Saltwater fish finally, include mostly cod, flatfish, flounder, and sea bass. The remaining fish species are almost all exclusively found in the West Frisian area (Figure 9.5).

Fish remains appear at first sight to be most diverse in West Frisia, similar to the discussion of large mammals. However, bearing in mind the size and location of West Frisia, fish remains from Haaglanden and Kennemerland may be considered more comparable to western West Frisia, whereas fish remains from the river area are more similar to the east of West Frisia, reinforcing the idea that the different parts of West Frisia are similar to different Dutch regions.

Hunting locations

Hunting locations were researched in the same manner as for West Frisia, namely by composing pie diagrams of the habitat preferences (Figure 9.6) of the animals found on the settlements in the different regions (see previous paragraph).

Large mammals

Small mammals were not included here, because their presence on a site combined with the limited size of their habitat will not inform about the landscape in its wider sense: a preference for an open habitat could already be fulfilled by the settlement itself.

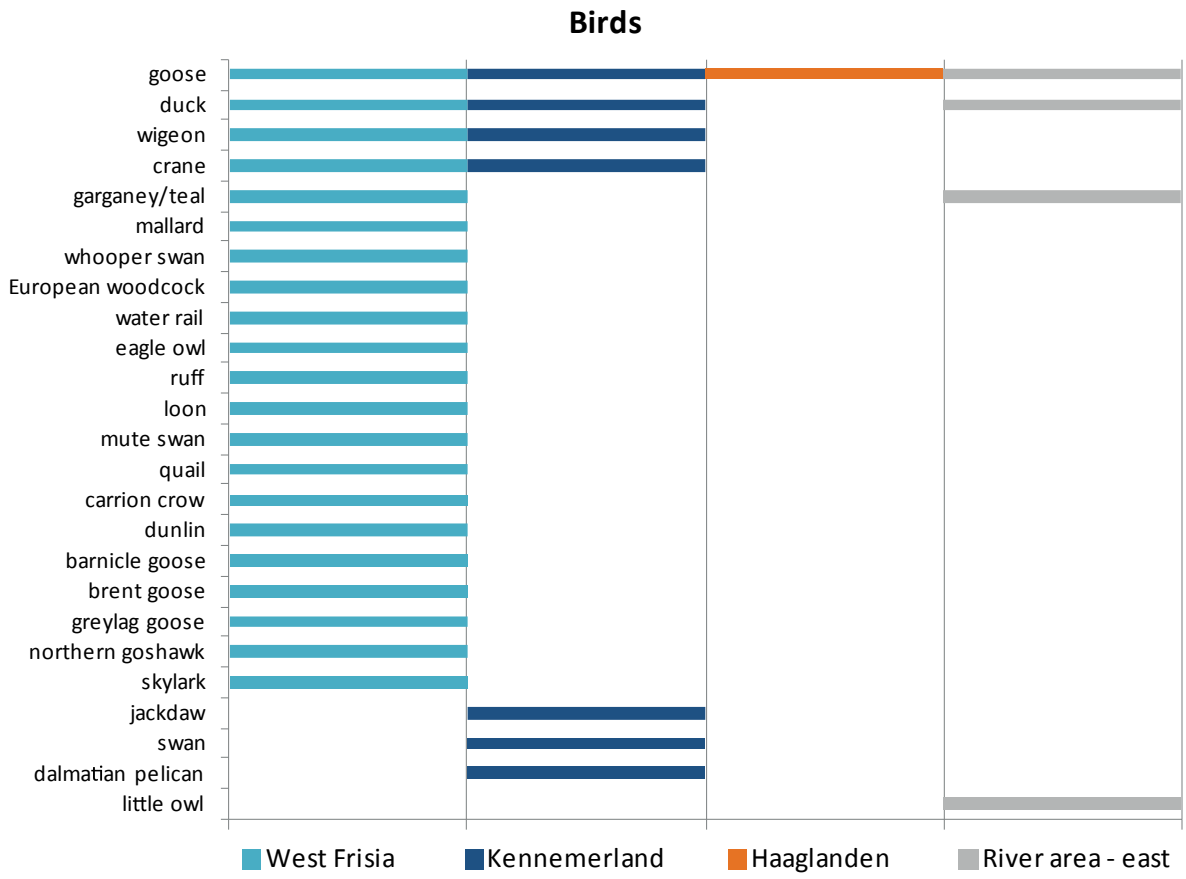


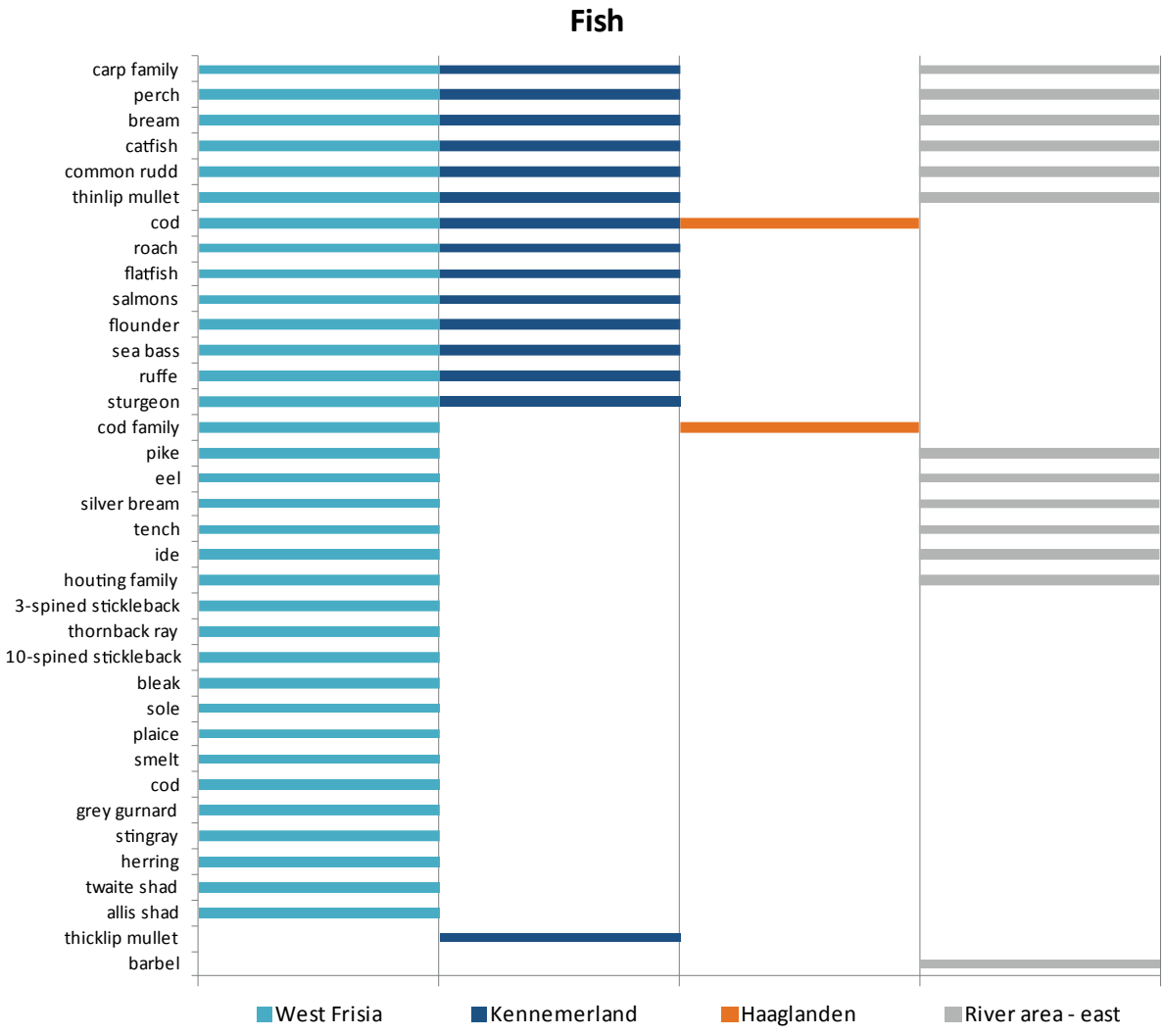
Figure 9.4. Presence/absence of bird species in the different Dutch regions in comparison with West Frisia.

All animals are most likely caught in the near surroundings of the settlement, because all reflect habitat types presumably located near the sites. The Hague Bronovo site, located near the coast, has yielded the remains of a whale, and the area of Velsen Hofgeest/Hofgeesterweg, also located near the coast on the edge of the Oer-IJ estuary, has yielded the remains of a whale, a seal, and a dolphin (Kleijne 2014). The river area did not generate any remains from marine mammals, but beaver and otter were found, reflecting the abundant water present in this area. All regions show the presence of forest in the surroundings, reflected by red deer, but even more so by wild boar. In Kennemerland and the river area, more types of forest dwelling animals were found, such as wolf, moose, marten, and brown bear. Open areas would also have existed in the surroundings of these areas, reflected by roe deer, wild cat, polecat, and fox. Hare, indicative of open fields, was not found, but this does not mean that no open grassland existed. Surely, the presence of humans and their livestock will have ensured a (partially) open landscape in all investigated areas.

Birds

Not all sites yielded bird remains, and if they did, many were not identified to species level. Of the two sites that did contain identifiable bird species, pie diagrams were constructed (Figure 9.7).

Although it was concluded that birds do not add significant information to a landscape reconstruction due to their high (daily) mobility (Chapter 2, section 2.4.2), some information may be drawn from the species represented in the diagrams above. The jackdaw and little owl, found in Kennemerland



Figures 9.5. Presence/absence of bird species in the different Dutch regions in comparison with West Frisia.

and Eigenblok respectively, can both be considered as resident bird species and both provide general indications for grassland (jackdaw: also shrubland). This complements the image obtained for large mammals, where grassland was not among the habitat preferences.

Fish

A general aquatic landscape reconstruction could be performed for most areas (Figure 9.8 and Figure 9.9), since almost every site yielded (enough) fish remains, except for The Hague Bronovo and Zijderveld. In The Hague, which is not represented by a pie diagram, only the remains of cod were uncovered, indicating saline conditions and the open sea. This of course, is no surprise given the location of this site (Figure 9.1). The other sites could be analysed for both the water types and salinity levels present in the surroundings of the settlements.

Almost all areas show a combination of stagnant to slow moving water, open water, fast flowing water, and a connection to the sea, but all in different ratios. Velsen – Hofgeesterweg in addition, shows evidence for the open sea, something which is to be expected so near to the Oer-IJ estuary and the

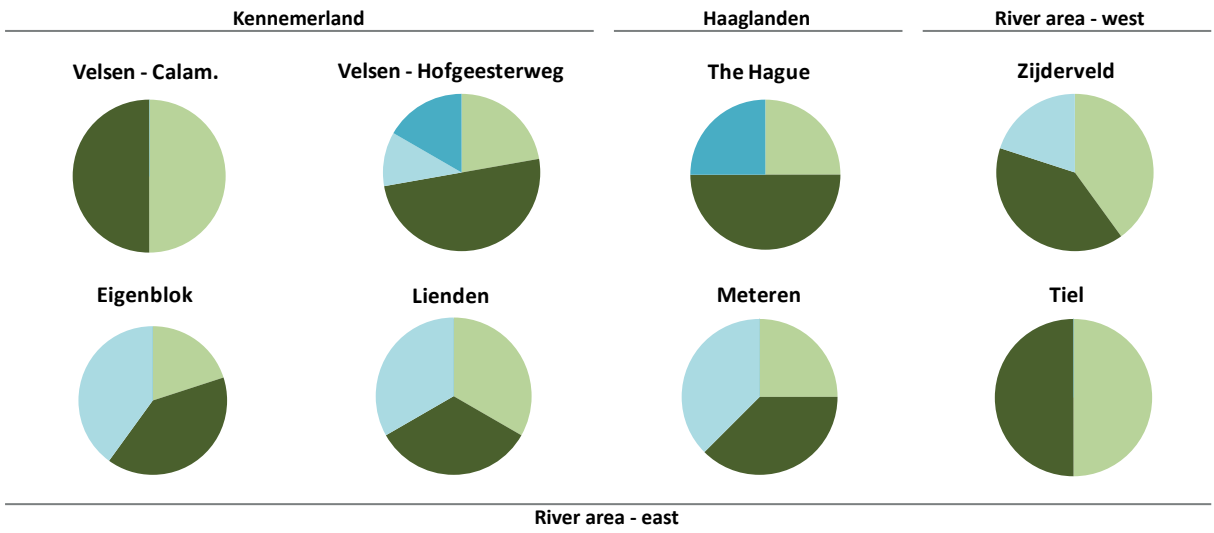


Figure 9.6. Pie diagrams of the habitat preferences of large mammals of the different sites. Velsen – Calam. refers to Velsen – Calamiteitenboog.

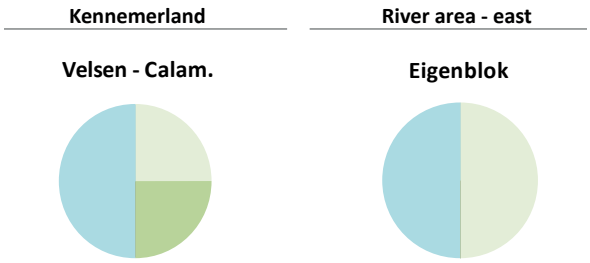


Figure 9.7. Pie diagrams of the habitat preferences of birds of the different sites. Velsen – Calam. refers to Velsen – Calamiteitenboog.

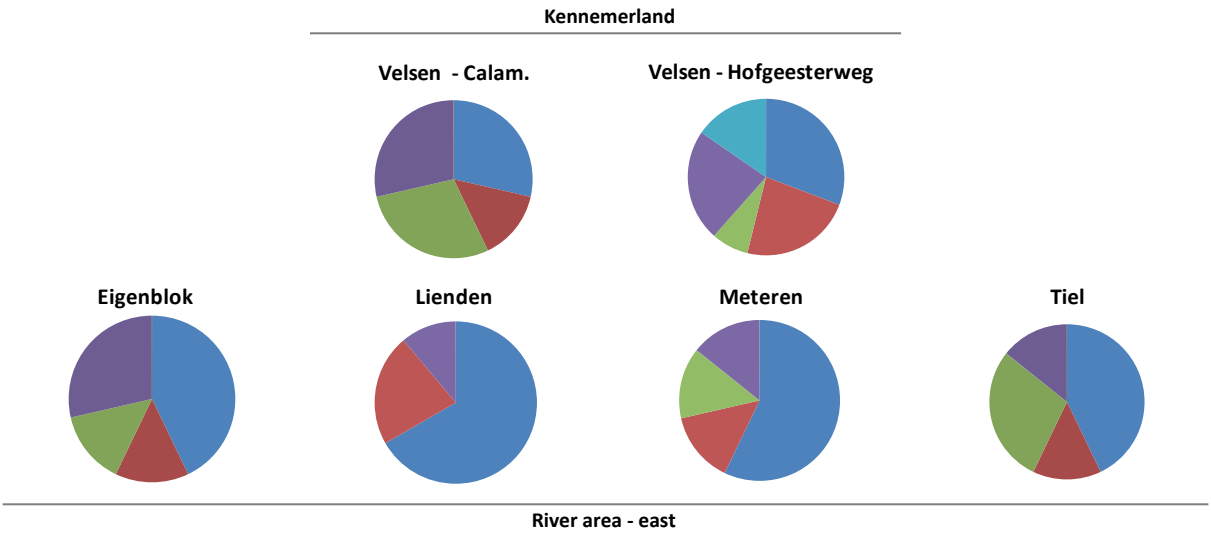


Figure 9.8. Pie diagrams of the water type habitat preferences of fish of the different sites. Velsen – Calam. refers to Velsen – Calamiteitenboog.

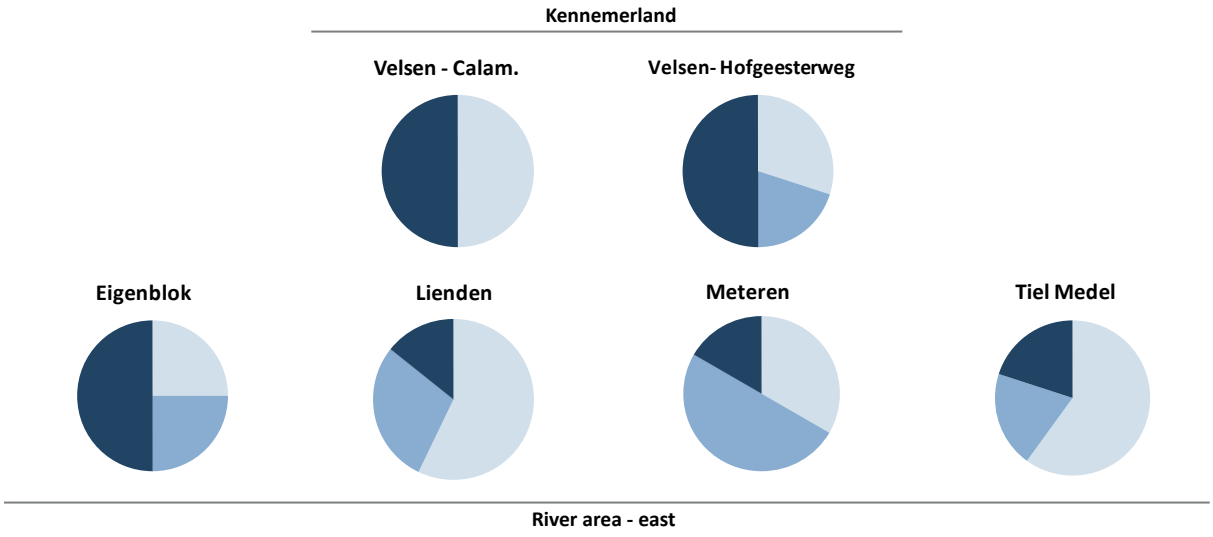


Figure 9.9. Pie diagrams of the maximum salinity tolrances of fish of the different sites. Velsen – Calam. refers to Velsen – Calamiteitenboog.

North Sea. The other site in Kennemerland, Velsen – Calamiteitenboog, does not yield fish which prefer only the open sea, but does show the presence of the migratory fish salmon and thicklip mullet. These fish can both be found in the estuary and upriver during migration. Therefore, the salinity tolerance of fish in the region of Kennemerland is high.

The river area sites show a varying degree of preference for fast flowing (river) water, but it is surprisingly absent in Lienden, which was supposedly situated very close to a river. All sites in this area do however possess fish with a preference for a connection to the sea (*i.e.* migratory fish). The remaining habitat preferences are for stagnant to slow moving waters, open water, and fast-flowing waters. The salinity tolerances of the fish species in the river area become increasingly lower the further away the sites are located from the North Sea coast. This observation increases the likelihood that fish were not (visibly) exchanged between the groups at the river area and ones on the coast or, alternatively, that people travelled to the North Sea to fish: fishing occurred locally. In Tiel – Medel, located east of Eigenblok, even the remains of a barbel were found, a fish which is entirely intolerant of salinity. The only saline tolerances found in the river area are those of migratory fish species.

The fish composition in the investigated areas Kennemerland and the river area is to a certain extent comparable to the situations in West Frisia, similar to what was observed in Figure 9.5. Velsen appears to be comparable to a combination of the images seen of western and eastern part of West Frisia, with both saline and freshwater influences being observed. However, the fish species at this site do seem to reflect the nearby sea less than fish at the West Frisian sites Hoogwoud and Schagen. The river area is very similar to the sites in the east of West Frisia. In West Frisia however, fish species preferring fast flowing water are nearly absent, due to the lack of large rivers in this area.

The combinations of large mammal species on the settlements indicates that man was inhabiting a mosaic landscape with elements of dry, wet, open, and forested areas. The fish species in turn reflect a varied aquatic landscape in the settlement surroundings. This variety of habitats ensures that a large and diverse set of resources is available around the settlements. These settlements all seem to be positioned at prime locations for habitation and exploitation. West Frisia stands out in this respect, because it has both freshwater and saline environments in relatively close proximity, setting it apart from any other area in the western Netherlands, including the river area.

Hunting practices

In almost every region, direct evidence for hunting was encountered. In The Hague Bronovo (Waasdorp 1991, 329; Bulten *et al.* 2013, 95), Noordwijk (Heeringen *et al.* 1998, 34-5), Kennemerland (Kleijne 2014), and Hattemerbroek (Hamburg *et al.* 2011, 368), flint arrowheads were found at the settlements. In Hattemerbroek – where no zoological remains were found due to preservation conditions – the uncovered arrowhead still provided actual evidence of hunting. The arrowhead had been used as part of active hunting gear confirmed by the fact that tar and shafting marks were present on the object. In addition, the remains of dry skin and longitudinal marks may indicate slaughtering animals as a secondary use (Knippenberg *et al.* 2011, 368).

At the researched sites from the river area, such arrowheads were not discovered. In Eigenblok however, a bronze arrowhead was present, as well as an arrow shaft polisher (Gijssel *et al*. 2002: 289, 327), both indicating the use of arrows at this site.

Near Noordwijk finally, in Noordwijkerhout – De Zilk, a wooden bow was found dating to 3500 ±100 BP (2000-1700 cal BC), placing it firmly in the Early Bronze Age (van der Wal 1952; Lanting *et al*. 1999). All these finds are representative of active hunting practices and underline the lasting importance of hunting during the Bronze Age. Passive hunting techniques, such as trapping or netting were not found or identified at any of the settlements. However, as discussed in Chapter 4, it is very rare to uncover such equipment because of the off-site locations where it is normally used, as well as the poor chances at preservation because it is often made of perishable organic material.

Still, a combination of active and passive hunting techniques will have been employed by Bronze Age farmers in order to capture the species observed in Figures 9.3-9.5.

Indications for seasonality and catching techniques
All identified mammal species as well as most bird species could have been present near the sites throughout the year. They are therefore usually not helpful when interpreting seasonality. Nevertheless, some small exceptions do exist. In Lienden, in the river area, two parts of red deer skull were found with a piece of antler still attached. Since red deer shed their antlers in early spring, they must have been caught before that time, most likely in autumn or winter. At Zijderveld, a similar find belonging to a young red deer was encountered, indicating a similar catching time. Besides these large mammals, one bird species found in the Kennemerland region also provided indications for seasonality. Here, the presence of widgeon indicates capture from October to March.

Comparatively, West Frisian wild large mammal species were also most likely caught from late summer to early spring (Chapter 4, section 4.4.3), and bird species were caught throughout the year. At several sites, it was possible to reconstruct fish catching techniques and seasonality based on the original sizes of the fish caught. At The Hague Bronovo site, the remains of a 60-80cm cod were found, indicating that it was probably caught in open sea, since usually only small cod appear close to the shore.

At Velsen – Calamiteitenboog, which is located close to the North Sea coast, the remains of a salmon around 44 cm long were uncovered. Since salmon are migratory, they can be easily caught in large numbers in both an active and passive manner. These fish only appear near the shore in (late) summer when they enter river systems to spawn. Therefore, the salmon from Velsen was most likely caught during that time. In the river area, several size reconstructions were possible. Fish species from Lienden vary in size from 10-50 cm for smaller cyprinids (including silver bream and perch) to 20-120 cm for pike. In addition, a catfish measuring around 125 cm was found here. The larger specimens in particular will have been caught during spawning, since they appear close to the surface and banks of the waterways during that time. For pike and catfish, this occurs from February-May and May-June, respectively. In Meteren – De Bogen, several fish size reconstructions were also possible. Various cyprinids (including ide and common rudd) were small, ranging from 10-50 cm. Several pike however, were reconstructed varying from 40-110 cm in length, indicating capture in spring and early summer.

Besides size reconstructions, migratory fish species, present at all sites in the river area, also provided information on seasonality. Among them are both anadromous and catadromous fish. One of the catadromous species found at Eigenblok, thinlip mullet, would have been caught between March and August. The anadromous species, houting (found in Eigenblok and Tiel – Medel), can only be found in freshwater as an adult when spawning, which occurs from October to December. Therefore, this fish was probably caught around autumn/early winter. The presence of barbel in Tiel – Medel, finally, is only present in lower lying river areas (such as in the Netherlands) from October to March. The remaining species found in the river area are all present year-round.

Use of wild animals

Wild animals, especially fish, would ultimately have been used for consumption. Mammals however, can also provide raw materials in the form of hides or pelts and antlers. In every region, except Hattemerbroek, (red deer) antlers have been uncovered which have been processed into tools (Van Dijk *et al.* 2002: 367, 378-9, 397; Bulten & Boonstra 2013, 135; Kleijne 2014). Since these antlers are not always shed prior to capture (see previous paragraph), it is possible that deer were primarily caught for their antlers (and skin), since these raw materials were unavailable at the settlement, besides the (additional) use of deer meat for consumption.

There was no evidence for skinning on any of the sites, but these marks are subtle on bones and not always included in standard archaeozoological investigations. However, the presence of many fur animals such as wild cat, fox, marten, polecat, and beaver on many of the sites does indicate the potential of these animals to provide the Bronze Age farmer with another source of raw material unavailable at the settlement. Birds finally, could have provided feathers and eggs, but these uses remain invisible in the archaeological record.

To summarize, all the areas researched show that hunting of mammals, birds, and fish would have occurred year-round and must have formed an integral and integrated part of the subsistence economy. This overview has made clear that West Frisia is no exception to this rule, but that it perhaps has more indications for hunting because of the good local preservation conditions.

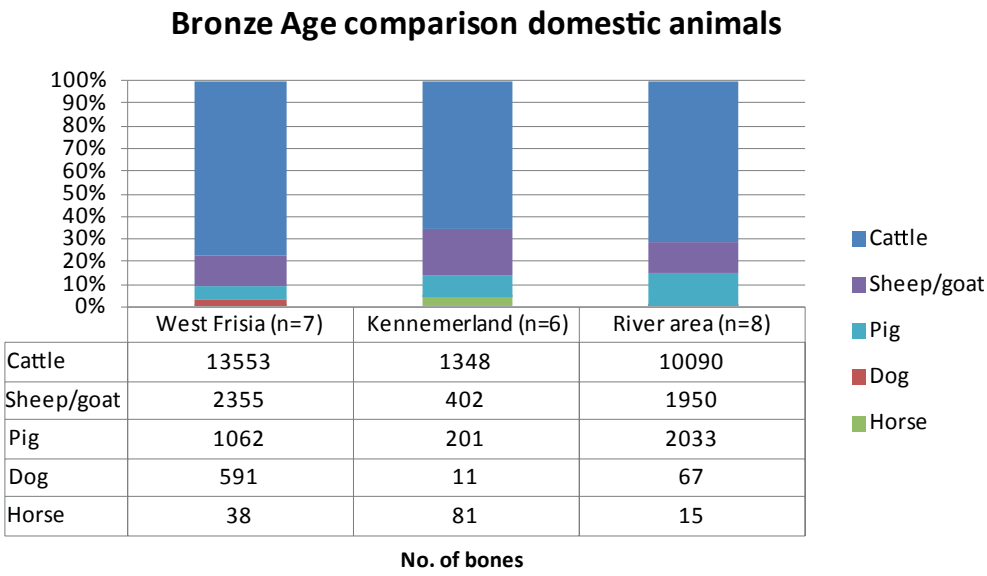
9.3.2 Animal husbandry

Domestic animal composition

The general composition of the remains of domestic animals at all the researched Dutch Bronze Age sites is very comparable (Figure 9.10). Every site has evidence of cattle, sheep/goat, and pig, usually complemented with dog and horse. These species do occur, however, at different ratios throughout the Netherlands and throughout the Bronze Age. In the Middle Bronze Age, the livestock is generally dominated by the remains of cattle, with varying additions of other species (Figure 9.11). In Kennemerland (Velsen) however, sheep/goat bones are relatively much more dominant than at the other sites, which are more strongly dominated by cattle. Dog and horse are found as well, but in very low numbers.

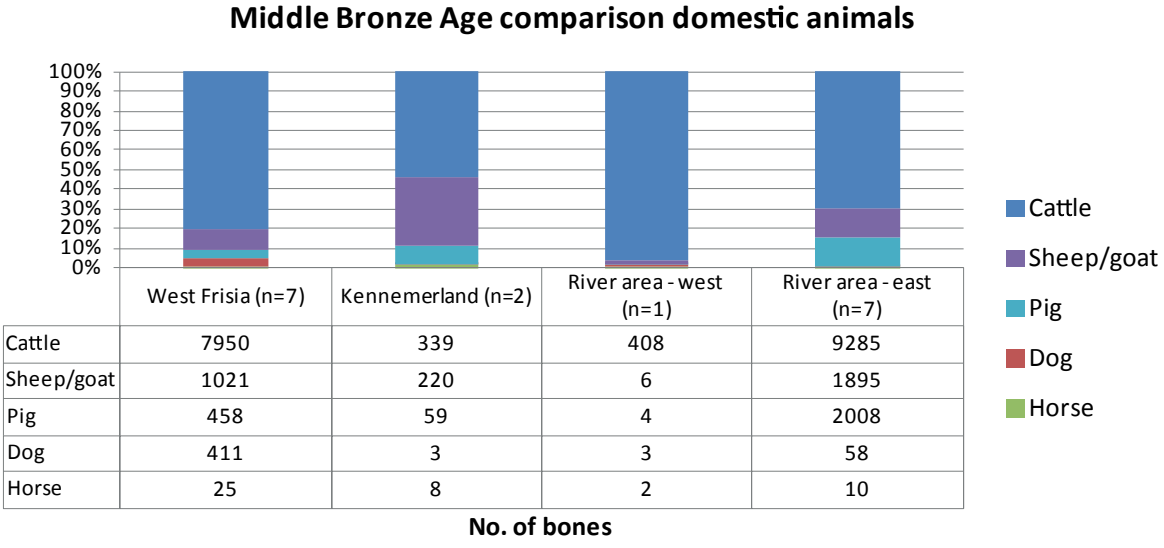
In the western river area (Zijderveld), cattle remains are present in overwhelming majority, with only 15 bones uncovered of the remaining domestic animal species. In the eastern river area, cattle is still the dominant species uncovered, but both sheep/goat and especially pig form a large portion of the livestock remains. Both species are more frequent in the assemblage in comparison with Middle Bronze Age West Frisia. In addition, it is interesting to note that in every Middle Bronze Age area, the remains of a different domestic animal species are more frequently present in the assemblage after cattle.

In the Late Bronze Age, shifts in the composition of uncovered domestic animal remains occur (Figure 9.12). Both remains of sheep/goat and pig seem to become less frequent in the eastern river area (Tiel-Medel) and Kennemerland. In Kennemerland, horse and cattle furthermore seem to become more prominent. In Late Bronze Age West Frisia, remains of sheep/goat actually become more frequent in the assemblage, at the expense of cattle. Overall however, it appears that in the Late Bronze Age, sites become more comparable in their domestic animal



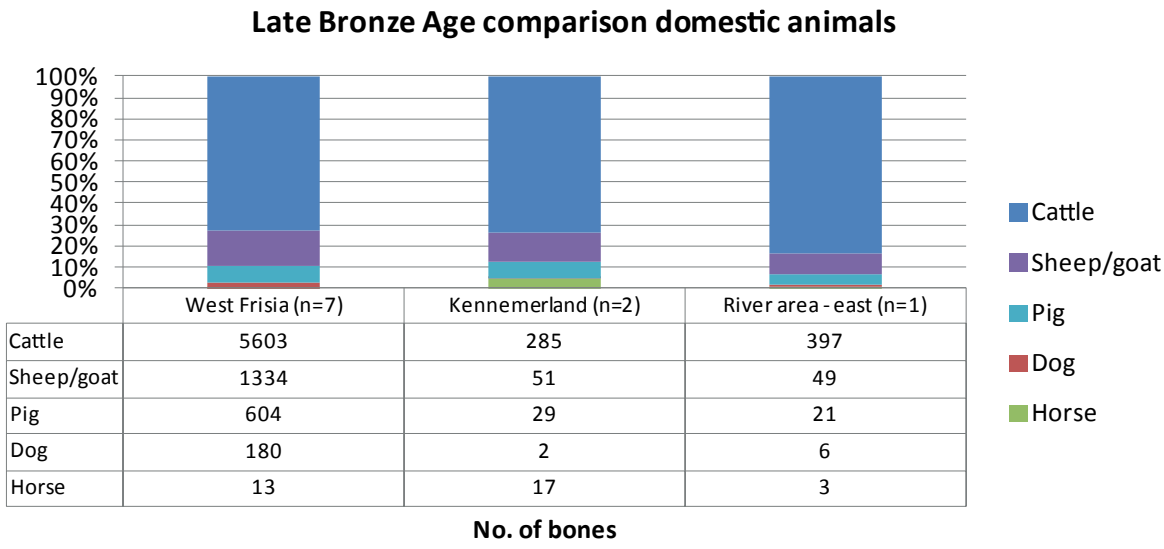
	West Frisia (n=7)	Kennemerland (n=6)	River area (n=8)
Cattle	13553	1348	10090
Sheep/goat	2355	402	1950
Pig	1062	201	2033
Dog	591	11	67
Horse	38	81	15

Figure 9.10. Ratios of domestic animal species in the Bronze Age in the different regions of the Netherlands compared with West Frisia.



	West Frisia (n=7)	Kennemerland (n=2)	River area - west (n=1)	River area - east (n=7)
Cattle	7950	339	408	9285
Sheep/goat	1021	220	6	1895
Pig	458	59	4	2008
Dog	411	3	3	58
Horse	25	8	2	10

Figure 9.11. Ratios of domestic animal species in the Middle Bronze Age in the different regions of the Netherlands compared with West Frisia.



	West Frisia (n=7)	Kennemerland (n=2)	River area - east (n=1)
Cattle	5603	285	397
Sheep/goat	1334	51	49
Pig	604	29	21
Dog	180	2	6
Horse	13	17	3

Figure 9.12. Ratios of domestic animal species in the Late Bronze Age in the different regions of the Netherlands compared with West Frisia.

composition, with cattle remains being dominant, and other species being present only in low numbers.

Animal breeds

In the river area and Kennemerland, both cattle and sheep were horned. The other areas did not yield the required bones to make these kinds of identifications. None of the regions possessed evidence for hornless individuals, which underlines what an interesting and valuable discovery the hornless cattle skull found in Enkhuizen Haling is (Chapter 5; van der Jagt 2014, 59). The absence of horns is a dominant trait, and there are no other indications for polled individuals in West Frisia, although numerous cattle and sheep skulls have been uncovered. West Frisian farmers must therefore either have obtained this individual or one of its progenitors from another area, or a spontaneous mutation must have occurred. Based on the data available, it does not seem that hornless cattle were present in the areas researched, or more examples would have surfaced of this dominant trait. It must be kept in mind though that the absence of remains from areas such as Hattemerbroek hinders further investigation towards the possible origin of polled livestock. However, since it already has been established based on isotopic evidence that West Frisian livestock was imported from the eastern Netherlands (cf. Brusgaard 2014; Chapter 5: sections 5.4.3, 5.4.4), it may very well be possible that polled livestock came from these areas as well. Future research in areas such as Hattemerbroek would be especially interesting to confirm this hypothesis (Chapter 11).

Location of livestock

Hoof prints can provide an indication for the locations on a settlement visited by livestock, but usually only cattle prints are preserved/recognised. No clear stable partitions in house plans were uncovered in any of the researched regions, so the presence of cattle in the houses could not be securely identified. However, hoof prints can provide some insight into the movement of cattle in other areas of the settlement. In Kennemerland, several areas with cattle hoof prints were uncovered. These were mostly centred around large pits, which could be interpreted as watering holes (Kleijne 2014). In the river area, two sites have yielded large amounts of cattle hoof prints: Zijderveld and Eigenblok. The hoof prints at both sites were found scattered over the entire excavated area, but concentrated around watering holes and fences. It appears that at these sites, fences were used as a partition to keep unwanted cattle away from the houses. The location of the prints indicates

that cattle was kept outside, also in close proximity to the houses, although a particular time or season could not be established. Also, the fact that the prints were preserved at all means that conditions of these paddocks where (too) wet at least part of the time. This may mean that cattle was kept outside during less favourable times of the year as well, perhaps due to the necessity of keeping cattle close to guard them from theft or predators, or out of convenience when cattle needed to be handled on a regular basis.

In West Frisia, not many cattle hoof prints were uncovered, and certainly no stake rows to the extent observed in the river area. There may be several reasons for this absence. First of all, the absence of prints and stakes could be explained by the loss of the original Bronze Age surface by deep-ploughing practices, removing all but the deepest features. Another reason could be that most cattle might not have been kept at the wettest parts of the environment or during the wettest time of the year, since higher and drier areas in the surroundings of the settlements were also available (cf. Chapter 8, section 8.4). Finally, stake rows, although sometimes encountered over short distances, might not have been the main means of separating areas. In West Frisia, many deep ditches were dug, which may have fulfilled the same purpose.

Slaughter practices

Livestock remains from three Middle Bronze Age river area sites were suitable for creating a mortality profile with the use of Faustitas (Appendix A1.7). Only cattle remains could be used for this analysis, since sheep/goat and pig remains did not reach the threshold number of 100 remains per species.

For every site it was checked whether a ravaging correction needed to be applied based on the ratio of distal and proximal humeri uncovered at a site, as well as the presence of pig and dog (Appendix A1.7). This was the case for Lienden and Meteren de Bogen; Eigenblok showed no distorted ratio. The resulting mortality profiles for each site, and the river area region at large, are shown in Figure 9.13.

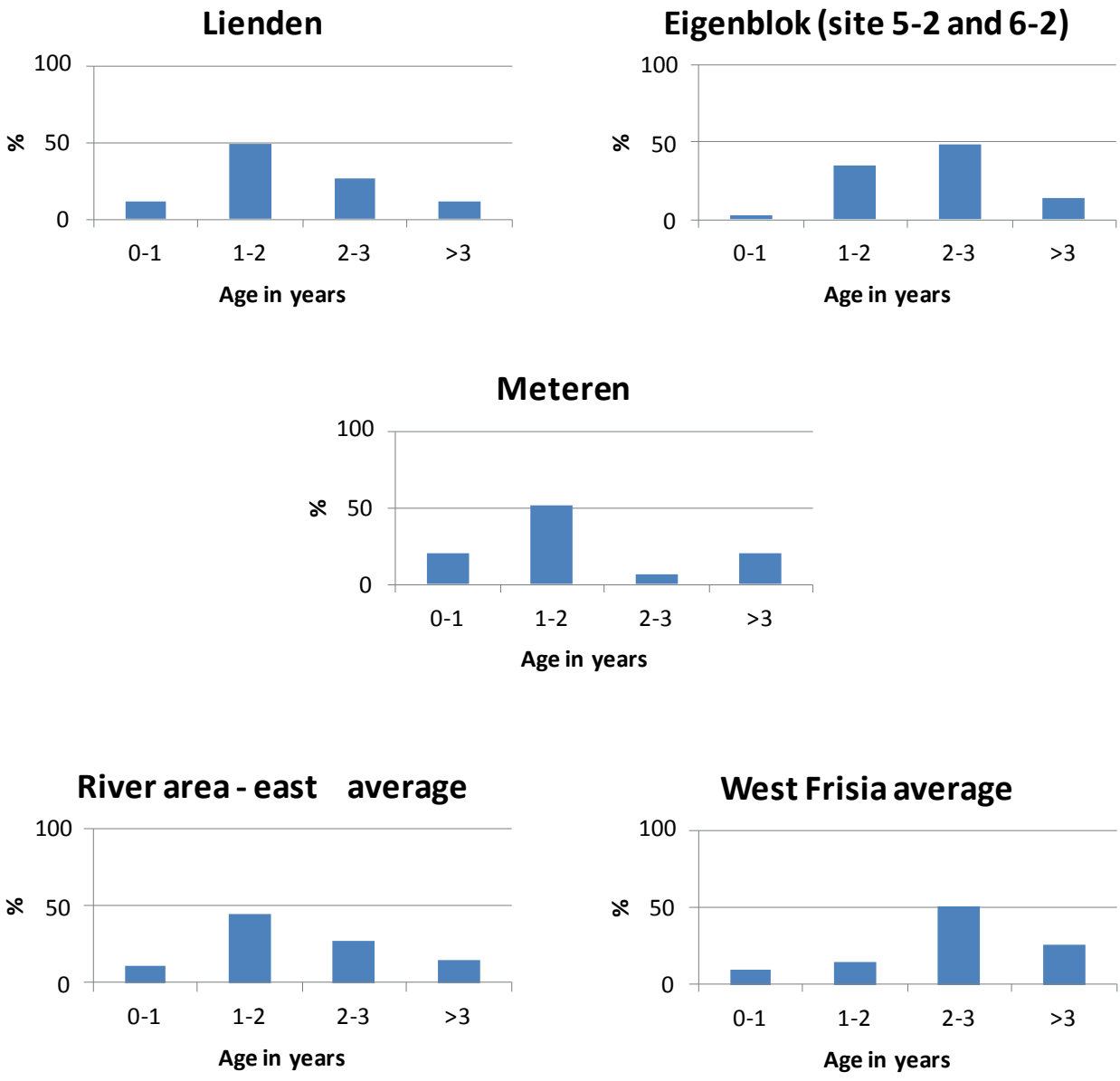
The individual sites show some variation, but cattle was mostly slaughtered between the 1st and 3rd year (Figure 9.13, top). On average, more animals in the river area died before they reached their 2nd year of life (Figure 9.13, lower left corner). In West Frisia on the other hand, cattle seems to have been slaughtered at a slightly higher age, 2-3 years old (Figure 9.13, lower right corner). In this respect, Eigenblok is similar to West Frisia, whereas Lienden and Meteren de Bogen resemble each other more closely.

Use of animals

The use of cattle was explored using the simulation of the programme Faustitas (Appendix A1.7). The resulting graphs including information on both individual sites and the river area at large are shown in Figure 9.14 and Figure 9.15. The growth rate of the herd, birth rate, as well as productivity values for meat and milk are included. The input for the simulation was kept the same as for West Frisia (cf. Chapter 5; Appendix A1.7), and included the assumption that herds must have a growth rate (L) higher than one, because they are self-reproducing units in the Bronze Age subsistence economy.

Similar to the slaughter ages from the previous paragraph, the Middle Bronze Age river area sites show some local variations here also, but overall, growth rate and birth rates between sites are comparable. The potential uses of the herd also show some fluctuations, but the potential for meat production seems consistently higher than for milk production.

When the average values of both the river area and West Frisia are compared, some further observations can be made. First of all, most values from the river area are higher in comparison with West Frisia, except for growth rate. The higher birth rate of cattle in the river area will have allowed for the slaughter of more animals and therefore a higher potential for meat production of the herd. The prevalence of pig remains in the river area during this time in comparison to West Frisia (Figure 9.17) is a further indication that meat production was a focus of animal husbandry in this area. In West Frisia, more mixed uses of herds exist (for both meat and milk production), as well as a generally lower birth rate and an on average higher age at slaughter.



Figures 9.13. Mortality profiles of the sites from the eastern river area in comparison to West Frisia. Lienden, Meteren – De Bogen, and West Frisia average have been corrected using the ravaging correction suggested by Munson (cf. Chapter 5, section 5.4.2). Original data from Lienden: n=251; Eigenblok: n=137; Meteren: n=115; River area – east: n=503; West Frisia: n=1251.

At many sites in the river area, cattle bones also show pathological evidence of other uses often related to traction or ploughing (Buitenhuis 2002; Van Dijk *et al.* 2002, 396; Cavallo & van Groenesteijn 2005, 137): intensive labour can affect certain bones of cattle, including their horn cores, toe bones, and pelvis, which all become modified by rigorous activity. Unfortunately, it was not possible to reconstruct the sex of these animals, but the use of cattle for traction in general in the river area is confirmed. In West Frisia, many cattle also showed pathological indications for heavy labour.

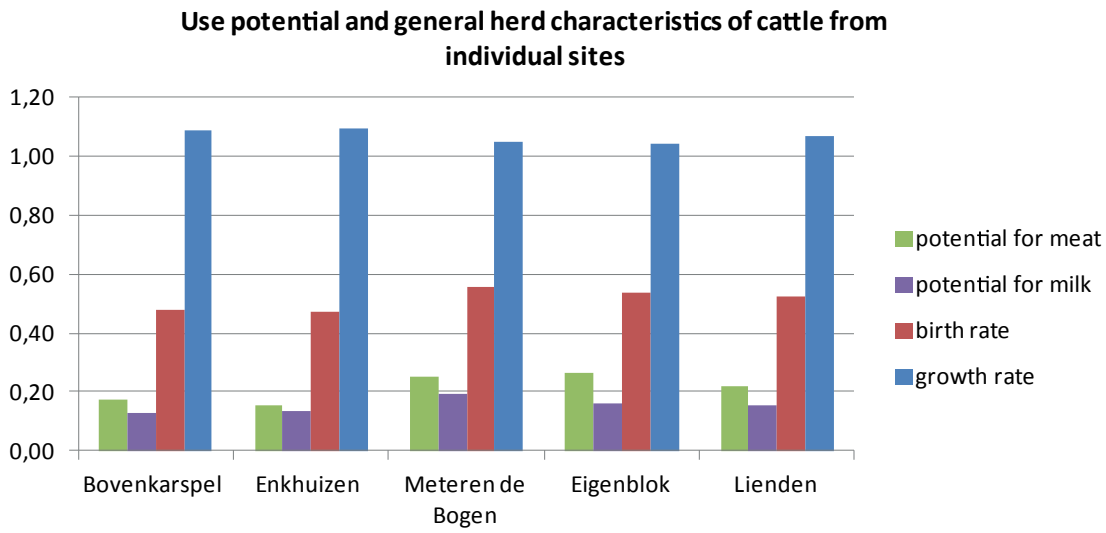


Figure 9.14. Use potential of herds and general herd characteristics of Middle Bronze Age sites from the eastern river area in comparison with West Frisian sites. Use potential is a relative value to evaluate the production potential of a herd for different uses (cf. Cribb 1985). The higher the value, the higher the potential.
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.

9.3.3 Crop husbandry

Crop composition

The crop composition at the different Dutch sites was investigated based on two groups of crops: major and minor crops. Major crops, including barley and wheat species, are assumed to contribute to the diet as major staple foods, whereas minor crops, including millet and linseed, are assumed to only marginally contribute to the diet. First, the major crops are discussed, after which the discussion of the minor crops will follow.

Major crops

The major crops cultivated in the Dutch Bronze Age sites researched are all species of wheat and barley. Wheat species include emmer, bread/durum wheat, and bread wheat; barley species include hulled and naked varieties of barley. An overview of the presence of the various crops in the different regions is provided in Figures 9.16-9.18.

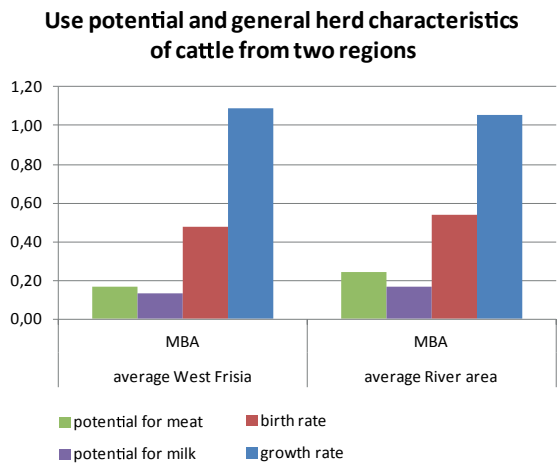


Figure 9.15. Use potential of herds and general herd characteristics of the Middle Bronze Age eastern river area region in comparison with West Frisia. Use potential is a relative value to evaluate the production potential of a herd for different uses (cf. Cribb 1985).

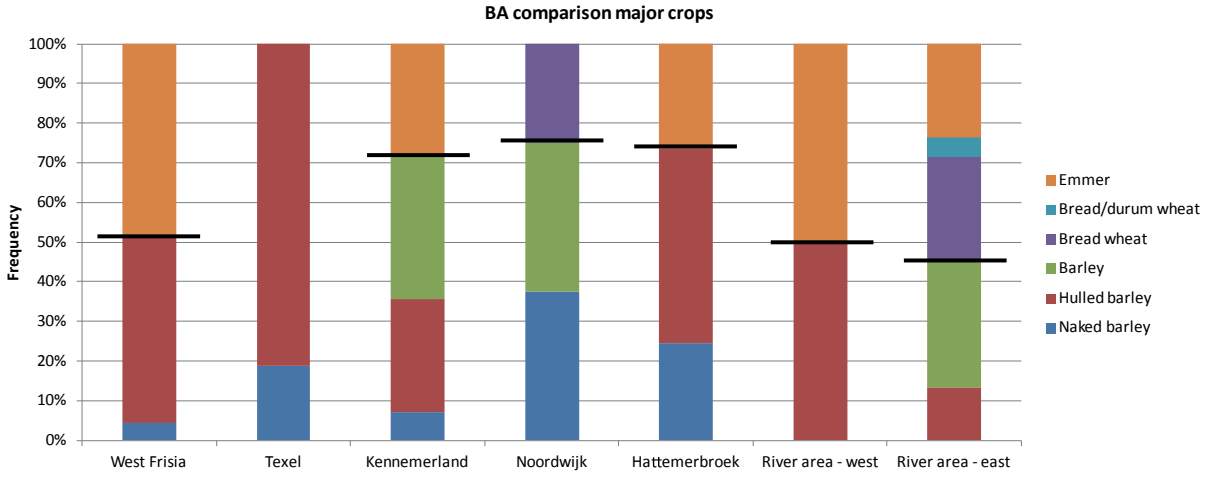


Figure 9.16. Ratios of major crop species in the Bronze Age in the different regions of the Netherlands compared with West Frisia. All information shown except from West Frisia (n=8) and the eastern river area (n=4) derives from one site.

Some variation in the frequencies of these different crops is visible in the researched areas. In Middle Bronze Age Kennemerland and Hattemerbroek, both hulled and naked barley are found, and hulled barley always more frequently than naked barley. In these same areas, emmer wheat is the second major crop, being just as common as hulled barley in Kennemerland, but slightly less so in Hattemerbroek.

Alternatively, in the river area, no naked barley is found in the Middle Bronze Age. Hulled barley is present, but in varying numbers. At Zijderveld (river area – west), few remains of crops were found in general. Only two charred grains of hulled barley, and one uncharred piece of chaff of emmer were uncovered. In the eastern river area, hulled barley is weakly represented, but the high amount of undifferentiated barley (*Hordeum vulgare*) signify the importance of this crop in general, matching that of the wheat varieties. Bread wheat, which is not encountered in any of the other regions in the Middle Bronze Age, seems to be the more dominant wheat species in Eigenblok, situated in the eastern river area. In the Middle Bronze Age, the major crop composition of Kennemerland, located to the south of West Frisia, and Hattemerbroek, located to the east, are comparable to the crop composition observed at the West Frisian sites. Both areas are connected to West Frisia by either coastal dunes or large freshwater lakes during this time (Figure 9.1), which would have made exchange of crops possible. It was already postulated in Chapter 6, section 6.4.8.3 that crops may possibly have originated in the east of the Netherlands, since this area had already been established as a possible origin of several West Frisian domestic animals (section 9.3.2; Chapter 5: section 5.4.3, 5.4.4). Indeed, the crop composition of Hattemerbroek is very similar to West Frisia, so crops may have originally derived from this location. In the Late Bronze Age, some shifts in crop composition can be seen. At Texel, only barley was uncovered, mainly represented by the hulled variety. The eastern river area on the other hand, shows the dominant presence of wheat, which mostly consists of emmer wheat during this time, followed by bread/durum wheat. The latter crop may be a continuation from the Middle Bronze Age bread wheat found in this area. Barley (undifferentiated) only forms a small portion of the uncovered cereal grains.

West Frisia stands out because it has a mix of crops that were individually uncovered in Late Bronze Age; emmer wheat and hulled barley are prevailing, with a small contribution of naked

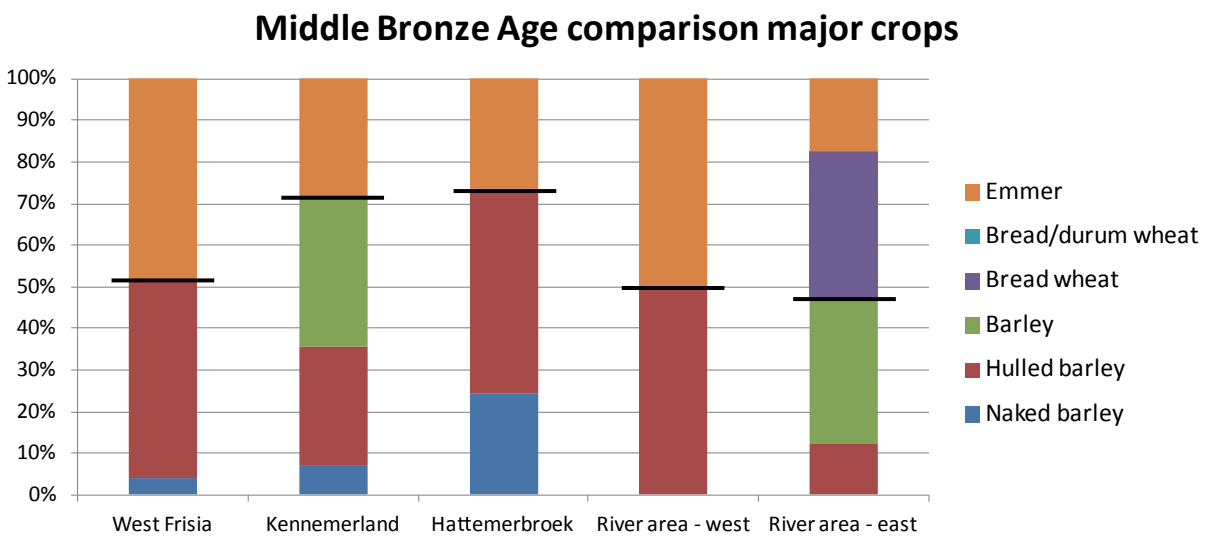


Figure 9.17. Ratios of major crop species in the Middle Bronze Age in the different regions of the Netherlands compared with West Frisia. All information shown except from West Frisia (n=8) and the eastern river area (n=4) derives from one site.

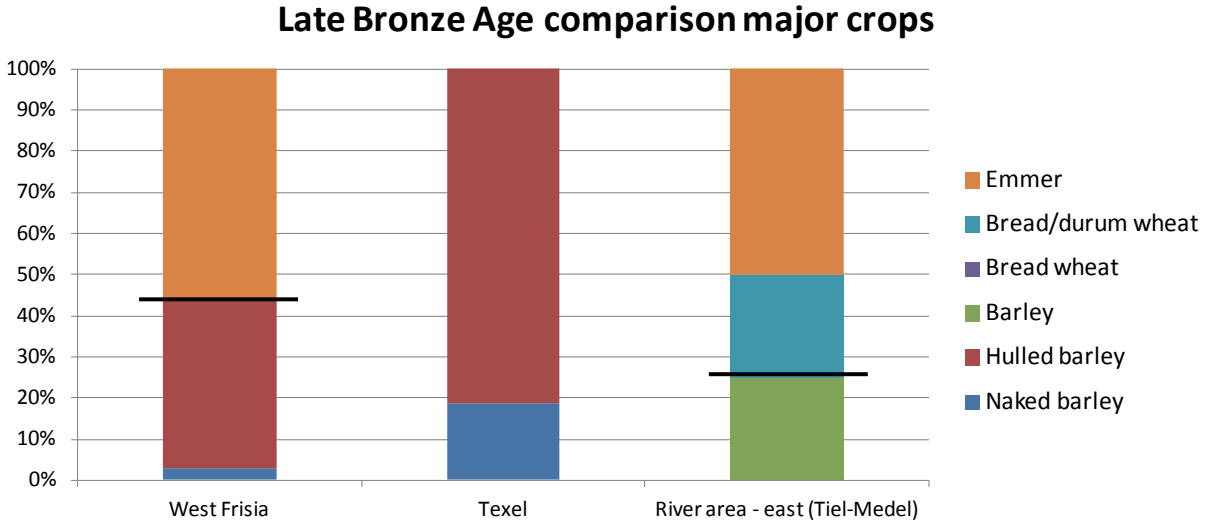


Figure 9.18. Ratios of major crop species in the Late Bronze Age in the different regions of the Netherlands compared with West Frisia. All information shown except from West Frisia (n=5) derives from one site.

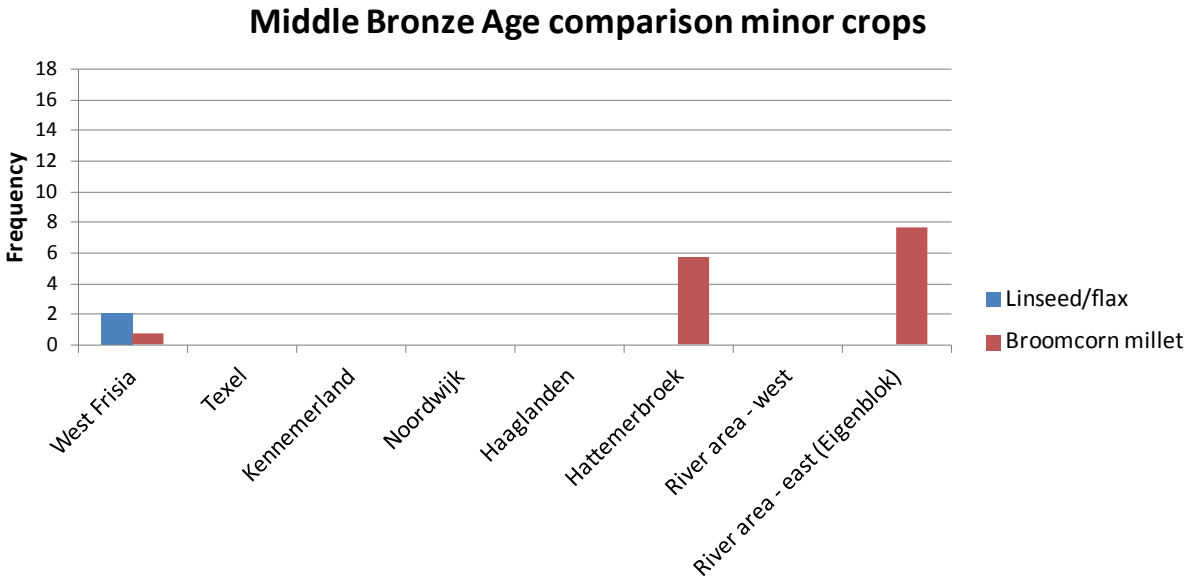


Figure 9.19. Ratios of minor crop species in the Middle Bronze Age in the different regions of the Netherlands compared with West Frisia. All information shown except from West Frisia (n=8) and the eastern river area (n=4) derives from one site.

barley. Bread wheat however, remains completely absent here.

Although only few sites are available for comparison, there appears to be a difference between more northern and southern sites in the Netherlands during the Bronze Age, based on their crop composition. Northern regions (including Texel, Kennemerland, and Hattemerbroek) exhibit a higher frequency of barley species of especially the hulled, but also of the naked variety. The southern sites (*i.e.* the river area) on the other hand, exhibit a more dominant presence of the wheat species emmer and bread/durum wheat, with the former becoming more dominant than the latter in the Late Bronze Age. West Frisia can be regarded as a combination of these northern and southern trends, exhibiting a continuing equal importance of hulled barley and emmer wheat in the Late Bronze Age.

Minor crops

The minor crops discussed here include linseed/flax and broomcorn millet. An overview of the presence of these crops in the different regions is shown in Figures 9.19-9.20.

In both the Middle and Late Bronze Age, only broomcorn millet is identified, and only in some of the researched regions: Hattemerbroek and the eastern river area. At both sites, the frequency of broomcorn millet is higher than in West Frisia, the highest values being observed in the river area. West Frisia additionally yields linseed/flax, although remains are very scarce. In the Late Bronze Age, broomcorn millet is only present in the eastern river area and in West Frisia, and the frequency of this minor crop increases in both areas in comparison to the Middle Bronze Age. Linseed/flax, however, is still only uncovered in West Frisia during this time, which means it is the only site researched yielding this minor crop, which decreases in frequency in the Late Bronze Age.

The presence of linseed/flax in West Frisia may be a unique aspect of this area, but it must be kept in mind that the seeds of this plant preserve particularly poorly, which means that the differences observed may also be the result of taphonomical processes (cf. section 6.4.8.2). Broomcorn millet, however, does seem to be a consistently cultivated crop throughout the Bronze Age, increasing in frequency towards the end of this period.

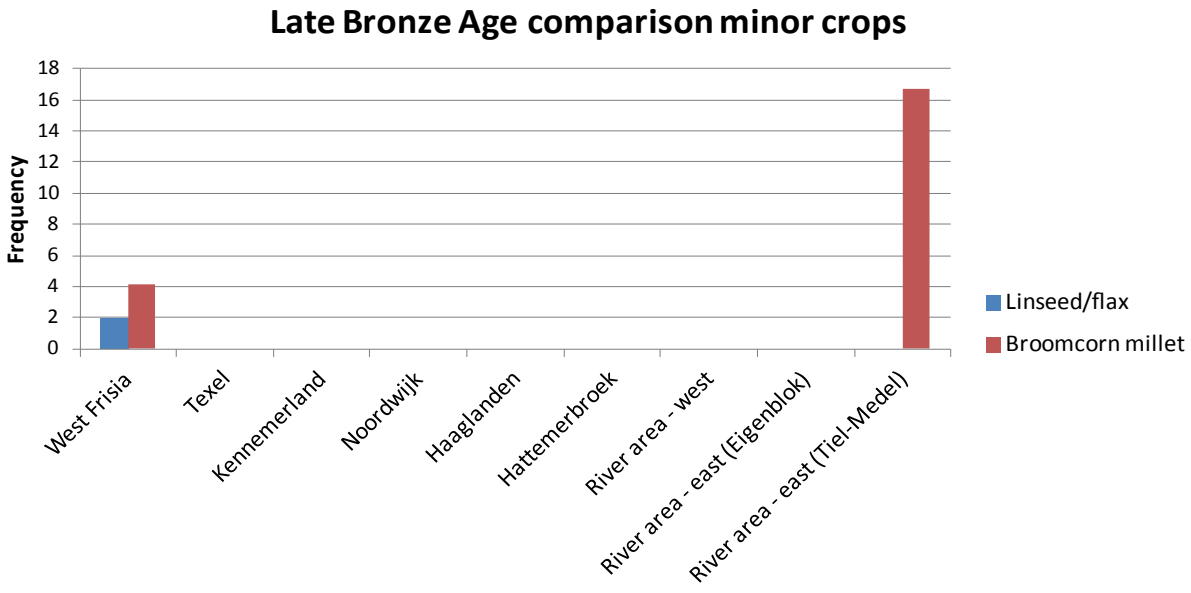


Figure 9.20. Ratios of minor crop species in the Late Bronze Age in the different regions of the Netherlands compared with West Frisia. All information shown except from West Frisia (n=8) and the eastern river area (n=4) derives from one site.

Arable fields

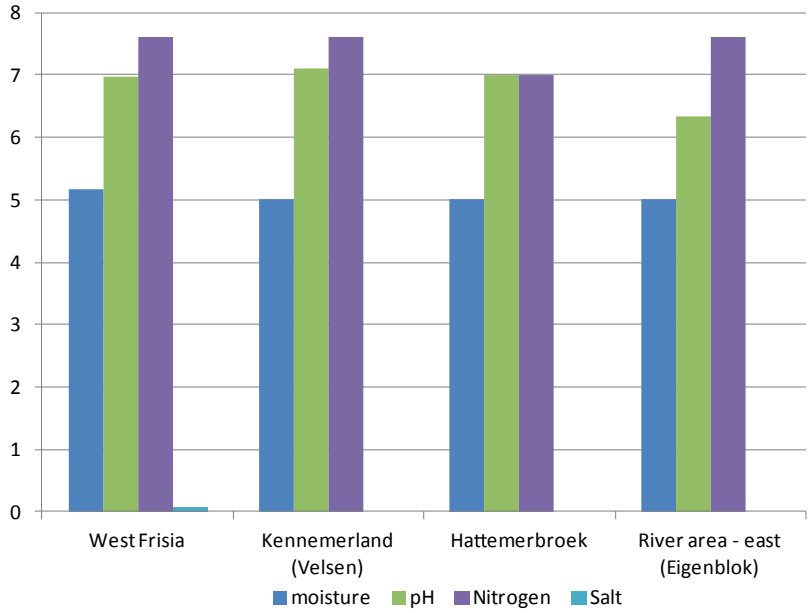
Plough marks are observed at many sites and in most regions. Only in Hattemerbroek, Zijderveld, and three sites in the eastern river area (Lienden, de Bogen, Tiel-Medel), no such marks are uncovered. Overall however, it can be assumed that crop husbandry was practiced locally in all areas. Similar to West Frisia, the arable fields themselves are hard to reconstruct because of discontinuous ard marks and/or excavated areas. Still, it is clear that in most areas the same field was used several times, since ard marks of different criss-crossed orientations appeared at the same location. The only information on the field conditions themselves is obtained through the preferences of crop weed species which occurred charred between crop remains from house contexts (including postholes, hearths, and house ditches). Due to limited number of charred remains from these selected contexts, only four regions are considered for this analysis. The quality of the fields of these different regions is summarized in Figure 9.21.

What becomes clear from Figure 9.21 is that fields in all areas were of excellent quality. They possessed exactly enough moisture, a pH of around 7, and a moderate to high nitrogen content. No indicators for (seasonal) flooding were encountered amongst the crop weeds, and neither were salt indicators. Arable fields from Kennemerland and the eastern river area were most comparable to the West Frisian situation, although West Frisian fields had a marginally higher moisture content.

Crop husbandry practices

Crop husbandry practices which could be researched include ploughing and harvesting. In the eastern river area at Eigenblok, the cattle hoof prints were uncovered at several locations in concurrence with ard marks. Since the arable field growing conditions at this location were not very moist at all, this observation, in combination with the presence of air bubbles in micromorphological slides, provides indications that ploughing occurred under wet conditions, because hooves need to sink into the soil in order to preserve as prints.

The crop weeds mentioned in the previous paragraph were all investigated with regard to their seasonality: either being classified as a summer or winter annual. In addition, their maximum growth was recorded.



Moisture	
5	medium moist
6	medium moist - moist
pH	
6	medium acidic-slightly acidic
7	slightly acidic-slightly alkaline
8	slightly alkaline-alkaline
Nitrogen	
6	medium nitrogen rich-nitrogen rich
7	nitrogen rich
8	nitrogen rich-extremely nitrogen rich
Salt	
0	does not tolerate salt (fresh water)

Figure 9.21. Abiotic growing condition preferences of crop weeds from different Dutch Middle Bronze Age sites in comparison with West Frisia. All information shown except from West Frisia (n=8) derives from one site.

These characteristics were employed to infer the sowing regime of the cultivated crops, as well as the height at which harvesting was performed.
All crop weeds investigated indicated sowing in spring, similar to West Frisia. The average harvesting height could only be established for three areas, because only samples which contained more than one crop weed species were included. In Kennemerland, the most prevailing maximum height of the crop weeds was 40 cm, with a spread of 40-100cm. The eastern river area is characterized by a dominant maximum height of 50 cm, with a spread of 40-60cm (*Fallopia convolvulus* was not included in this range, because it is a binding weed). Both these areas are comparable to West Frisia, which also portrays a maximum crop height of 40-60cm. Crop weeds at Hattemerbroek however, had maximum heights of 70 and 100 cm. At this site, only one sample was available, so more research is required before firm conclusions may be drawn for this region. In general, it appears that in Kennemerland and the eastern river area, harvesting occurred at comparable heights to West Frisia. Possibly, since reaping occurred relatively low, straw may have been valued in these subsistence economies.

Harvest processing

Just two samples satisfied the prerequisites for an analysis of harvest remains, conform Stevens (2003; cf. Chapter 6, section 6.3.4): every other sample contained too few charred remains.

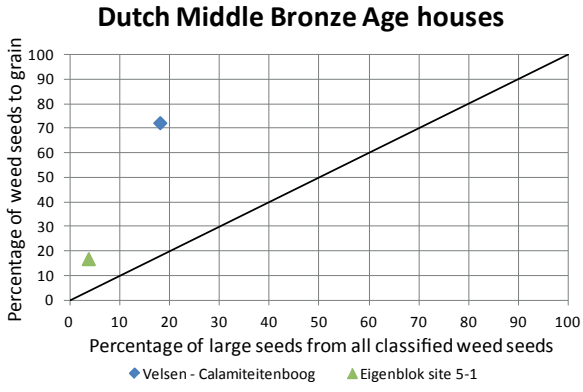


Figure 9.22. Spread of the Middle Bronze Age house data from the Kennemerland region (Velsen – Calamiteitenboog) and the eastern river area (Eigenblok).

The first sample derived from a posthole from a house plan at Velsen (Kennemerland), the second from a posthole from a house plan in Eigenblok. Both samples date to the Middle Bronze Age.

The results of the analysis are shown in Figure 9.22 and both samples fall into the category "household level organization". Although only two samples could be included in the analysis, it does provide indications that in these areas in the Middle Bronze Age, households might not have been large, similar to most sites in West Frisia.

Storage
No clear indications for storage existed in West Frisia. The absence of underground silos, however, indicates that storage may have occurred above ground, most likely inside the house (cf. Chapter 6). In Kennemerland and Haaglanden, also no clear storage structures were identified. In the other researched regions, however, several separate storage structures were uncovered such as at Texel, Hattemerbroek, and the entire river area.

9.3.4 Wild plant gathering

Wild plant composition

Plant species which are accepted as having been collected, such as fruits, nuts, and berries, were all included in the analysis and derived from all contexts and states of preservation. Other wild plant species were only included when deriving from house contexts such as postholes, hearths, and house ditches, to increase the plausibility of their use by people. To elucidate the use of wild plants in the diet in other regions, and investigate the dietary breadth as accurately as possible, both charred and uncharred remains were considered. For this purpose, however, only the eastern river area yielded enough data. The analysis of which parts of edible plants were most likely collected was performed in the same manner as for West Frisia (cf. Chapter 7, section 7.4.2.1).

Wild fruits and nuts
Collected wild plants such as fruits, nuts, and berries, observed in the different regions, are summarized in Figure 9.23 and Figure 9.24, and include, in decreasing frequencies, sloe plum, hazelnut, elderberry, blackberry, rosehips, and berries in general. Other collected plants, such as juniper berry and acorn, were only found in Noordwijk, and the eastern river area, respectively. The range of collected plants in West Frisia is present in a different composition and frequency, which sets it apart from the rest of the Dutch regions researched.

Collected plants in West Frisia include mostly berries, with elderberry being represented best, followed by blackberry and raspberry, the latter of which is only found in this region. In West Frisia, no sloe plum is uncovered, which is striking, and hazelnut is only found in low numbers. Although seemingly different at first, the absence of these fruits and nuts may very well be related to the fact that the appropriate vegetation type for these species has never been able to fully develop due to combined high impact by humans and animals (cf. Chapter 8, section 8.2.3).

The different compositions observed in the different regions seems to reflect that wild plants were collected when available in the near surroundings of the settlement, and that it was a local practice, similar to hunting.

In general, except for the absence of sloe plum, the composition of collected wild plants in West Frisia is most comparable to Kennemerland and Hattemerbroek.

Other wild plants
The yield of wild plant remains from house contexts from the different sites was generally low, although cereal grains from these contexts are usually equally rare. Therefore, only the regions Hattemerbroek, Kennemerland and the eastern river area were considered, since these yielded enough data for further analysis. A total of 46 wild plant species was uncovered in the house contexts of these regions, with 32 species being found in the river area (including Lienden, de Bogen, and Eigenblok), 21 species in Kennemerland (including Velsen Calamiteitenboog), and 12 in Hattemerbroek. Of these species, only the edible species (*i.e.* edibility score higher than 1; cf. Chapter 7, section 7.4.2) were included in this section, to investigate wild plant gathering for consumption.

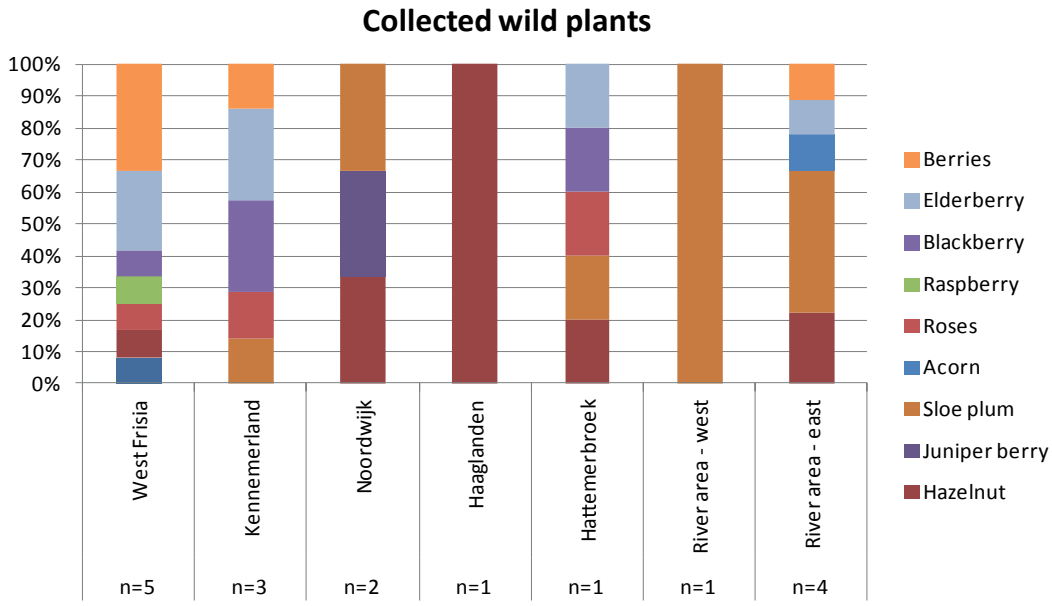


Figure 9.23. Frequency of collected wild plant species in the Bronze Age in the different regions of the Netherlands compared with West Frisia.

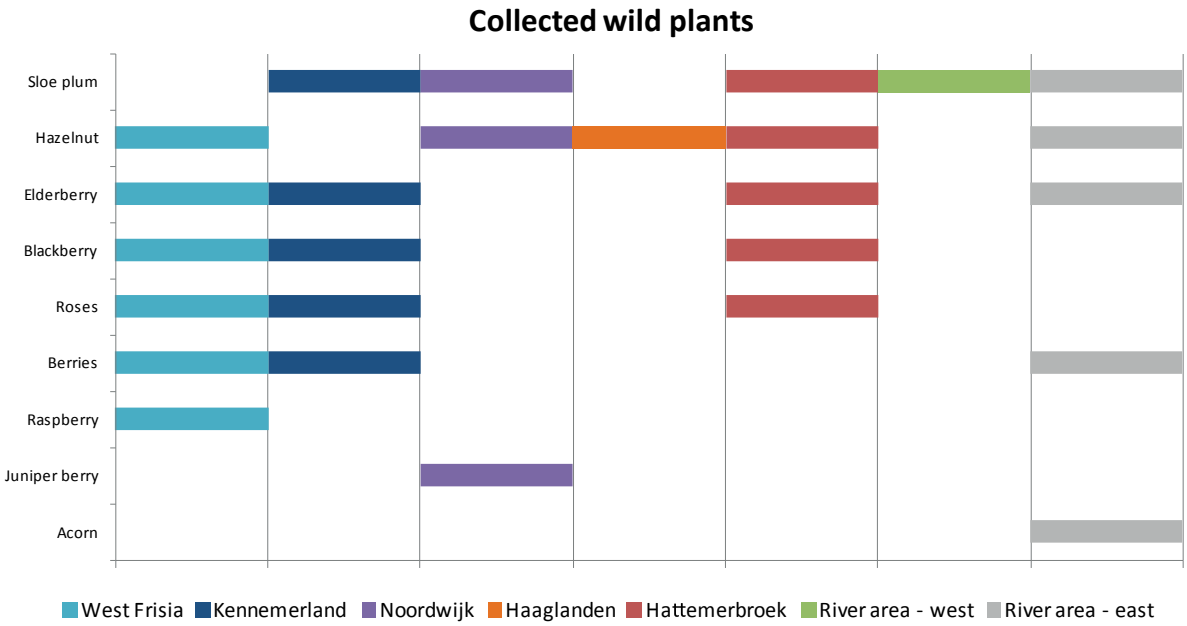


Figure 9.24. Presence/absence of collected wild plant species in the Bronze Age in the different regions of the Netherlands compared with West Frisia.

Other uses of the uncovered wild plants are included below in the section on use of plants.

The edible plants in the researched areas were not all preserved in the same manner. The eastern river area possessed favourable preservation conditions (compare with Chapter 7, Figure 7.4), yielding both charred and uncharred remains. Kennemerland and Hattemerbroek however, only yielded remains in charred form (compare with Chapter 7, Figure 7.5). The latter two regions are therefore limited in the amount of information they can supply about the dietary breadth, and their data can only be analysed to a certain extent. When only charred remains are uncovered, plant species which are very frequent can be relatively safely considered to have been collected for their seed (Table 9.2: category "seed"). However, when a plant species is only present in charred form and in low frequencies, it is impossible to assess whether it has been collected for its seeds or its vegetative parts (Table 9.2: category "unknown"). Low frequencies of charred remains can possibly signify both edible uses without a comparative measure in the form of uncharred remains (cf. Chapter 7, section 7.3.3). The data of the eastern river area, however, can be analysed completely and can then be compared to West Frisia in a more accurate manner (Table 9.2 and Figure 9.25).

What becomes immediately apparent from Table 9.2 is that indeed the regions of Kennemerland and especially Hattemerbroek provide very little concrete information on edible plant use due to the limited indications their charred data can provide. Some plants can however, be assumed to be collected for their seed, such as fat hen/fig-leaved goosefoot (*Chenopodium album/ficifolium*), hastate/spreading orach (*Atriplex hastata/patula*), manyseed goosefoot (*Chenopodium polyspermum*), sheep's sorrel (*Rumex acetosella*), black nightshade (*Solanum nigrum*), and corn spurrey (*Spergula arvensis*), most of which have also been presumed to be collected for consumption based on the West Frisian data. Two species however, chickweed (*Stellaria media*) and seaside bulrush (*Bolboschoenus maritimus*), show either a mixed use or another use than was observed in the data from West Frisia. No plants in the regions Kennemerland and Hattemerbroek could be assigned to being collected for their vegetative parts, but this will be due to the local preservation conditions.

The eastern river area allowed, as mentioned above, for a more detailed comparison with (the Late Bronze Age situation of) West Frisia, because remains were favourably preserved (Figure 9.25). When remains are predominantly preserved in low frequency in uncharred form, the vegetative part of the plant was most likely for consumption; when remains are most frequently preserved in charred condition, the seeds of the plants were most likely consumed (cf. Chapter 7, Table 7.7). From Figure 9.25 it is clear that the six wild plant species on the left were probably collected for the consumption of their seeds, whereas the seven species on the right were collected for their vegetative parts. The latter observation is partly confirmed by the species known from ethnobotany to be only collected for their vegetative parts (green boxes in Figure 9.25). This pattern is largely in concurrence with what is observed in West Frisia (Table 9.2). The only two differences observed are in the species stinging/annual nettle (*Urtica dioica/urens*) and common plantain (*Plantago major*). *Common plantain* was collected for its seed based on the West Frisian data, whereas it is used for its vegetative parts in the river area. Stinging/annual nettle does not match either edible use, since it shows only high frequencies of uncharred remains. If it was used for the consumption of seeds, high frequencies of charred remains would be expected as well, and if it was used for the consumption of its vegetative parts, the amount of seeds is too high. Therefore, a different use is proposed for this plant, which is further discussed in the section on use of plants below. Finally, the mixed use of chickweed observed in West Frisia is further emphasized by the differential use of this plant in both the river area (vegetative parts) and Kennemerland (seeds).

Overall, it appears that many of the same wild plant species were collected in the Bronze Age, and of these species, the same parts were used for consumption: a group of plants gathered for consumption of seeds could be identified, as well as a group for vegetative parts. Although many species are similar in all the regions researched, some variations in use between regions also exist, which may signify local differences

Table 9.2. Edible plant use of species deriving from house contexts from the different Dutch regions.

Region		West Frisia	River area - east	Kennemerland	Hattemerbroek
Preservation state		charred and uncharred	charred and uncharred	only charred	only charred
Taxa	**English name**				
Chenopodium album/ ficifolium	Fat hen/ Fig-leaved goosefoot	seed	seed	seed	seed
Atriplex hastata/patula	Hastate/ Spreading orach	unknown	seed	seed	unknown
Chenopodium polyspermum	Manyseed goosefoot	unknown	seed	seed	-
Echinochloa crus-galli	Barnyard grass	seed	seed	-	-
Rumex acetosella	Sheep's sorrel	seed	seed	-	seed
Solanum nigrum	Black nightshade	seed/fruit	-	seed/fruit	unknown
Vicia hirsuta/ tetrasperma	Hairy/Smooth tare	seed	-	unknown	unknown
Spergula arvensis	Corn spurrey	-	-	-	seed
Mentha aquatica/ arvensis	Water/wild mint	vegetative	vegetative	-	unknown
Capsella bursa-pastoris	Shepherd's purse	vegetative	vegetative	-	-
Lythrum salicaria	Purple loosestrife	vegetative	vegetative	-	-
Schoenoplectus lacustris	Bulrush	vegetative	vegetative	-	-
Aster tripolium	Sea aster	vegetative	-	unknown	-
*Urtica dioica/urens***	Stinging/Annual nettle	vegetative	vegetative/ other use	-	-
*Plantago major**	Common plantain	seed	vegetative	-	-
*Stellaria media**	Chickweed	mixed	vegetative	seed	unknown
Rumex conglomeratus/ crispus/ sanguineus	Sharp/Curly/ Red-veined dock	mixed	seed	unknown	-
Polygonum aviculare	Knotweed	mixed	-	unknown	unknown
*Bolboschoenus maritimus**	Seaside bulrush	vegetative/ other use	-	seed	-
Sinapis arvensis	Charlock	-	-	unknown	-
Althaea officinalis	Marsh mallow	-	-	unknown	-
Apium graveolens	Wild celery	-	-	unknown	-

Green emphasis in left column=edible plant only collected for vegetative parts.
*= different edible use in every region; **=other use besides consumption likely.

in practice. Finally, the better the local preservation conditions are, for preserving both charred and uncharred remains, the broader the range of detected edible species becomes, and especially the range of plants collected for their vegetative parts. West Frisia remains the best site for interpreting these latter plant species, due to its excellent preservation conditions.

Gathering locations

The growing locations of the wild plant species uncovered from house contexts from the different sites provided information on gathering locations. Most wild plant remains derive from a variety of habitats, strengthening the likelihood of conscious

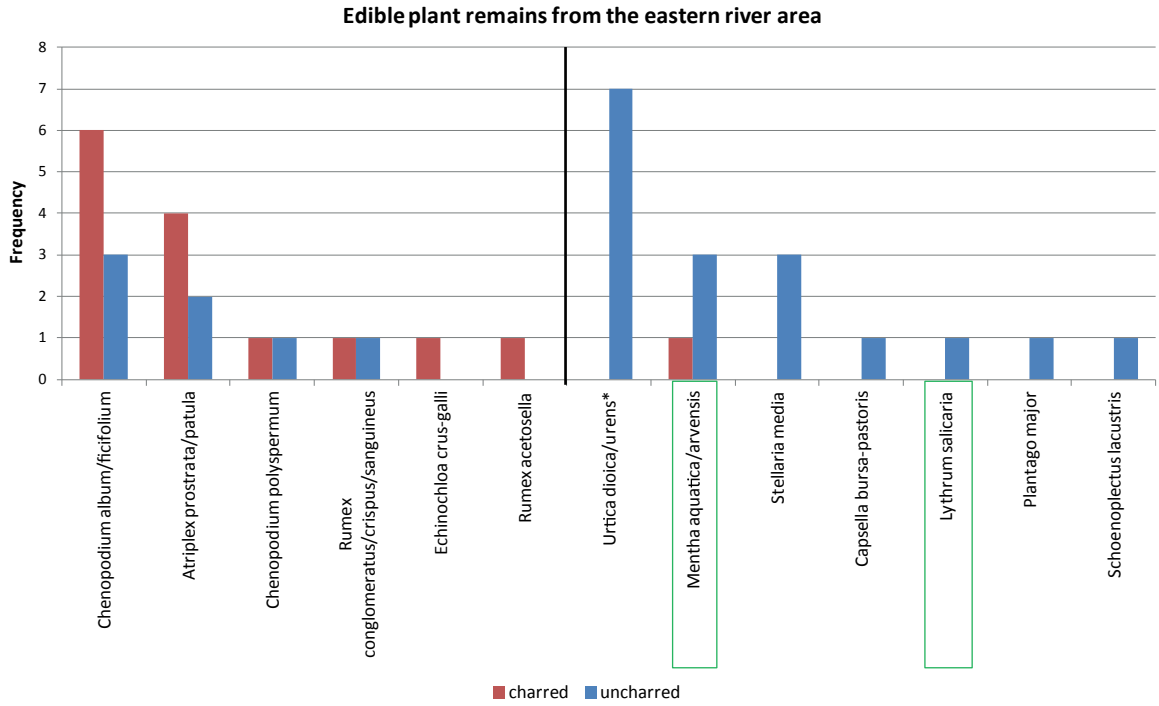


Figure 9.25. Frequencies of charred and uncharred seeds edible plant species from house contexts from the eastern river area. *=does not match with edibility expectations, probably other use; green boxes denote plant species collected for the consumption of their vegetative parts only (PFAF 2016).

gathering practices rather than random accumulation. Gathering locations which could be identified by the species include wet, dry, trodden, untrodden, saline, freshwater, forest, and arable locations. The remains from each site reflect the assumed landscape types present in the direct surroundings of that site, similar to what was observed through investigation of wild animal remains. The assemblage of charred plant remains from house contexts shows that people throughout the Dutch Bronze Age exploited their direct surroundings for the benefit of the subsistence economy.

Gathering practices

Chapter 7 has already shown that reconstructing gathering practices purely based on charred seeds and fruits greatly underestimates the actual extent of gathering throughout the year. All the remains from the sites are seeds, nuts, berries, and fruits, and indicate gathering from at least June to November (the seed-bearing period of most species), but plants will also have been gathered at other times of the year. The entire spring and most of the summer period provide people with vitamin rich vegetative parts, whereas in winter, starch-containing roots and tubers can be collected (see next paragraph) as an addition to diet (Chapter 8, section 8.3.1). Apart from the periods signified by the uncovered seeds, it can be assumed that Bronze Age people from the researched areas gathered throughout the year. Wild plant gathering will have formed a constant and valuable addition to the subsistence year-round, also in other areas of the Netherlands.

Use of plants

Wild plant uses comprise both use as raw material and for nutritive purposes, which is discussed separately below. The information below is based on direct evidence, when raw material itself was uncovered on the sites, as well as on indirect evidence, with the possible uses of the uncovered species provided by ethnographic records (PFAF 2016).

Raw material
In Voorburg (Haaglanden), several wooden remains were found in a well, including an oaken hammer and wattle work, which was possibly the original lining of the well (Hagers *et al.* 1992, 77-9).

The region around Velsen (Kennemerland) has yielded several wooden objects, including an oaken bowl, wattle works made of alder and willow, rope made of juniper, a besom and a basket made of willow, and a fork made of alder wood (Willemsen 1991a and b). Remains from this area also included many wooden objects used for building. In Hattemerbroek, several wooden remains were found, although their function could not be reconstructed (Kooistra 2011, 474-5). In Zijderveld and Eigenblok, wooden remains were uncovered which were part of the construction of houses and storage structures (Brinkkemper *et al.* 2002: 509; Vermeeren 2005, 99-113). Eigenblok furthermore yielded some other examples of wild plants used as raw material; a charred piece of rope was uncovered, as well as the remains of charred wattle work made of alder. The wattle work was found together with charred grain, which led to the assumption that grain may have been stored in baskets (Brinkkemper *et al*. 2002: 508, 529). The other sites in the river area yielded several pieces of wood, but no clear artefacts could be discerned.

Based on the wild plant species, some indirect uses of wild plants could be discerned, which included use for fibre, dye, tannin, soap, oil, repellent, basketry, thatch, and bedding. The frequency with which *Urtica dioica/urens* was found indicated that it was possibly used for consumption and many other functions.

To summarize, several direct uses of wild plants could be identified in the different areas, but most uses seem to be based on wooden remains. Indirect uses based on ethnobotanical examples show a range of possible uses comparable to those observed in West Frisia, although most of these uses could not be confirmed by direct finds. Therefore, more attention must be paid to their possible presence in future research (Chapter 11).

Nevertheless, all of the above examples show the knowledge about and incorporation of wild plants in Bronze Age subsistence throughout the Netherlands.

Diet
Chapter 8 has already made clear that consumption of only fruits, nuts, and berries during the restricted time of autumn is not enough for adequate vitamin intake throughout the year. Even drying fruits and berries for use at a later time is not an option to maintain a good health, since this process decreases the vitamin C levels in fruits dramatically.

Besides the edible plants listed in Table 9.2, of which especially the vegetative plant parts will have added essential micro-nutrients to the Bronze Age diet, it is also interesting to note that at several sites some direct indications for the use of vegetative parts of plants, possibly for food, were also found. Hattemerbroek yielded the most diverse charred vegetative plant matter, including parenchyma (in the posthole of a house), roots, stems, and fruit. However, no species was identified. From this site, it was also possible to perform elaborate botanical and chemical residue analyses on food crusts in pottery (Kubiak-Martens & Oudemans 2011). The botanical residue analysis revealed that tubers or roots were cooked in the pot (Kubiak-Martens & Oudemans 2011, 455-6), reinforcing the proposed idea that the consumption of vegetative plant matter still played a role in the Bronze Age subsistence economy in other regions of the Netherlands besides West Frisia.

At other locations, charred vegetative tissue was also uncovered in postholes of houses, including the stems of large grasses (Noordwijk), and charred parenchyma, charred roots, and charred stems (Eigenblok and Meteren de Bogen). Although the species of these latter finds could not be identified and their use as edible plant could not be confirmed by residue analyses, it is worth being aware of these possible indications of wild plant consumption now that it is known to have happened during this time period. Possibly, (more) appropriate data will become available for analysis in the future.

9.3.5 Summary and discussion

The richness of remains in West Frisia has greatly aided the understanding of Bronze Age subsistence on a detailed level. By using this area as a starting point for comparison, several differences and similarities between the different Dutch regions have surfaced.

Overall, there seems to be a varying dominance of the different domestic animal and crop species available in the Bronze Age. The practices behind it however, appear largely the same. Crop husbandry practices are very comparable, although slaughter practices differ between West Frisia and the river area, with the potential for meat production being higher in the latter. In all regions, there is ample evidence for hunting and gathering, which will have exploited the locally available fauna and flora, and will have continued to aid subsistence throughout the Bronze Age. Similarities between the subsistence strategies of West Frisia and areas such as Kennemerland and Hattemerbroek may furthermore indicate connections with these neighbouring areas, although more research is required to confirm this.

Finally, it has again become clear that researchers should be very aware that low frequencies of wild plant and animal remains do not necessarily signify a lower importance for the subsistence economy, because the purpose of wild resource exploitation will have shifted with regard to previous periods.

The richness of the West Frisian botanical and zoological remains have revealed practices that would not have been easy, or even possible, to recognize or interpret in the other researched areas. This makes West Frisia invaluable for reconstructing Bronze Age subsistence, and concurrently means that extra care should be taken before drawing conclusions based on (more) incomplete datasets.

Table 9.3. Overview of the different Bronze Age periods in the Nordic countries (cf. Thrane 2013, 746) and the Netherlands with their respective dates (cf. Louwe Kooijmans *et al*. 2005, 28).

Nordic Bronze Age		**Dutch Bronze Age**
Nordic Early Bronze Age (NEBA)	**1700-1100 BC**	**Middle Bronze Age (MBA)**
period I	1700-1500 BC	Middle Bronze Age A
period II	1500-1300 BC	Middle Bronze Age B
period III	1300-1100 BC	Middle Bronze Age B
Nordic Late Bronze Age (NLBA)	**1100-500 BC**	**Late Bronze Age/Early Iron Age (LBA/EIA)**
period IV	1100-900 BC	Late Bronze Age
period V	900-700 BC	Late Bronze Age – Early Iron Age
period VI	700-500 BC	Early Iron Age

Table 9.4. Specific information of the sites from each researched European region.

Region	Site and toponym	Date	Remains	Reference
8. Denmark	Bjerre	NEBA (1500-1100)	Zoological	Nyegaard 1996
	Thy	NEBA (1700-1100)	Botanical	Kelertas 1997
	Lindebjerg	NEBA (1700-1500)	Botanical	Rowley-Conwy 1978
	Voldtofte/Kirkebjerg	NLBA (900-500)	Botanical, zoological	Rowley-Conwy 1983; Nyegaard 1996
9. Sweden	Ystad – Köpinge area	NEBA-NLBA (1500-500)	Botanical, zoological	Berglund 1991 and references therein
	Ystad – Bjäresjö area	NLBA (1100-500)	Botanical, zoological	Berglund 1991 and references therein
	Ängdala	NLBA (900-700)	Zoological	Nyegaard 1996
10. Switzerland	Hauterive-Champréveyres	LBA (1050-880)	Botanical, zoological	Jacquat 1989; Borrello and Chaix 1983
	Cortaillod – Est	LBA (1010-965)	Zoological	Borrello *et al.* 1986

9.4 THE RESEARCHED AREAS: EUROPE

Three European areas[13] are chosen for comparison with the Dutch Bronze Age, and West Frisia in particular, which are based on the same selections mentioned for the Dutch sites in section 9.2.

These areas; include Denmark, southern Sweden, and Switzerland, all of which possess sites which are located close to a saltwater or freshwater coast, similar to the selected Dutch sites. Danish and southern Swedish sites are all located in relatively close proximity to the (North and Baltic) sea, and are chosen for comparison with West Frisia and the Netherlands to investigate whether any similarities can be observed between the areas in terms of practices and available resources. Several indications already exist in West Frisia for possible contacts with these areas based on the presence of flint sickles from Helgoland (an island between Denmark and Germany) and bronze fibulae finds which resemble finds and decoration types from Denmark and southern Sweden.

Switzerland, with its lakeside settlements, on the other hand, is chosen as a contrasting area, as it is expected that at least the available resources will differ from West Frisia and the Netherlands. The practices at these Swiss sites, however, may be comparable to a certain extent with eastern West Frisia, because they are also located close to relatively large freshwater lakes, although in a different climate and geography.

13. Other coastal regions, which include the fenlands in East Anglia, Great Britain, and northern Germany, were not investigated, although they were promising areas for comparison with West Frisia. The reason for the exclusion of these areas in this study is that both these areas are currently being researched or have been researched in other PhD projects (Floor Huisman, Durham University: https://www.dur.ac.uk/archaeology/staff/?mode=staff&id=13238; Henrike Effenberger; "Pflanzennutzung und Ausbreitungswege von Innovationen im Pflanzenbau der Nordeuropäischen Bronzezeit und angrenzender Regionen"; Die Akademie der Wissenschaften und der Literatur, Mainz: http://www.adwmainz.de/mitarbeiter/profil/henrike-effenberger.html). Therefore, for more information on these areas, the interested reader is kindly referred to the (forthcoming) results of these (ongoing) projects.

Figure 9.26. Locations of the researched sites in Denmark and southern Sweden (region 8 and 9). a: location of an excavated site; 1: Thy; 2: Bjerre; 3: Lindebjerg; 4: Voldtofte/Kirkebjerg; 5: Ystad – Köpinge; 6: Ystad – Bjäresjö.

9.4.1 The sites

Before the sites are introduced, it must first be clarified that the Bronze Age in Nordic countries occurs at a later time than the Bronze Age in the Netherlands. The Nordic Bronze Age is subdivided in the Nordic Early Bronze Age (NEBA) and the Nordic Late Bronze Age (NLBA), and each of these is further sub-divided into three periods (Thrane 2013, 746), which are listed in Table 9.3. This skewed periodisation between the Netherlands and the Nordic countries, implies that the Dutch Middle Bronze Age occurs simultaneous with the Nordic Early Bronze Age, and the Dutch Late Bronze Age with roughly the first two periods of the Nordic Late Bronze Age. As the NLBA lasts well into the Dutch Early Iron Age (EIA), some developments which are present in the NLBA might have to be compared to the EIA in order to form a fair comparison. Possible differences in timing of technological advances or spread of resources in both areas might therefore be related to time period, and this aspect will be taken into consideration during comparison.
Specific information on the (location of) the different regions and their sites is summarized in Figures 9.26-9.27 and Table 9.4.

Individual sites were again selected based on the presence of botanical and/or zoological remains and

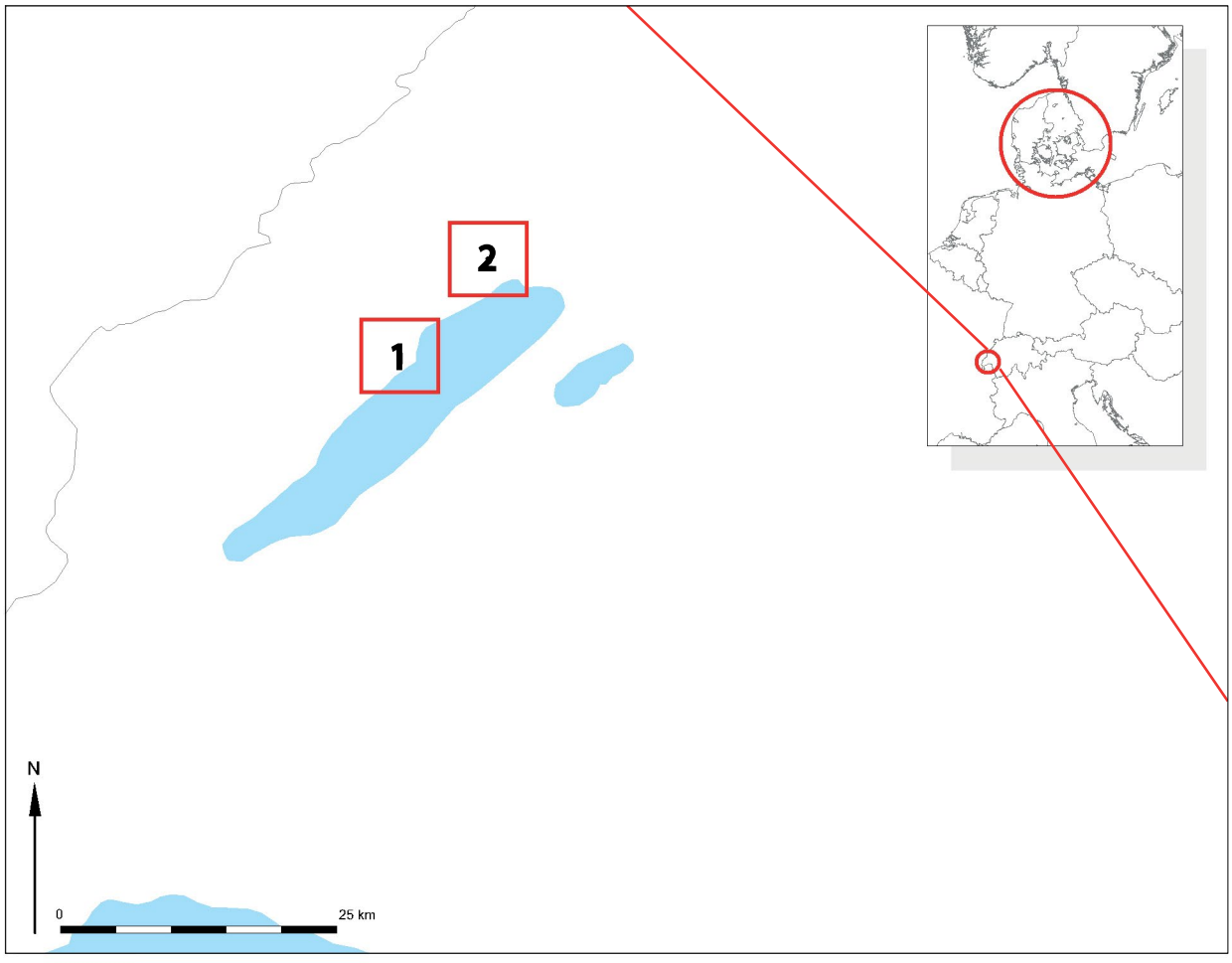


Figure 9.27. Locations of the researched sites in Switzerland (region 10). a: location of an excavated site; 1: Hauterive-Champréveyres; 2: Cortaillod-Est.

their potential to answer of the subsistence related questions listed in the previous chapter (section 8.8). Several different levels of presence and preservation of remains were encountered, which resulted in a varying level of detail in the description of Bronze Age subsistence in both different regions. Regions are discussed separately, and when more than one site is available for a certain subject, they are discussed separately before drawing conclusions on the entire region. Finally, in each discussion of the different subsistence strategies, a comparison with the West Frisian and also the Dutch situation (without West Frisia) is incorporated, where applicable.

9.5 COMPARISON BETWEEN EUROPEAN, DUTCH, AND WEST FRISIAN SITES

9.5.1 Hunting

Wild animal composition

In Figures 9.28-9.29, the wild mammal composition of the sites in Denmark (DK), Sweden (SE), Switzerland (CH), West Frisia (WF), and the other Dutch sites (NL) are summarized. Bird and fish remains were too scarce to be included in this analysis, but based on the local character of hunting practiced at the researched sites (see next paragraph),

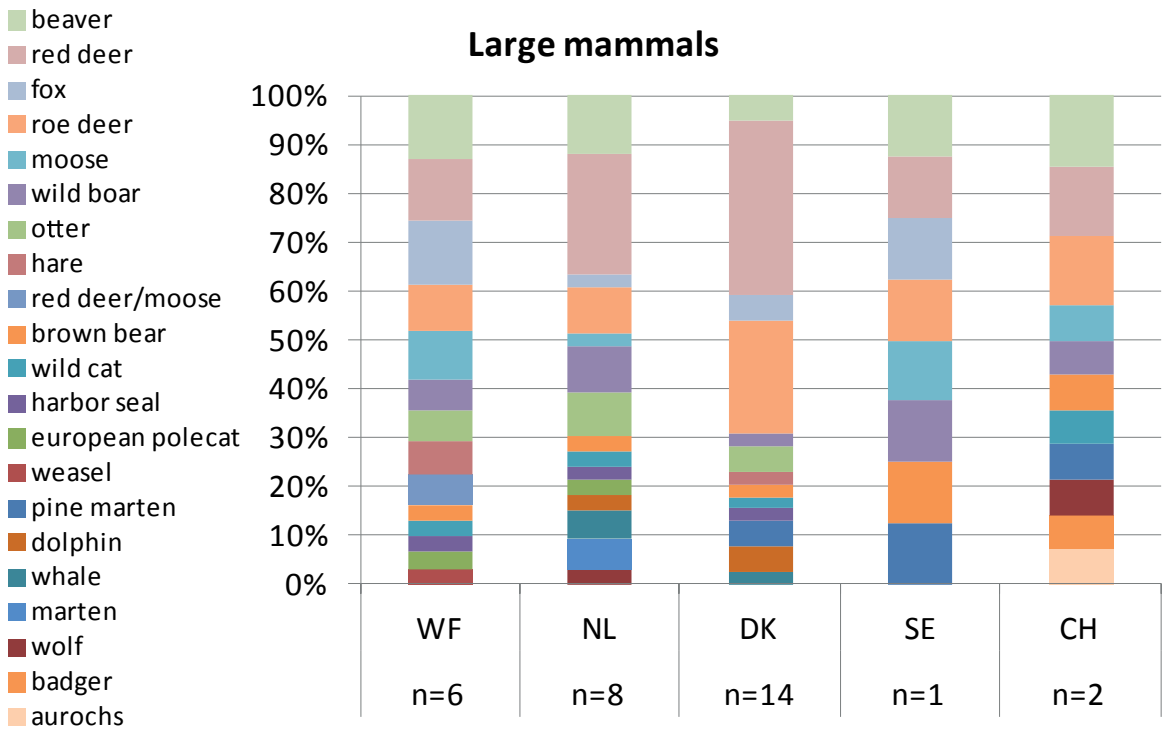


Figure 9.28. Frequencies of large mammals from the different European regions in comparison with West Frisia and the Netherlands.

it is expected that birds and fish would have come from the surroundings of the settlements.

Figure 9.28 gives insight into the most frequently uncovered species in each region. On the other hand, Figure 9.29 provides a quick overview of the different uncovered wild animal species per region by only showing their presence, which facilitates inter-regional comparison.

Both figures portray a wide range of wild large mammals found, although the number of remains is generally low. The large mammals red deer, roe deer, beaver, wild boar, and brown bear are uncovered in every region, with the first four species also being found most frequently at most locations. These species appear to belong to a "standard set" of hunted large mammals in the Bronze Age, which are found regardless of geographical location or climate. Other species which are present in many, but not all of the regions include fox, wild cat, moose, harbour seal, otter, and pine marten. Pine marten is not found in West Frisia or the Netherlands, which may be due to the absence of an appropriate habitat for this species in these areas during the Bronze Age. The remaining wild animal species are only uncovered in one or two regions. The variety of large mammal species in West Frisia, and the Netherlands at large, is only really comparable to the Danish sites, but this may be related to the higher number of samples available from these areas. It is clear however, that the wide range of mammal species observed in every region again indicate that also in other European areas in the Bronze Age, hunting skills and knowledge required for the capture of these animals were still present.

Hunting locations

The animal species observed in the previous paragraph show capture in the (varied) close surroundings of the settlements (data not shown), with strong indications for the sea at coastal sites in Denmark, and a variety of landscape types – including grassland, shrubland, wetland, and forest – present at all the sites. At the Swedish site of Ängdala no marine mammals were found, although it is located near the coast. However,

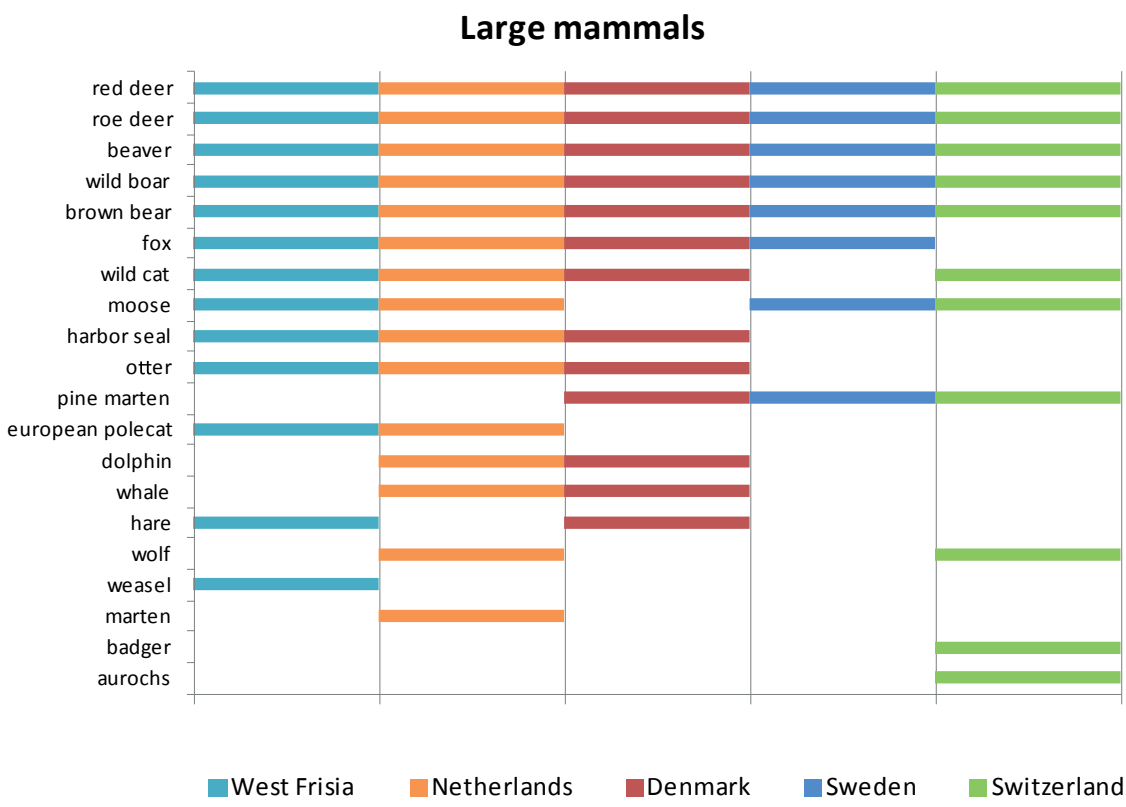


Figure 9.29. Presence/absence of large mammals from the different European regions in comparison with West Frisia and the Netherlands.

marine fish species were present (Nyegaard 1996, Table 86), indicating exploitation of this habitat type as well. Similar to the West Frisian situation, hunting appears to have been a relatively local practice. The wide variety of habitat preferences from the animal species present in each region and at each site again indicates that wild resources from various locations in the surroundings of the settlements were still exploited during this time, similar to in West Frisia.

Hunting practices

A few direct indications for hunting are found in Denmark, but not Sweden. As already mentioned in Chapter 4 (section 4.3.2), several wooden tread traps – indicating passive hunting – have been uncovered in bogs. Furthermore, bone, flint, and bronze arrowheads have also been uncovered at several locations (Nyegaard 1996, 148 and references therein), indicating that active hunting was still occurring during this time.

Unfortunately, no clear evidence for the hunting of game were found at the researched sites in Switzerland, although the species found (*e.g.* wolf, brown bear) could not have been caught without the appropriate equipment. In Hauterive-Champréveyres however, a wooden net float was uncovered, identifying probable passive fishing practices.

Use of wild animals

In the Nordic countries, as well as in Switzerland, authors who discuss hunting in these areas in the Bronze Age postulate several reasons for why hunting occurred, although none emphasizes the importance of this practice due to the limited amount of remains. However, one of the reasons proposed,

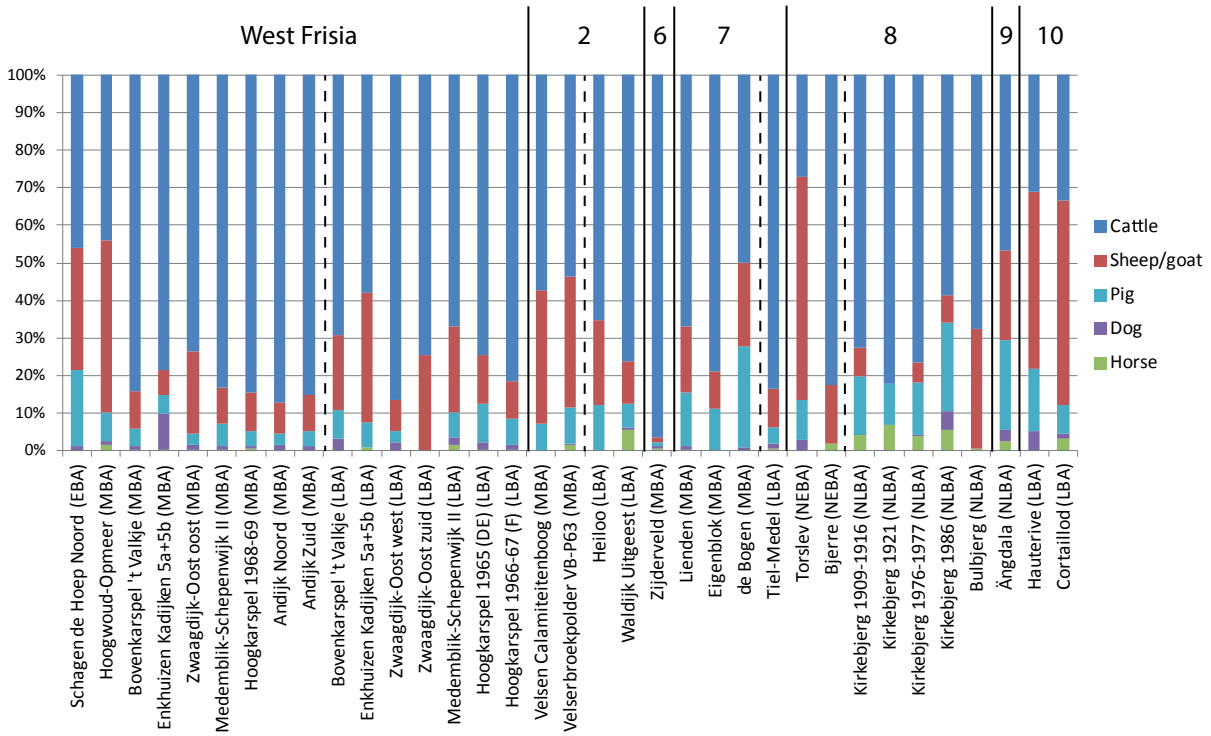


Figure 9.30. Comparison of the domestic animal compositions of the West Frisian, Dutch, Danish, Swedish, and Swiss sites. Numbers above the graph refer to the numbers of the different regions in accordance with Table 9.1 and 9.3. 2: Kennemerland; 6: River area – west; 7: River area – east; 8; Denmark; 9: Sweden; 10: Switzerland.

which is in concurrence with the reasons for hunting postulated in West Frisia (cf. Chapter 4, section 4.4.5.4), is that hunting was mainly carried out for the procurement of raw material. One type of raw material is the antlers of red deer, high frequencies of which have been found in Denmark, Sweden, and Switzerland (Nyegaard 1996, 147; Borrello *et al.*, 1986: 63, 66). The other type of raw material is pelts or skins of animals. In all three regions, many species may have been captured for their fur, including beaver, fox, otter, marten, wild cat, seal, hare, wolf, and badger. Of course, brown bear, moose, and deer skins could also have been targeted raw materials. Both Borrello *et al.* (1986, 66) and Nyegaard (1996, 152) indicate the potential of hunting for fur in the Bronze Age. Nyegaard further postulates that it is not unlikely that large parts of the population will still have been dressed in wild animal skins during this time (Nyegaard 1983, 102). The discovery of the Bronze Age wooden traps from several areas of Europe (Chapter 4, Figure 4.3) would concur with this idea, since trapping results in minimal damage of the animal's skin during capture, as opposed to piercing by weapons.

The image obtained from the Nordic and Swiss examples is very comparable to the Dutch situation, since many fur animals are found at the various researched Dutch and West Frisian sites. Furthermore, the only clear example of Dutch Bronze Age clothing (*i.e.* the Emmer-Erfscheiden bog body; Chapter 8, section 8.3.2) is made from a mix of domestic and wild animal skins (van der Sanden 1996). Apparently, the importance of wild animals in the Bronze Age in general may have shifted from being a major source of food to a source of raw material and an additional source of meat to complete subsistence. Clearly, hunting was not abandoned during the Bronze Age in any of the researched areas, and it maintained its importance in the subsistence economy, although its main purpose may have become different than in previous periods.

9.5.2 Animal husbandry

Livestock composition

The five species of livestock kept in the Dutch Bronze Age (*i.e.* cattle, sheep, goat, dog and horse) are all also present in the researched international regions, although not always in the same ratios (Figure 9.30). Denmark, represented by four sites here, shows variation between two of its areas: Northern Jutland (including sites Torslev, Bjerre, and Bulbjerg), and the island of Funen (*i.e.* Kirkebjerg) (Figure 9.26).

In NEBA Northern Jutland (Torslev and Bjerre), cattle is observed and also a generally high percentage of sheep, with minor additions of pig, dog, and horse. Torslev especially shows a high percentage of sheep, but only few pig and dog bones, and no horse. At Bjerre, cattle remains are dominant, followed by sheep goat, and horse; no remains of pig or dog were found.

In the NLBA, Northern Jutland (Bulbjerg) still has a reasonable amount of sheep remains, but cattle remains now outnumber those of sheep/goat, and no dog and very few horse remains are found.

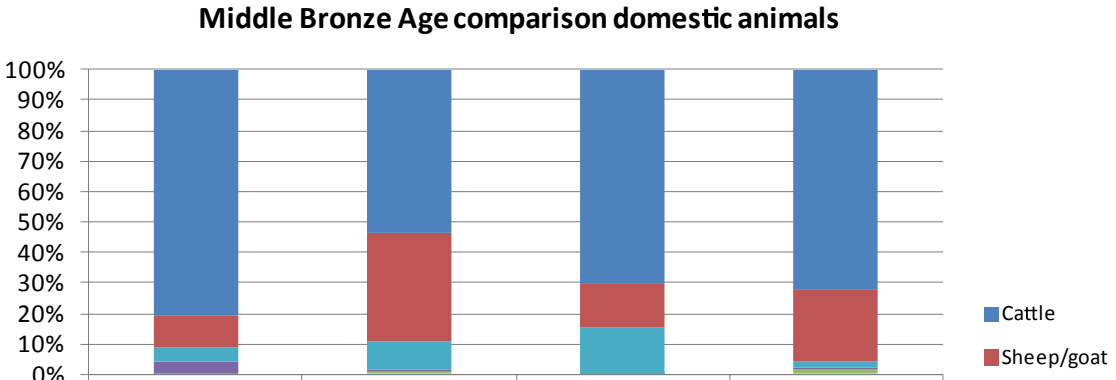
On the island of Funen (Kirkebjerg), a low amount of sheep remains was uncovered, even being completely absent in some areas. Pig bones however, were present at relatively high numbers, followed by horse bones, and finally dog. Towards the later NLBA (*i.e.* Kirkebjerg 1986), the amount of especially pig and horse, but also dog remains seem to increase further at the expense of sheep/goat and cattle.

Comparing Denmark to West Frisia reveals that in no particular area or time period, did the two areas match. The only slightly comparable sites might be the sites Torslev and Schagen de Hoep Noord, although Schagen is dated to an earlier period. In general, Danish sites never show the particular ratios of the different species of livestock kept at the West Frisian or other Dutch sites. Northern Danish sites show a higher amount of sheep bones than on the southern island of Funen, where pigs are the major domestic animal kept after cattle: situations which do not occur in West Frisia, or the Netherlands as a whole, except for Meteren de Bogen. Furthermore, horse remains are more frequently found on the island of Funen than in West Frisia. Only the LBA site Uitgeest Waldijk shows comparably high frequencies of horse bones. A clear increase in sheep remains from the Middle to the Late Bronze Age, such as was observed in West Frisia, was not visible in Denmark. Areas here appear to be consistent in either their low or high sheep/goat share through time. Although each region seems to possess the same set of domestic animals, the average values for remains of livestock for each area (Figure 9.31) reveal that none of the regions are comparable with respect to prevalence of certain species.

The Swedish site Ängdala also differs from the West Frisian and Danish sites. Here, both sheep and pig are equally present after cattle.

This trend is also observed at a more extreme level at the LBA sites near lake Neuchâtel, Switzerland: Hauterive-Champréveyres and Cortaillod-Est. In this area, the number of sheep/goat greatly outnumber any other livestock species present, which are, in decreasing order, cattle, pig, horse, and dog. The (N) LBA average values for livestock remains (Figure 9.32) again show that none of the researched regions are directly comparable in terms of domestic animal species ratios.

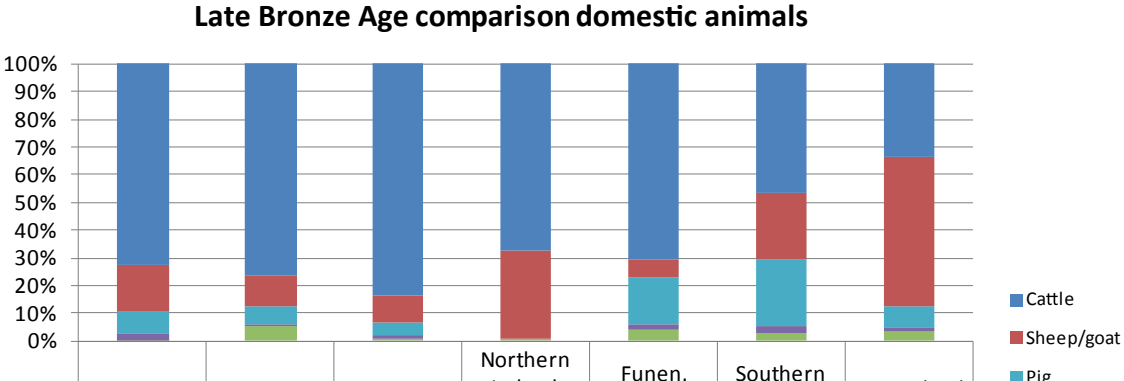
Based on the comparison of West Frisian, Dutch, Danish, Swedish, and Swiss sites, it appears that during the Bronze Age, the same livestock species were kept, but different ratios of bones are observed in each region. Due to the good preservation conditions at most sites, these observations are deemed comparable. Nyegaard does, however, remark that the preservation conditions in Northern Jutland were not optimal (Nyegaard 1996, 148), meaning that the assemblages of particularly Bjerre and Bulbjerg should be met with caution. Still, high amounts of sheep/goat and even juvenile individuals of cattle are present at these sites, which means that, if anything, the original share of sheep/goat in the assemblage would have been even higher in Northern Jutland. The specific reasons for the observed differences between regions is hard to interpret and could be related to (a mix of) local environmental, subsistence economical, temporal, and social conditions.



	West Frisia (n=7)	Kennemerland (n=2)	River area (n=7)	Northern Jutland, Denmark (n=2)
Cattle	7950	339	9285	139
Sheep/goat	1021	220	1895	46
Pig	458	59	2008	4
Dog	411	3	58	1
Horse	25	8	10	3

No. of bones

Figure 9.31. Ratios of domestic animal species in the Middle Bronze Age from Northern Jutland in comparison with West Frisia and the Dutch regions.



	West Frisia (n=7)	Kennemer-land (n=1)	River area (n=1)	Northern Jutland, Denmark (n=1)	Funen, Denmark (n=3)	Southern Sweden (n=1)	Switzerland (n=2)
Cattle	5603	236	397	145	4754	909	1091
Sheep/goat	1334	34	49	69	448	466	1772
Pig	604	20	21	0	1161	471	269
Dog	180	2	6	0	93	56	40
Horse	13	17	3	1	290	49	105

No. of bones

Figure 9.32. Ratios of domestic animal species in the Late Bronze Age from the different regions of Europe in comparison with West Frisia and the Dutch regions.

Table 9.5. Ranges of shoulder heights of domestic animal species in West Frisia, Denmark, and Switzerland.

	West Frisia (Bovenkarspel)	Denmark (Kirkebjerg)	Switzerland (Cortaillod-Est)
Cattle	102.4-111.6 cm	107-116 cm	102.3-106.9 cm
Sheep/goat	ca. 62.3 cm	57-69 cm	69.8 cm (goat)
Pig	ca. 82 cm	70-87 cm	73-77 cm
Dog	48-61 (65) cm	58-61 (68) cm	56-60 cm
Horse	??	ca. 133 cm	"small"

Animal breeds

Denmark and Sweden

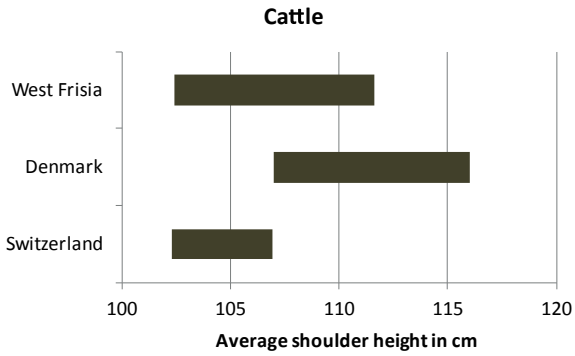
Only the Danish site Kirkebjerg provided information on breeds and sizes of livestock. Although no evidence of polled (*i.e.* hornless) sheep/goat was found, the presence of some individuals with relatively short horns might indicate an intermediate form between horned and polled animals (Nyegaard 1996, 43). Cattle remains showed no signs of polled individuals. Therefore, horns did not provide clear indications for different breeds.

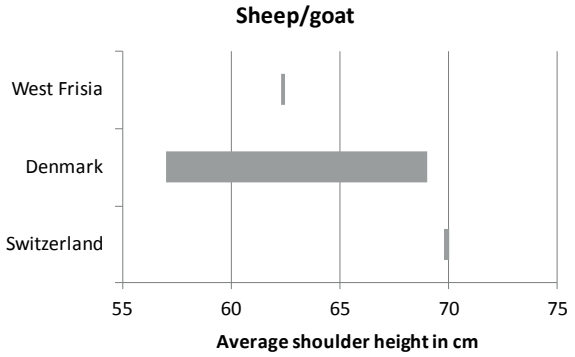
However, reconstructed shoulder heights, which were summarized in Table 9.5 and Figure 9.33 for all livestock species except horse, do provide clear indications for the possible presence of different breeds in the Bronze Age. From this table and figure, it is apparent that the shoulder heights of most Danish animals overlap with the values of West Frisian animals: especially the West Frisian values of sheep/goat and pig fall within the Danish ranges. Dogs and cattle however, seem to be of consistently larger size in Denmark than in West Frisia (Figure 9.33). The size difference of cattle between the two areas is also observed when the range of metapodial distal breadths between the areas are compared (Figure 9.34).

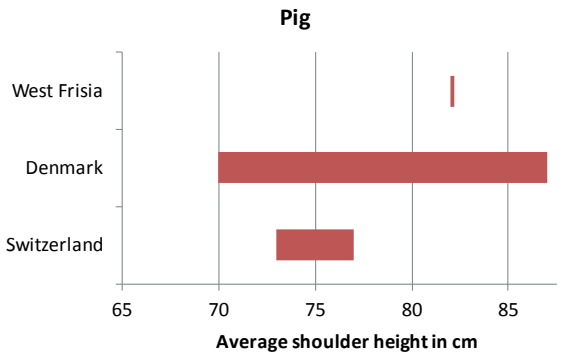
Dogs furthermore, are present in varying size and body type, ranging from medium dogs with a more frail stature to large and strong individuals, which are found in both Denmark and West Frisia. Nyegaard (1996, 53-4) interprets this difference in size and build as the necessity of different dog breeds for specialized functions, such as aiding people with shepherding or hunting. The latter possibility is, however, rejected by Nyegaard due to the fact that he interprets the limited amount of wild animal species bones uncovered at Kirkebjerg as evidence for the minor role of hunting in the (Nordic Late) Bronze Age. The in-depth analysis of West Frisian wildlife has shown that this is not necessarily a valid assumption (cf. Chapter 4), and the possibility of specialized hunting dogs remains a possibility. Alternatively, people may have required strong guard dogs to protect their livelihood and flocks.

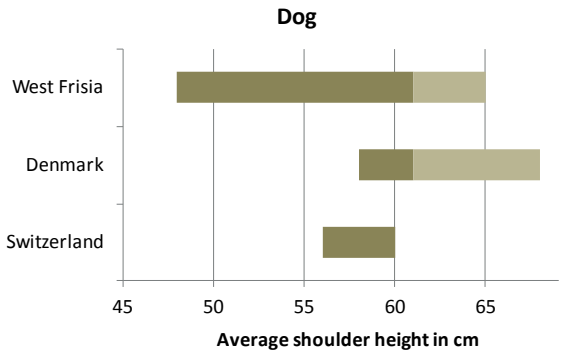
Switzerland

In Cortaillod-Est, the remains of a hornless sheep were found. These types of sheep have been present in Switzerland since the Middle-Neolithic (Borrello *et al.* 1986, 50). Shoulder heights could not be calculated for all species. An exact size of the horses could also not be calculated, but in comparison to other Bronze Age horses, which are already of limited size by modern standards, they appear to be small (Borrello *et al.* 1986, 57). Shoulder heights of the remaining species are shown in Table 9.4 and Figure 9.33. Most species, except goat, appear to fall within the lower part of the ranges observed in West Frisia and Denmark. Furthermore, dogs in Switzerland are robust and strong, with strong jaws. Their size ranges from medium to large, and they are larger than the dogs in Switzerland dating to both the Neolithic and most of the Iron Age (Borrello *et al.* 1986, 56). However, these dogs are not as large as some of the specimens found in the other regions. Still, relatively stronger and larger dogs seem to be preferred in Switzerland as well, which could again be related









to the practice of shepherding (*e.g.* protecting the large sheep flocks), hunting, and/or guarding the settlement. Of course, as is often the case, a mix of these possibilities probably lies closest to the truth.

Overall, in addition to livestock composition ratios, all regions also seem to differ in their animal breeds. Denmark yielded examples of consistently larger cattle and dogs than West Frisia, whereas Swiss animal are mostly small. Sheep appear at all sites, but vary in their genes related to the possession of horns. Throughout the researched European sites, sheep horns range from full-size horns (West Frisia), small horns (Denmark), and complete absence of horns (Switzerland). This variation in sheep breeds is consistent with what is observed based on recent genetic studies (cf. Chapter 5; Appendix A1.5). Large (male?) goats seem to appear in both Switzerland and Denmark, whereas pigs are of similar size in Denmark and West Frisia, but are small in Switzerland. Dogs of varying size are found at all sites, possibly reflecting different specialized breeds. Horses finally, are consistently small in every region, reaching to the size of an average present-day pony.

Location of livestock

Denmark and Sweden

Only in Denmark, substantial evidence of keeping animals inside Bronze Age houses was found. In several areas of Denmark, direct and indirect indications exist. These indications are manifold, and range from the presence of actual stall divisions, to a difference in posthole distances in one part of the house. The absence of hearths in certain parts of the house as well as phosphate analysis are other indications (Nyegaard 1996, 13; Robinson 2003: 156, 159,161). These barn parts are usually found in the eastern part of the house, but are also sometimes located in the central part (Robinson 2003, 160).

On the left: Figure 9.33. Comparison of the average shoulder heights of the different domestic animal species in West Frisia, Denmark, and Switzerland. Since shoulder heights of horse were only present in Denmark, this animal species is excluded. Lighter shades of colour in the graph of dog signify that an outlier value exists of one individual up to the maximum height observed.

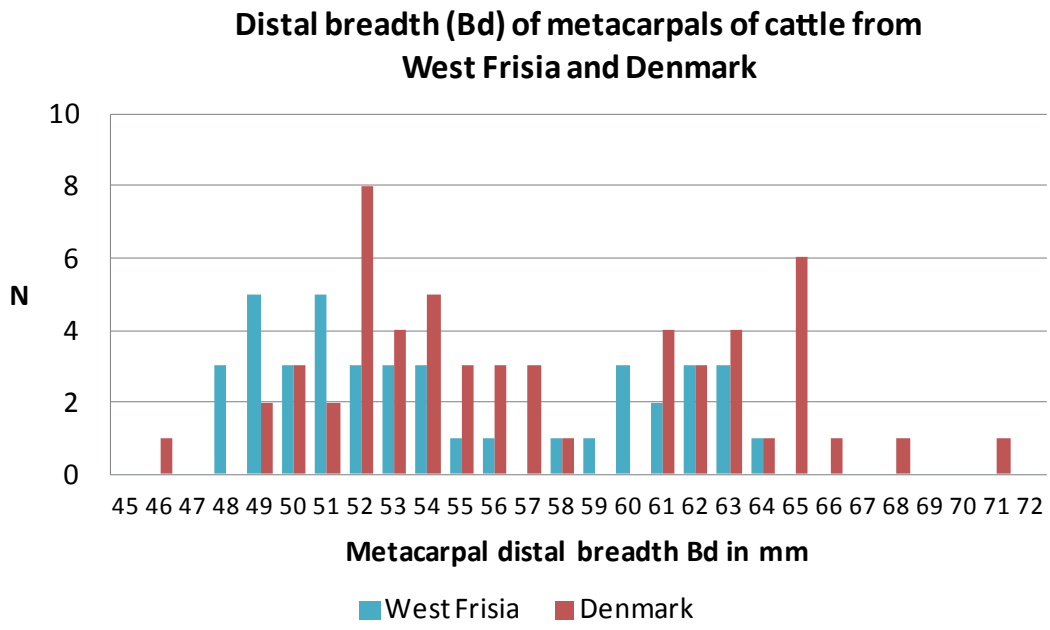


Figure 9.34. Comparison of the distal breadth of cattle metacarpals of West Frisia and Denmark (data from: IJzereef (unpubl.), and Nyegaard (1996, figure 15), respectively).

Besides houses with stall partitions, several burnt houses of the Pre-Roman Iron Age in Denmark provided examples of barns without clear separations for animals (Kveiborg 2009a-f; cf. Chapter 5, section 5.4.3). Instead of wooden stall partitions, some of these stables were probably separated by partitions of wicker, or, alternatively, animals were fastened to beams or the outer wall of the house with the aid of rope (headgear). Since these different methods of keeping animals will not be visible as postholes during excavation, they may easily be missed as an option for how a prehistoric barn may have functioned. These Danish examples are therefore very valuable, providing evidence for alternative possibilities for keeping animals, which may also have been performed similarly in West Frisia, especially considering the fact that West Frisian houses also showed no signs of wooden stall separations in the house lay-out.

In Denmark, outside structures which may be related to animal husbandry were also observed, and consist of circular posthole configurations, which may have functioned as animal pens (Nyegaard 1996, 13). Comparable structures were observed in great numbers in West Frisia. Therefore, these structures may perhaps also be related to animal husbandry. However, due to a scarceness of finds from the circular structures in West Frisia, this could not be confirmed and other possible functions are by no means excluded.

Switzerland

No clear examples of designated animal locations in Bronze Age Switzerland were observed. Neolithic examples do exist however, with animals possibly being kept inside pile-dwellings over a lake (Akeret *et al.* 1999).

Slaughter practices

The programme Faustitas (Appendix A1.7) was used to re-interpret slaughter ages data, including considering the effects of taphonomy as much as possible. Unfortunately, only one (Danish) NLBA site, Kirkebjerg, provided the raw data required for the analysis with Faustitas, and only for cattle remains. The other sites and regions could therefore not be

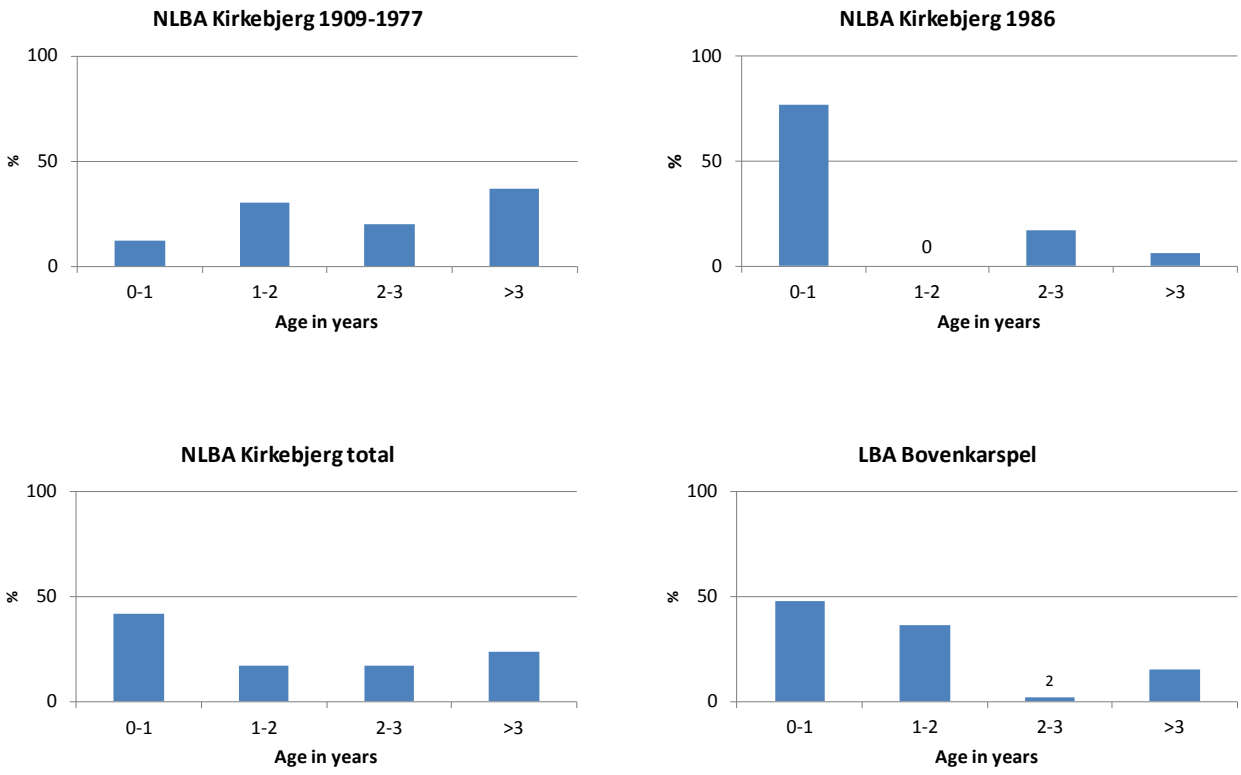


Figure 9.35. Mortality profiles of the sites from (Nordic) Late Bronze Age Denmark (i.e. Kirkebjerg) in comparison with Late Bronze Age West Frisia (*i.e.* Bovenkarspel). All sites have been corrected using the ravaging correction suggested by Munson (cf. Chapter 5, section 5.4.2). Original data from Kirkebjerg 1909-1977: n=646; Kirkebjerg 1986: n=157; Kirkebjerg total: n=803; Bovenkarspel: n=288.

included here. When and if the raw data becomes available in the future, this analysis could be completed. The results of the analysis on the data of all excavations from Kirkebjerg (1909-1986), as well as average values of Kirkebjerg and Bovenkarspel are summarized in Figure 9.35.

As can be seen, the general trends of slaughter ages between the different sites of NLBA Kirkebjerg and LBA Bovenkarspel are not very comparable. In period V of Kirkeberg's NLBA (excavations from 1909-1977), most animals are slaughtered around 1-2 years of age, as well as around 3-4 years, whereas LBA Bovenkarspel is characterized by slaughter mainly at a young age (0-2 years old). In period VI of Kirkebjerg (1986), the mortality profile is more comparable to that of Bovenkarspel. However, this Danish site only comprises of one context, and the results obtained should therefore be interpreted with caution.

When the average Danish and West Frisian data are compared, the overall high peak in 0-1 year old animals is similar, but the ratios of the other ages of culled animals are different: in West Frisia, 1-2 year old individuals are the second highest group of cattle slaughtered, whereas in Kirkebjerg, this is the 3-4 year old age group.

Use of animals

Cattle

Faustitas was also used on the data from Kirkebjerg to analyse the use and long-term viability of the herds. The results of the analysis are shown in Figure 9.36. In Denmark, no clear signs of specialization are visible in the data from 1909-1977 or the combined data for Kirkebjerg. This image is comparable to the Middle Bronze Age in West Frisia (Figure 9.37), which also showed no clear specialization, and similar values for growth and birth rates.

In the data from the excavation of 1986 however, it appears as if production has increased in general, and milk production seems to have become more important. However, since this data derives from only one context, caution is advised.
Using this caution, it remains interesting to note that the 1986 NLBA Kirkebjerg data and LBA Bovenkarspel data both show an increased production potential of the herd, combined with an increased birth rate, and a decreased growth rate. In combination with the slaughter ages observed in the previous paragraph, a possible interpretation could be postulated. For some reason, LBA West Frisian and perhaps NLBA period VI Danish farmers suddenly needed to produce more animals (hence the higher birth rate and production potential) in comparison to the previous period. However, concurrently, a higher number of young individuals was slaughtered (see Figure 9.35, lower half), which resulted in the growth rate and long-term viability of the herd being negatively affected (Figure 9.37). In Denmark, the herd seems to mainly have potential for milk during this time, whereas the West Frisian herd has a higher potential for meat. The growth rate of herds at both sites was equal or even less than one, meaning that these herds would eventually not be able to sustain themselves if no changes were made to the animal husbandry practices.

The use of cattle for milk is also emphasized by the presence of ceramic sieves in Denmark which are often related to cheese making (Nyegaard 1996, 158), similar to the ones found in West Frisia (Chapter 5, Figure 5.28), the analysis on Bronze Age human dental calculus which has revealed mostly bovine milk consumption in northern European areas (Chapter 8; Warinner et al. 2014, Suppl. Table 1 and 2) also emphasizes this use. Another use of cattle in Denmark evidenced by the bone material is traction. Many bones from Kirkebjerg portray pathologies on the metapodia which are commonly related to intense labour in the form of traction (*e.g.* ploughing and pulling of carts) (Nyegaard 1996: 33, 159).

Swiss cattle also show possible signs of labour, shown by the fact that horns show pathologies potentially caused by pulling a yoke (Borrello *et al.* 1986, 54).

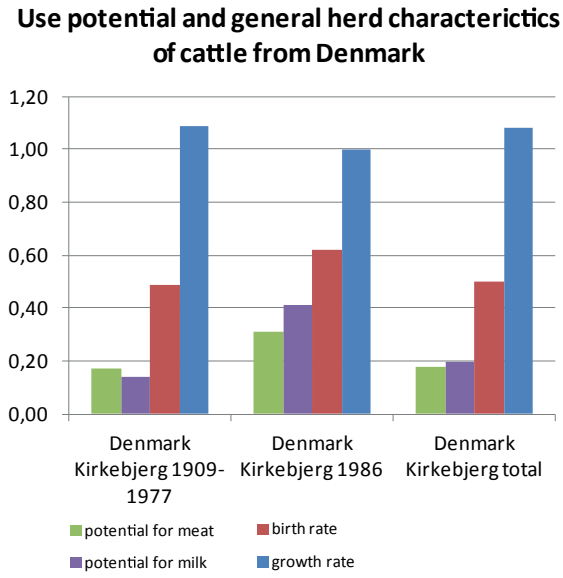


Figure 9.36. Use potential of herds and general herd characteristics of the Late Bronze Age site Kirkebjerg. Use potential is a relative value to evaluate the production potential of a herd for different uses (cf. Cribb 1985). The higher the value, the higher the potential.
Birth rate indicates the number 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.

Sheep/goat

Although no analysis on the use potential of sheep/goat was possible with the aid of Faustitas, both the Nordic and Swiss regions possess indications for sheep/goat use based on the presence of slaughter marks (*i.e.* meat), and tools created from horn and bone (*i.e.* raw material) (Nyegaard 1996, 44-5; Borrello *et al.* 1986, 66). In addition, milk and wool are not suggested to be the main reasons for keeping sheep or goats, although of course both could very well have been exploited before being slaughtered for meat (Nyegaard 1996: 44, 160-1). Use of milk is further made plausible by the presence of ceramic sieves in Denmark (Nyegaard 1996, 158).The idea of multiple uses of sheep/goat fit very well with the image for West Frisia.

Pig

Pigs are presumably only kept for their meat and fat, evidenced by the slaughter at relatively low age in both Denmark and Switzerland (Nyegaard 1996,

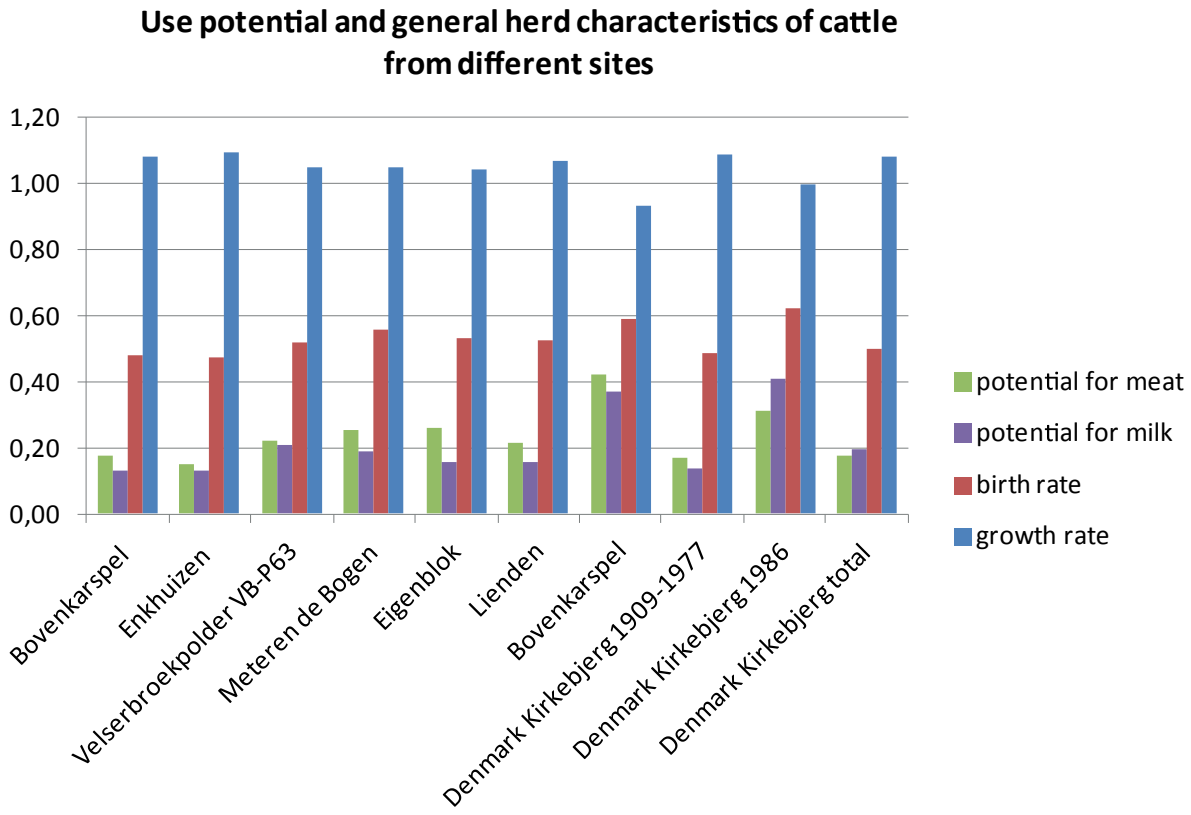


Figure 9.37. Use potential of herds and general herd characteristics of West Frisian, Dutch and Danish sites from the Middle and Late Bronze Age. Use potential is a relative value to evaluate the production potential of a herd for different uses (cf. Cribb 1985). The higher the value, the higher the potential. 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.

40; Borrello *et al.* 1986, 56). The prolific pig makes an excellent variable addition to subsistence. When fodder is sufficiently available, pigs can provide abundant meat at a high rate and within a short time. During less favourable years, fewer pigs can be kept until more bountiful times.

Dog

As mentioned above in the paragraph on breeds, dogs appear at varying sizes in all regions, possibly indicating specialized functions. They may have been used as a shepherd dog, hunting dog, or guard dog.

Horse

In Denmark, several indications for the use of Bronze Age horses exist, both direct and indirect. Besides pictorial evidence of horses pulling carts/wagons (*e.g.* the Sun Chariot, found in a bog near Trundholm in north-west Sealand), the presence of several Bronze Age red deer antler bridles indicates that the horse was used as a riding and/or traction animal (Nyegaard 1983, 33-5). In addition, harness equipment and wagon parts have been uncovered at several locations (Nyegaard 1996, 160 and references therein). However, many horses were slaughtered in the prime of their lives, indicating that their use as riding or traction animals will not have been very intense (Nyegaard 1996, 153). Moreover, slaughter at this prime age indicates that the ultimate use of the horse was for meat. Horse hair, finally, has also been used, for example to create objects such as a hairnet, which was found in a Danish grave at Skrydstrup (Broholm 1949, 210).

9.5.3 Crop husbandry

Crop composition

Not all site publications yielded raw data on the frequency of the remains of the different cultivated crops. For this reason, a more general discussion is held here, based on presence/absence and postulated dominance of the crops in the various regions by the respective authors. Data from overview articles is also used. This means that in this section, additional sites are included to those of Figures 9.26-9.27 and Table 9.4, the references of which can be found in the sections below.

Major crops

Denmark and Sweden

Denmark and Sweden have very similar cereal assemblages. Both show a presence of naked barley, hulled barley, and emmer wheat. Other cereals include einkorn for the Nordic Early Bronze Age, and bread/club wheat and spelt for the Nordic Late Bronze Age (Figures 9.38-9.39).

In Denmark, wheat is the more dominant crop in the NEBA, followed by naked barley, and then hulled barley (Robinson 2003, 148: f2; Andreasen 2009, 54). The type of wheat cultivated differs per site and includes mostly emmer, but also spelt and bread wheat. The Danish NLBA is still characterized by a shared dominance of emmer wheat and naked barley, but both spelt and hulled barley are becoming increasingly prevalent (Robinson 2003, 148: f2).

Naked barley is the dominant crop in the NEBA in Sweden, followed by wheat (emmer and einkorn), and hulled barley. The NLBA in Sweden is still characterized by a dominance of barley, but hulled barley now becomes equally dominant to naked barley, at the expense of wheat (Berglund 1991; Gustafsson 1998).

Switzerland

In Switzerland, an equally elaborate range of cereals as in the Nordic countries was present (Figure 9.39). Cereals include hulled barley, emmer, einkorn, spelt, and bread wheat. Based on frequency, spelt is the most dominant crop, followed by emmer wheat, einkorn, and finally hulled barley (Jacquat 1989, Plate 3).

The summary figures 9.38 and 9.39 were made based on relative dominance. When regions are compared, it is clear that in the northern countries, a wide variety of crops was cultivated, with a more or less equal distribution between wheat and barley species. In Switzerland, mostly wheat species were cultivated.

The most dominantly occurring cultivated species in Denmark are emmer wheat and naked barley, which both appear to be the dominant crops throughout the NEBA and NLBA. In Sweden, a relatively higher dominance of barley is observed, mostly naked barley in the NEBA, changing to a dominance of the hulled variety in the NLBA. In LBA Switzerland, wheat species are in overwhelming majority, with spelt forming the dominant species.

The almost equal ratio observed between wheat and barley species in West Frisia seems most comparable to the Nordic countries throughout the Bronze Age. However, even though the overall ratios of wheat and barley are comparable between the Nordic countries and West Frisia, the variety of crops in Denmark and Sweden is different and much wider during this period as well as the later Bronze Age. In the LBA, the dominance of emmer seems to increase in West Frisia, whereas both Denmark and Sweden show no such trend. Conversely, in both Nordic regions the hulled variety of barley does seem to experience a relative increase in frequency during the (N)LBA, and this is not observed in West Frisia.

Switzerland, of which only LBA data is available, shows different ratios between wheat and barley species from all the other regions and time periods, with wheat species being very dominant. This situation is only comparable to the Netherlands when the separate Dutch areas are considered: a comparable high dominance of wheat species was observed in the LBA Dutch river area also (Figure 9.18, previous section 9.3).

Minor crops

Denmark and Sweden

Danish NEBA sites only yielded linseed/flax (Robinson 2003, 148: f2). In the Danish NLBA, minor crops again include linseed, but also broomcorn millet, rye, and gold-of-pleasure (Robinson 2003,

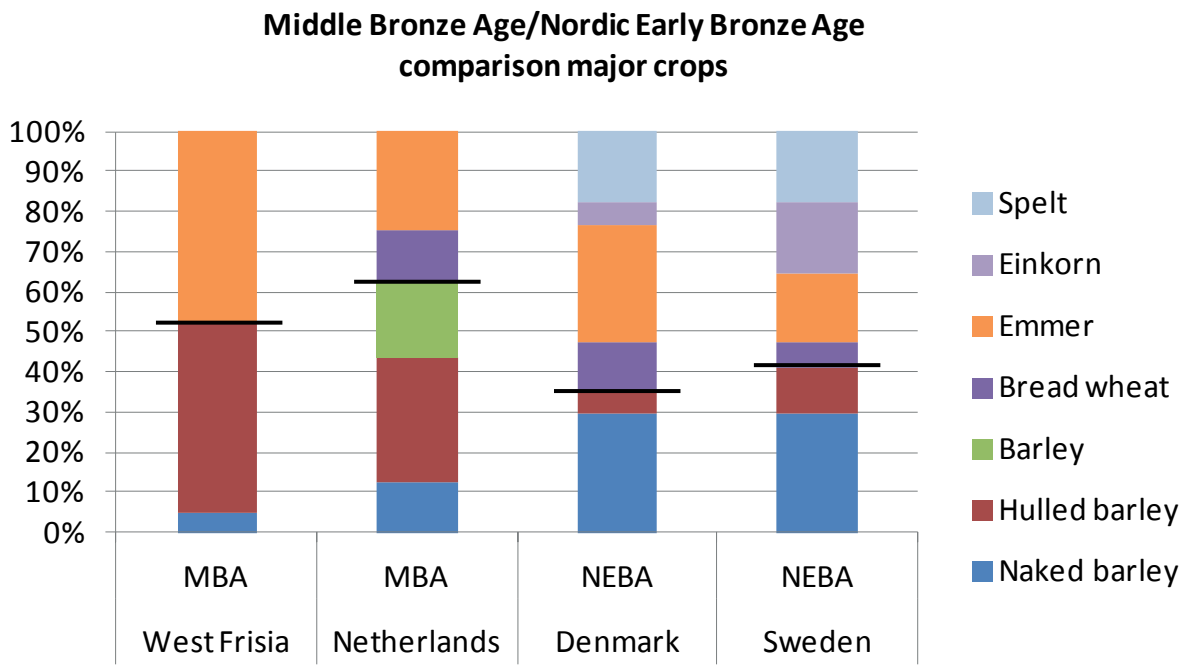


Figure 9.38. Ratios of major crop species in the Middle Bronze Age/Nordic Early Bronze Age in the different regions of the Europe in comparison with the Netherlands and West Frisia.

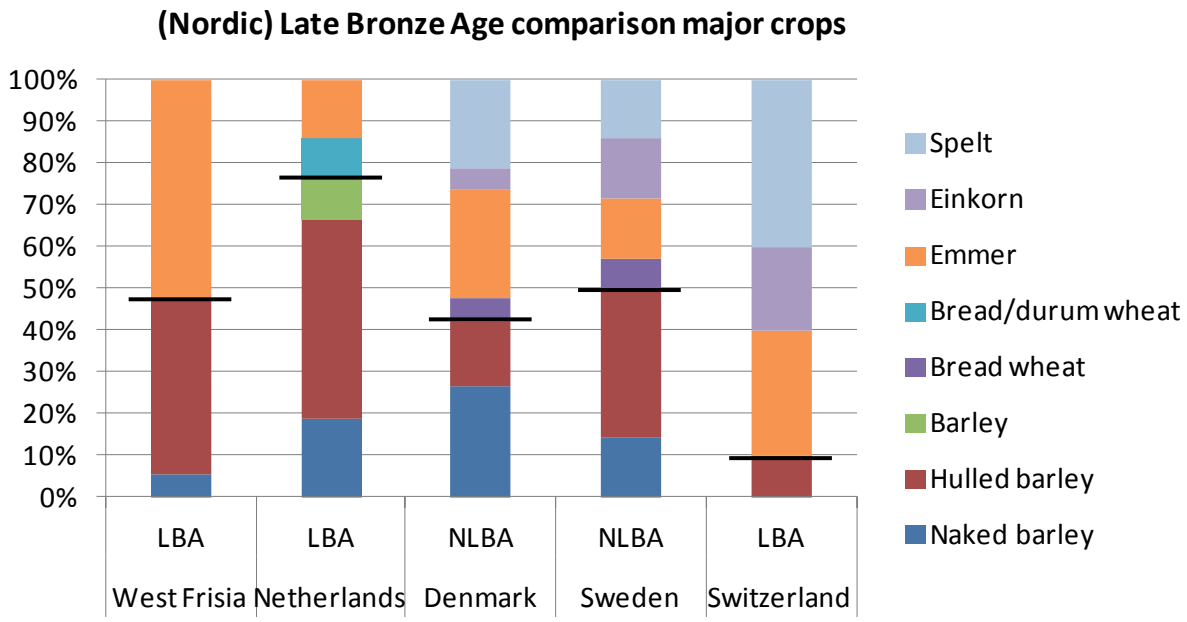


Figure 9.39. Ratios of major crop species in the (Nordic) Late Bronze Age in the different regions of the Europe in comparison with the Netherlands and West Frisia.

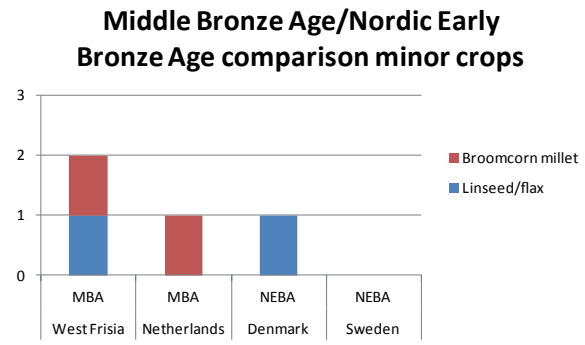


Figure 9.40. Presence/absence of minor crop species in the Middle Bronze Age/Nordic Early Bronze Age in Denmark, the Netherlands, and West Frisia.

148: f2). In Sweden, both linseed (Gustafsson 1998) and broomcorn millet are found in the NLBA.

No cultivated pulses or legumes were found in the Nordic countries, which is in concurrence with the outcome of the overview used in Chapter 6, section 6.3.1 in which Bronze Age crop assemblages of the areas of Western Central Europe (WCE), Southern Scandinavia (SSc), and the North Sea Coast (NSC) were summarized.

Switzerland

The Swiss sites yielded remains of linseed/flax, broomcorn millet, foxtail millet, gold-of-pleasure, and opium poppy. In this area, pulses and legumes were also uncovered, including lentil, pea, and broad bean. Summarizing graphs were made of all the regions, but since frequencies of remains were unknown, only presence and absence of minor crops was plotted (Figure 9.40 and 9.41). It is clear from these graphs that a varying range of minor crops existed in Bronze Age Europe. In the NEBA/MBA, only very few minor crops are present in the different regions, and are completely absent in Sweden. Denmark resembles West Frisia with regard to the presence of linseed/flax, but broomcorn millet is absent from the Danish assemblage.

In the NLBA, sites in all regions show a wider range of minor crops, with broomcorn millet, and gold-of pleasure, but also often linseed/flax becoming a definite part of the Bronze Age farmer's crop spectrum. Switzerland stands out with its very broad array of minor crops, since pulses and legumes, and opium poppy are available here as well.

In LBA West Frisia, gold-of-pleasure is noticeably absent. An explanation for this absence can be found in the somewhat skewed time periodization between the areas, as mentioned in section 9.4, as well as geographical location. Gold-of-pleasure occurs earlier in Central Europe than it does in its northern parts (Zohary & Hopf 1988, 125), so its availability in Switzerland during the Late Bronze Age comes as no surprise. However, the latest period of the NLBA in the Nordic countries also shows the presence of this crop, even though they are located further north than West Frisia. At first sight, this seems surprising, but the NLBA spans roughly the Dutch Late Bronze Age and the Early Iron Age (Table 9.3). Since gold-of-pleasure is commonly found in the Netherlands during the Iron Age, it makes sense that it is not yet present in West Frisia during the Dutch Late Bronze Age, but will have already reached Nordic countries during the Nordic Late Bronze Age. Sure enough, gold-of-pleasure is present on the West Frisian Iron Age site of Opperdoes, which confirms that skewed time scales are the cause of these observed differences (Buurman 1993, 72-3).

The variety of minor crops available in West Frisia during the NEBA/MBA period is relatively wide in comparison to other regions, with both linseed and millet being cultivated. Possibly, these minor crops formed a buffer for West Frisian farmers because their range of available major crops was limited in comparison.

For the LBA, it is hard to compare West Frisia with the Nordic countries, due to the fact that the NLBA also encompasses part of the Dutch Iron Age. Overall, West Frisia maintains its two minor crops in the LBA, which are comparable to those in the NLBA Nordic countries, although gold-of-pleasure was not (yet) a part of the West Frisian crop range during this time. It is much more difficult to reason the other way around however, since it is hard to assess whether the minor crop spectrum present at the NLBA Danish and Swedish sites was already available during the first half of the NLBA (*i.e.* the Dutch LBA), or whether the availability of (parts of) their minor crops assemblage

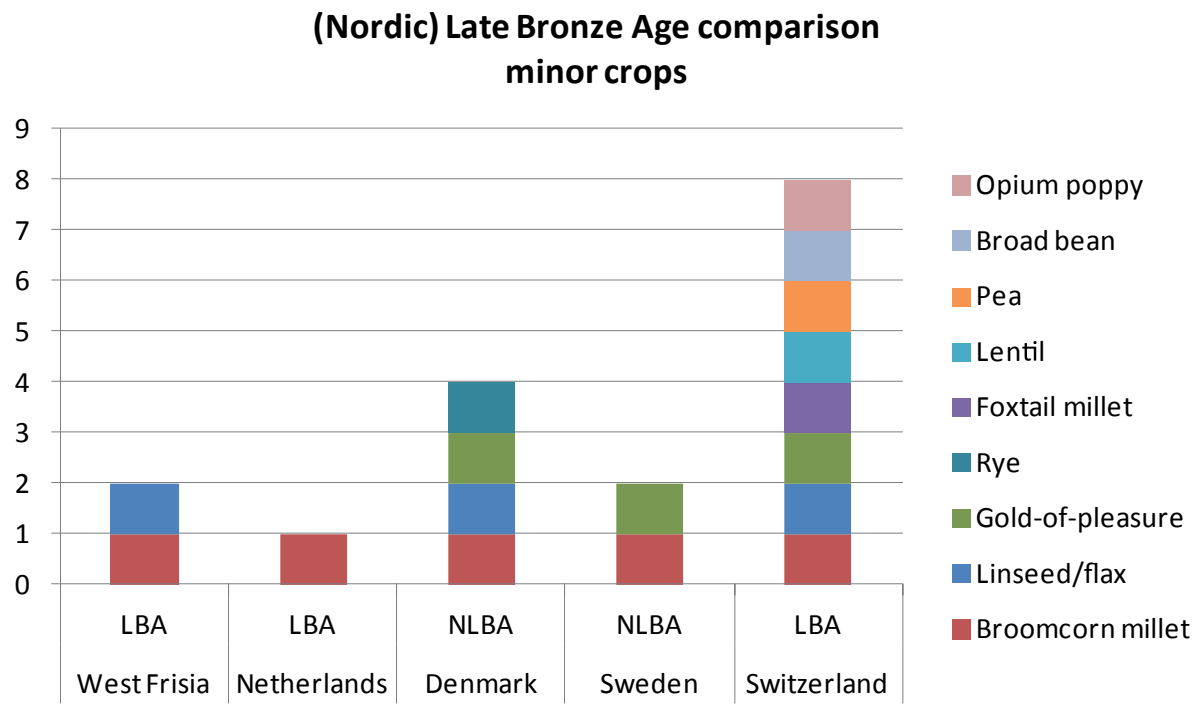


Figure 9.41. Presence/absence of minor crop species in the (Nordic) Late Bronze Age in Switzerland, Sweden, Denmark, the Netherlands, and West Frisia.

is more comparable to the Dutch (Early) Iron Age situation.

Arable fields

Denmark and Sweden

In Denmark, details from several regions are available to investigate the arable field conditions, both from the Nordic Early and Late Bronze Age (Robinson 2003). In the NEBA in Denmark, manuring of arable fields is not observed everywhere. Several NEBA sites on Jutland show no indications that manuring was being practiced during this period (Andreasen 2009, 25), but in the same article, it is mentioned that the bad preservation conditions in this area may be the cause of this. Conversely, in another area of Denmark, Djursland, indications do exist for improving the soil during this time period. Throughout the Nordic Bronze Age, including the NEBA, fertilizing the soil with household refuse was practiced. In the NLBA, the Danish sites show a larger variety of fertilizers being used, which include household waste, fen peat, manure, and stubble burning (Robinson 2003, 163). It appears that the Nordic Bronze Age farmers applied a range of fertilizers to improve their arable field conditions, which diversified even more in the NLBA.

In Sweden, archaeological and organic remains dating to the NEBA were not sufficient to evaluate the use of manure, but the NLBA finds seem to (indirectly) indicate that manuring might have occurred (Berglund 1991, 76). This indication derives from a combination of observations including changing internal structures of houses which may indicate that a barn was used for keeping animals inside for the collection of manure (although no stable partitions have been detected). Another observation is the increasing dominance of barley in this time period in comparison with the NEBA (also see Figures 9.38-9.39).

Overall, it seems that in NLBA Denmark and Sweden, manuring was occurring on a regular basis, consisting of several types of fertilizer, of both vegetative and animal origin.

Switzerland
In Hauterive-Champréveyres, no indications for the use of fertilizer have been found in the crop weed assemblage (Jacquat 1989, 55). In addition, manuring was not deemed necessary for this particular area at this time, due to very rich local soil conditions (Jacquat 1989, 68).

The few indications for manuring in West Frisia also confirm that a wide spectrum of fertilizers will have been necessary to manure the arable fields (Chapter 6, section 6.4.5; Appendix A1.11): the use of a combination of household waste, manure, and stubble burning will have been available to Bronze Age farmers to improve the quality of their fields.

Crop husbandry practices

Denmark and Sweden
For Denmark, it is assumed that crops were spring-sown (Andreasen 2009, 24-5). Moreover, based on the ratios of crop weed seeds found, no weeding is expected to have occurred in the NEBA in for example Jutland, Denmark (Andreasen 2009, 26). Sowing probably occurred on separate fields for different crops, indicated by the fact that crop remains of different species were found in separate containers at two Danish sites. This also means that families might have possessed more than one arable field (Andreasen 2009, 23-4).

The presence of crop weeds with low maximum growing heights, such as chickweed (*Stellaria media*), common field pansy/heartsease (*Viola arvensis/tricolor*), and corn spurrey (*Spergula arvensis*), at almost all Danish Bronze Age sites indicates that reaping occurred at the base of the stem or via uprooting, signifying the potential importance of straw throughout the NLBA.

Swedish sites did not yield enough information to investigate crop husbandry practices.

Switzerland
In Switzerland, most crops will have been spring-sown, especially the pulses, legumes, and oil seed plants. Alternatively, gold-of-pleasure may also have been sown in autumn, and spelt wheat will definitely have been a winter crop (Jacquat 1989, 67). Crops were most likely sown as monocultures, evidenced by the presence of charred lumps consisting of cereal grains from only one species at a time, which is unlikely to be the result of tedious sorting of two species after harvest (Jacquat 1989, 68). This means that families required multiple arable fields to grow all their crops.

Reaping occurred low on the stem, shown by the fact that many low growing crop weeds were uncovered, such as scarlet pimpernel (*Anagallis arvensis*), ground pine (*Ajuga chamaepitys*), and small bur-parsley (*Caucalis platycarpos*). Again, straw seems to have been important, either as fodder, insulation and/or thatching material (Jacquat 1989, 68).
Both regions researched seem to have several similar crop husbandry practices to West Frisia (cf. Chapter 6). Spring sowing was practiced everywhere (although also autumn sowing occurred in Switzerland), as was reaping low on the stem or uprooting. The possession of multiple arable fields may also have been a consistent practice during this time, to accommodate the cultivation of multiple crop species.

Harvest processing

Due to the abundance of the Swiss data and the limited scope of this chapter, this data was not analysed in terms of household size based on harvesting practices (cf. Chapter 6, section 6.4.4). A few sites from three regions in Denmark however, with data of a more manageable size, were analysed, including sites in Jutland, Northern Schleswig, and Djursland (Robinson 2003, Table 3-8). Sites from both the NEBA and NLBA were employed, and only contexts from houses, including hearths, postholes, and cultural layers from settlements.

The results of the analysis are shown in Figure 9.42. Since only summarizing information was used for this analysis (Robinson 2003), sites are represented by only one data point.

Interestingly, the sites from Denmark dating to the NEBA all fall in the category “large households”. The only site from West Frisia which portrays similar characteristics during this time period is Middle Bronze Age Bovenkarspel (Chapter 6, Figure 6.20).

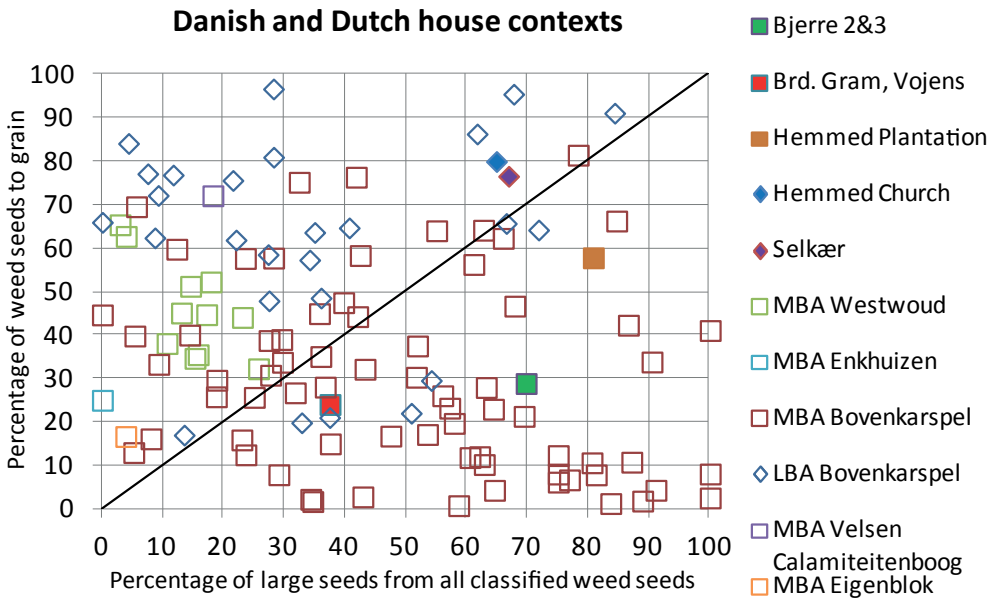


Figure 9.42. Harvest processing practices of the Dutch (empty symbols) and Danish sites (filled symbols. Squares denote MBA/NEBA sites; diamonds represent LBA/NLBA sites. x-axis represents the percentage of large weeds in a sample, y-axis represents percentage of small weeds in a sample. Many small weeds are related to unclean storage of harvest and small households, whereas few large weeds in a sample are related to clean storage of harvest and large households (cf. Chapter 6, section 6.4.4).

Based on the data presented, Danish NEBA sites from all areas mostly possessed larger households than sites in West Frisia (except Bovenkarspel) and the Netherlands at large. However, due to the proximity of one sample to the 45° line (*i.e.* Brødrene Gram, Vojens, Northern Schleswig), it is possible that this sample in fact reflects a mixed situation. More samples are necessary to draw stronger conclusions about the harvesting practices from this particular area and time period.

The two examples of NLBA sites fall just left of the 45° line, and seem to have shifted slightly towards smaller households, similar to the LBA Bovenkarspel situation. Again, samples are few and close to the line, so conclusions must be interpreted with caution until more data is available.

It seems that the sites in Denmark are generally comparable to the West Frisian situation, but only regarding Bovenkarspel. In the NEBA/MBA, Danish sites fall within the category "large households", whereas most West Frisian households are still "small" during that time. In the NLBA/LBA, both Bovenkarspel and Denmark seem to experience a shift in size towards smaller households which are related to the more unclean storage of crops.

Storage

Several examples of grain storage in Denmark are summarized by Andreasen (2009). She lists finds of wooden containers, leather sacks hung from the ceiling, and ceramics in which the grain was stored (Andreasen 2009, 55 and references therein). Presumably, grain was stored in the eastern part of the house, either on an attic or below the ground, provided that there was no barn in this part (Andreasen 2009, 55). Bronze Age examples of storage in Switzerland are unknown to the author.

9.5.4 Wild plant gathering

Wild plant composition

Wild fruits and nuts

Wild fruits and nuts from Danish and Swiss sites

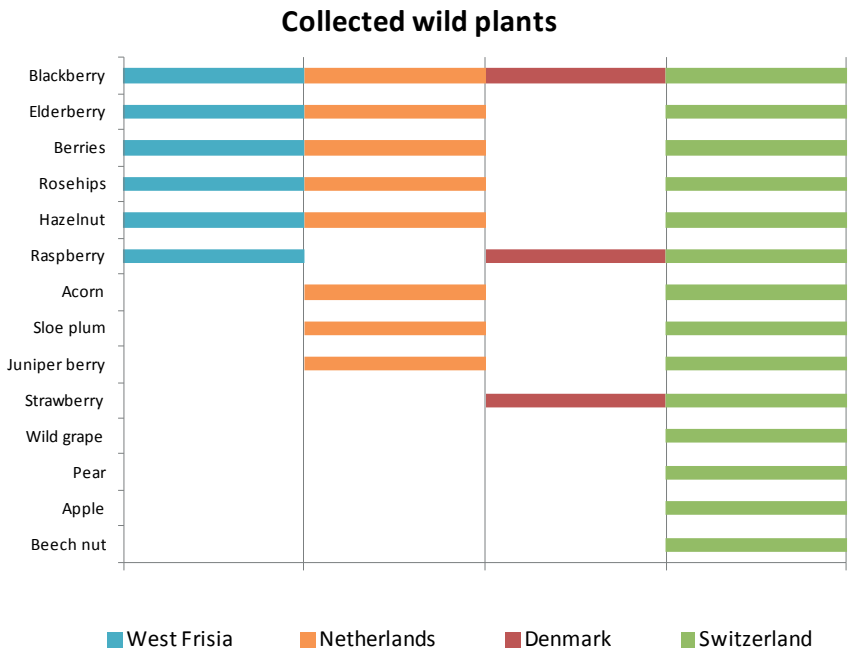


Figure 9.43. Presence/absence of collected wild plant species in the Bronze Age in Denmark and Switzerland compared with the Netherlands and West Frisia.

were summarized from all contexts and states of preservation (Figure 9.43); other wild plants were only included here when obtained from house contexts. Swedish data was insufficient. The total list of wild plants from Switzerland was too elaborate to be included here, but it is discussed in summary, where appropriate, in each of the following paragraphs. Several fruits and nuts were found in both regions, including wild strawberry, raspberry, and blackberry. Switzerland furthermore yielded apple, pear, sloe plum, wild grape, numerous other berries, hazelnut, acorns, and beech nuts (Jacquat 1989, 77-8). Other wild plant species are only included in following discussions on wild plant use when obtained from house contexts.

Other wild plants

The wild plant species from both regions are represented by mostly charred seeds or fruits, or remains of unknown preservation condition. This means that an analysis similar to that performed for West Frisia and the Netherlands could not be attempted for the European regions. However, it can be assumed that the collecting practices in these areas will have resembled the Dutch trends, also considering the fact that many of the plant species possess other consumption possibilities besides seed (including consumption of roots, leaves, stems, and flowers). Still, in order to test this assumption, more data will need to be analysed in the future.

Gathering locations

Both the Nordic and Swiss regions possess a range of wild plant species that derive from many different habitats. They include, amongst others, heather, forest, open grassland, arable fields, wetland areas, and mountains. Similar to the Dutch situation, people exploited a wide variety of landscape types present in the (presumably) near surroundings of the settlement to aid their subsistence.

Gathering practices

Considering the essential nature of wild plants in Bronze Age subsistence based on the results of Chapter 8, it is assumed that wild plant gathering will also have occurred year-round in the other European regions in order to meet raw material and dietary requirements.

Use of plants

Direct indications for wild plant use in the Nordic countries are restricted here to what is mentioned in the site references of Table 9.4, and some further stray examples. The overall extent of wild plant use in the Nordic countries cannot be entirely covered by this small selection, but it will be able to provide an impression of the variety of possibilities during this time period. Indirect indications for plant use in Denmark were investigated using the PFAF ethnobotanical online database (PFAF 2016).

In the Swiss lakeside settlements, the preservation conditions were so excellent, that a large variety of wild plant species was uncovered. Due to this abundance, only some examples of wild plant use are highlighted here. For more elaborate reading, see Pillonel (2007) and Jacquat (1989).

Raw material

Denmark and Sweden

At several sites, wooden objects were uncovered – excluding the building material here – which include ards, wooden (grain storage) containers, oak coffins, and even a folding chair (Andreasen 2009: 24-6, 32-2 and references therein; National Museum of Denmark 2016a; 2016b). Furthermore, the famous cloth made from nettle fibres is a Danish find, as are numerous other textiles made from various plant fibres (Bergfjord *et al.* 2012; Scandinavian prehistoric costume 2016). Clearly, wild plants played a very important role in all aspects of Danish Bronze Age life.

Indirect indications for wild plant use in Denmark include uses such as insecticides and repellents, thatch, basketry, dye, tannin, fuel, bedding, soap, rope, fibre, and of course wood as building material. Unfortunately, the Swedish data was again insufficient for a similar study of wild plant use.

Switzerland

The Swiss lake-side settlements have yielded many examples of the use of wild plants. Direct indications include numerous types of wooden objects, which range from various types of building material, to everyday objects including: wood working tools, such as handles of axes, adzes and chisels, hammers, and wedges; agricultural equipment, such as hoe, rake, digging stick, and sickle handles; food processing tools, such as a whisk, various containers, dishes, ladles, and a bucket. Other wild plant uses include examples of various crafts such as creating wickerwork, basketry, and making pottery. Evidence for the construction of textiles and clothing was also present in the form of spindle whorls and related equipment, as well as buttons. Finally, boat fragments were uncovered, as were floats, which are both related to the practice of fishing (Pillonel 2007).

Indirect indications mentioned by Jacquat (1989, 89-91) for plant used as raw material include use as fodder, bedding, dye, and fibre. Most likely, a more in-depth analysis of the plant remains from Hauterive-Champréveyres with the use of the PFAF ethnobotanical online database (PFAF 2016) would reveal even more potential applications. However, due to the large amount of data and the limited scope of this chapter, a complete analysis of the Swiss botanical data is not attempted here. Overall, however, the assemblage of wild plants uncovered in Switzerland does provide a more detailed view into the elaborate skill and knowledge present amongst Bronze Age farmers. It also underlines the effect that less favourable preservation conditions can have on the range of possibilities postulated for a society. Surely, a comparable spectrum of tools and equipment such as found in Switzerland must have existed in the other regions as well.

Diet

Denmark and Sweden

Clear indications for wild plant collection for the diet in Denmark are obtained from the presence of berries, fruits, and nuts, such as acorns, hazelnuts, dried apples, wild strawberries, raspberries, and blackberries (Andreasen 2009, 33-4). There are also several indications that other wild plants, not so often considered as an addition to the diet, were purposefully collected. They include finds of clean concentrations of wild plant seeds such as soft brome, black bindweed, and corn spurrey (Behre 2008; Andreasen 2009, 34). Corn spurrey was also indicated as being collected for its seed based on the data from Hattemerbroek (Table 9.2), which now seems confirmed as a practice. Black bindweed, however, was not included in the analysis of section 9.3.4 as it was classified as being unsuitable for consumption based on ethnobotanical references

(cf Chapter 7, section 7.4.2). The finds from Denmark signify that the edibility of a plant is very subjective: the range of edible plants in both West Frisia and the Netherlands can now be viewed as a further underestimation of reality.

Although an in-depth analysis was not possible based on the available Danish data, it should be mentioned that of the 34 edible species uncovered in Denmark, more than a quarter of the species (*i.e.* nine) are only collected for the consumption of vegetative parts. Since plants collected for this purpose are always underrepresented in comparison with plants collected for their seed, it can be imagined that the original range of collected plants for vegetative parts will have been extensive.

Switzerland

The potential to investigate dietary uses of wild plants was very high in Switzerland. Apart from the cereals mentioned in the previous section 9.5.3, several wild plant species were collected for their various parts. These include plants of which the roots, tubers, leaves, flower heads, and stems are consumed (Jacquat 1989, 76-7). Furthermore, several fruits and nuts were found, including apple, pear, sloe plum, wild grape, and numerous berries, hazelnut, acorns, and beech nuts (Jacquat 1989, 77-8). Other culinary uses of wild plants are represented by several plants used as potherbs and oil plants. Clearly, wild plants still formed an integral part of the subsistence economy in LBA Switzerland.

Preservation conditions will have been a major limiting factor when interpreting wild plant use on many Bronze Age sites, which has resulted in a greatly impoverished image of a farmer's life. Rare finds with good preservation conditions, such as in Switzerland but also West Frisia, can provide valuable insights into the daily life of Bronze Age people which would otherwise remain invisible.

9.5.5 Summary and discussion

West Frisia was originally considered as a case study for communities along the North Sea coast. Due to the fact that research on coastal communities in eastern Great Britain and northern Germany is done in different research projects (see note 1), the comparison of West Frisia with other regions has been extended to include other coastal sites. These include the Nordic sites in Denmark and southern Sweden (also on the eastern coast), as comparative regions, whereas the lakeside villages in western Switzerland were chosen as a contrasting example of Bronze Age subsistence near a lakeshore in central Europe. What has become clear from both comparisons is that the Bronze Age was a period in which each area possessed its own unique set of crops. At first glance, the same set of domestic animals was kept everywhere, but there are indications that different breeds were kept in each region. However, not only the domestic plant and animal species differed; also varying ratios of the available crops and livestock species were observed. The set of domestic resources clearly differed between regions, which was possibly a result of a combination of local environmental, subsistence economical, temporal, and/or social conditions.

What has furthermore become clear from the comparison of West Frisia with the different regions is that basic crop and animal husbandry practices are largely comparable. The purpose of keeping livestock may, however, have differed from region to region.

In contrast to domestic resources, which appear to have been diverse in both composition and relative frequency, wild resource exploitation was comparable between regions and a constant factor. Overall, both the hunting of large mammals and the collection of wild plants seemed to have targeted similar species regardless of region, and was probably performed with a similar purpose: indications for hunting large mammals for raw material in the form of antlers or hides/pelts exist in both Denmark, Sweden, and Switzerland; wild plant use included many examples of raw material, as well as additions to the diet, with many different (vegetative) wild plant parts being consumed. Both wild plant and animal exploitation will have occurred throughout the year, to form a constant addition to subsistence. These resources will have been exploited in the immediate surroundings of the settlements, since none of the species show clear indications for non-local habitats.

The rich dataset from West Frisia has provided a good basis for comparison with the Nordic coastal communities, where the available botanical and especially zoological data was less well preserved. Switzerland, where more pronounced differences occurred in both crop and animal husbandry practices, provided a good contrasting example to compare with West Frisia. Furthermore, the excellent preservation of remains at the Swiss lake-side sites has enabled a more detailed insight into Bronze Age subsistence, and provided more concrete evidence for the elaborate role of wild plants in it.

10. Evaluation of approach and results

The new approach adopted in the re-evaluation of the old and new data of West Frisia has greatly benefited from the incorporation of my background in both biology and in archaeology. The combination of fields of study has allowed for a truly interdisciplinary approach to the subsistence economy. This was achieved by incorporating the research field of systems biology to analyse a complex system such as farming; by creating an expectation of practice and only then comparing it to the observed archaeological data; and finally by being aware of and correcting for the potentially large impact of internal and external data biases which can cloud the subsequent archaeological interpretation of past human practice.

My background in biology includes knowledge of and experience with the research field of systems biology, in which individual genes, proteins, and metabolites are investigated, which are eventually combined in an attempt to understand an entire organism. This unique approach has similarly been employed to investigate a complex system such as a subsistence economy. First, the separate parts of this type of economy were researched, including animal and crop husbandry, hunting and gathering. However the separate parts are merely the means by which farmers can maintain their subsistence. The actual subsistence economy, rather, is a dynamic and complex system consisting of many interacting components that change their configuration depending on many factors including environmental conditions, temporal conditions, and social conditions. Therefore, the results of the analyses of the different components of subsistence were combined to view the farming system as a whole. Similarly, the landscape was reconstructed using all available indicators for the environment, which included biological information on both plant and animal species, which were eventually combined to view the landscape in its entirety, as an ecosystem. By researching the subsistence and landscape in this manner, many new insights were gained into the complexity and interconnectivity of both farming and nature.

Furthermore, the approach in this thesis did not only involve taking what was found archaeologically into consideration, but above all what could logically be expected of a Bronze Age subsistence farming system. This expectation was achieved first and foremost by using ethnographical studies with records of present-day farming communities comparable to the presumed Bronze Age situation. Ethnography has proven to be a very useful tool in identifying basic practices related to farming and wild resource exploitation, rather than using it for the comparison of cultural phenomena. These basic practices were shown to be similar in different areas of the world, regardless of geographical location, climate, and time period, and so provided a sound basis for comparison with prehistory. Practices which are (nearly) invisible in archaeology, such as wild plant consumption, were recognized as a result, and it is these practices which turned out to be the most essential for living a healthy life as a farmer.

Finally, by investigating the process behind each subsistence strategy, several problems could be identified with regard to practical approaches and scientific reasoning based on (flawed) bio-archaeological datasets. For these problems, new methods and viewpoints were introduced, incorporating the effects of taphonomy on botanical and zoological archaeological assemblages in order to arrive at an, as much as possible, unbiased dataset. Similar to biological research, this dataset was subsequently compared to the expectation made for each aspect of the subsistence economy/landscape. Differences or similarities observed based on this comparison could therefore be more securely related to the revelation of past human practices, which is the main focus of archaeological research.

10.1 NEW MODEL FOR BRONZE AGE FARMING IN WEST FRISIA

Bronze Age farming in West Frisia consisted of the employment of four subsistence strategies,

including crop and animal husbandry, but also hunting and gathering, in order to acquire the basic necessities of life. For this purpose, the settlement surroundings were exploited by people for both domestic and wild resources. This left a considerable mark on the landscape, as households would have required on average 0.3 km^2 of land to obtain these commodities. Especially in the Middle Bronze Age, humans and livestock, as well as wild animals impacted the environment, and West Frisia can be characterized as having been densely populated. However, during this period, forests still existed over extensive areas in the landscape.

In the Late Bronze Age, increasingly wetter surroundings reduced the size of suitable inhabitable land which would have negatively impacted the number of people and livestock in West Frisia. Farmers who did remain in this area would have practiced all subsistence strategies as before, perhaps with slight changes in crop and animal husbandry in order to adapt to the changes in the landscape. Hunting and gathering however, would have remained the same stable and flexible addition to subsistence as it was in the Middle Bronze Age.

The diet of Bronze Age farmers would have mostly consisted of cereals, followed by meat (both domestic and wild), milk, wild plants, and fish. The vegetative parts of wild plants would have been essential to this type of cereal-based diet to uphold a healthy condition by providing essential vitamins A and especially C, which could not (easily) be obtained from other food sources. Meat from wild animals and fish would also have formed essential additions to the diet during times when domestic meat was unavailable. Hunting and gathering would therefore have been essential activities for the Bronze Age diet, even though their reflection in the archaeological record is comparatively limited. That Bronze Age West Frisian people were indeed able to sustain a relatively healthy lifestyle is reflected by their average length and their ability to heal well from trauma. Only slight indications for periodical minor nutrient-deficiencies could be identified, which may be related to times of general nutrient scarcity, such as during winter.

Clothing remains have not been identified in West Frisia, but, based on comparison with contemporaneous finds, the West Frisian Bronze Age wardrobe would most likely have consisted of a combination of linen and woollen garments, as well as clothing made from skins and pelts. Dyeing of textiles would also have been a very real possibility, since for example textiles from this time period often show signs of dyeing, and West Frisia has yielded many plants suitable for dyeing in its botanical assemblage.

Houses in West Frisia were mainly constructed of wood. The interior of these houses, however, has never been truly reconstructed. Based on both the expectation and the actual finds of Bronze Age tools related to the subsistence activities, it is clear that these interiors were far from empty. West Frisian houses will have contained several activity (storage) areas, in which activities such as clothing manufacture, cooking, tool making, sleeping, consumption (*i.e.* storage), and animal husbandry (*i.e*. barn) occurred. For the production of nearly all the tools and equipment required on a settlement, raw material obtained from wild plants and, to a lesser degree, wild animals is indispensable, which again underlines their importance for subsistence, regardless of uncovered quantities.

Although house plans usually appear very similar at every site, some inter-house differences were observed at Bovenkarspel Het Valkje with regard to household size and function. Both small and large households were identified, in which significantly different compositions of domestic animal species were observed, regardless of the size of the house plan. In addition, analysis of the different compositions of botanical remains has revealed that house plans should rather be termed building/structure plans, since different building functions can exist, including separate farmhouses, separate barns, and combinations of farmhouse and barn in one building.

To obtain the different resources, each season of the year would have been spent performing different activities. In autumn, sheep would have been transported from the increasingly wet areas

in the surroundings to higher, and dryer locations. Breeding of all cattle, sheep, and goat would also occur at this time. On the arable fields, manuring (with animal dung, household waste, etc.) and ploughing to prepare fields for sowing in spring would begin. Exploitation of wild resources during this time would have included hunting game, migratory bird and fish species, and the collection of fruits, seeds, and berries. In winter, vulnerable and valuable animals would have been placed inside to protect them from the weather and predators, with other livestock kept outside. Pig breeding would also have occurred at this time. Arable fields would mostly have been left alone, whereas a second round of ploughing to prepare the seed bed may have occurred towards the end of winter. Since winter would have been a quiet time for farming activities, this season could be spent repairing or making tools and equipment. Other activities during this time would have included active game hunting for large mammals, and trapping of fur animals, and at the end of winter, catching of migratory birds and fish. Throughout winter, roots and tubers would have been the main wild plant resource available. In spring, all domestic animals would have been returned to the grazing fields, where most would now have given birth, making milk available to the farmer. Animals dying during this process would have been culled and processed for (later) consumption. Hunting would have been limited during this time due to abundance of domestic resources. However, eggs and fish would have been available now. Wild plants in their growing stages would have made young shoots and leaves available. In summer, livestock would have grazed in different areas of the landscape, and become available for breeding in late summer. On the arable fields, weeding would have occurred, and later in the summer, harvest would take place. After harvest, stubble fields would have been grazed by livestock and/or burned. Hunting water fowl would have been a viable option in summer, as they experience a flightless period during this time due to moult. The wild plant parts available would have included greens and seeds, followed by fruits, nuts, and berries.

In the Late Bronze Age, periodical flooding of the landscape would have made certain areas inaccessible for exploitation during winter. The resulting reduced amount of available appropriate land would have been able to accommodate less people, livestock, and wild animals than before, which is reflected in the investigated crop and animal husbandry practices. Crops were stored in a more unclean state, probably related more limited available time for harvest due to deteriorating weather conditions or less people available to help. Animal husbandry practices investigated reflect a change in strategy, towards an increased production potential for meat and milk, but a less viable composition of the herd in the long-term. These changes show that people were adapting to changing environmental conditions, rather than migrating to other areas to evade these changes. Thus, throughout the Bronze Age, West Frisian farmers remained self-sufficient by combining both domestic and wild resource exploitation to complete their subsistence in a dynamic environment.

10.2 IS WEST FRISIA SPECIAL?

West Frisia has often been regarded as a different, almost special region within the Netherlands and the Dutch Bronze Age. Prominent characteristics of this area include many aspects of subsistence, which are the results of the analyses of Chapter 4-7. For example, animal husbandry is characterized by the presence of many cattle bones and an equal use potential of cattle for meat and milk, the latter of which is deemed a universal aspect of small-scale mixed farming communities. A presence of mainly hulled barley and emmer wheat was observed, with a slight increase in the frequency of emmer wheat occurring in the Late Bronze Age. The presence of both linseed/flax and broomcorn millet furthermore, show that other crops were also cultivated. The presence of large households at Bovenkarspel in the Middle Bronze Age was apparent, but it is the only West Frisian site with this size of household. Wild resource exploitation shows a wide range of wild animals hunted, a marked absence of collected fruits and nuts, and the overall presence of many wild plant species.

The comparison of West Frisia with other Dutch regions (including Texel, Kennemerland, Noordwijk, Haaglanden, Hattemerbroek, the western river area, and the eastern river area), and European

regions (including Denmark, southern Sweden, and Switzerland) has, however, put this area into perspective. Several aspects of West Frisian subsistence are certainly different than those observed in the other regions, but all investigated sites show local variation. Available crops and domestic animal breeds appear to differ in each region, both in composition and relative ratios.

In addition, some of the observed differences have only become apparent after the analysis of practices based on the rich West Frisian data. For example, herd characteristics and livestock use were analysed for the West Frisian situation, and, after comparison with other regions, have revealed inter-regional differences in the purposes for herds kept. In West Frisia, an equal use of cattle for meat and milk was observed, whereas other regions inclined more towards use for meat (Dutch river area – east), or milk (Nordic Late Bronze Age Denmark).

Besides differences in many of the investigated subsistence strategies between regions, there are also similarities observed, but again, these have only become apparent after the reconstruction of practices based on the West Frisian data. For instance, the analysis of harvest processing has enabled the identification of different household sizes in both West Frisia and Denmark, and the recognition of a trend towards smaller households in the (Nordic) Late Bronze Age in these regions. It has also been established that other practices regarding crop husbandry were similar in many regions, including sowing time, harvesting height, and overall conditions of arable fields.

Hunting and gathering appear to have been constant factors aiding subsistence throughout the Bronze Age, throughout the different regions. The most frequently found large mammal species were hunted in every region, regardless of climate, geographical location, and time period. This basic "set" of animals was furthermore complemented with locally available or desired animals, which are different in every region, but do fall within similar categories, including fur animals, and migratory bird and fish species. Wild plant gathering also shows a similar trend to hunting, in which a basic "set" of wild plants was gathered, and which was further complemented with locally available or desired plants. These latter plants, although belonging to different species, also seem to belong to consistent categories, which include consistent uses such as fibre, bedding, basketry, and dye (observed in all regions), as well as tannin, soap, repellent, and thatch (observed in both the Dutch and Nordic regions). Both hunting and gathering would have occurred on a year-round basis, exploiting different animals and plants in different seasons to obtain raw material and food to complement subsistence.

West Frisia can thus be regarded as special where its excellent preservation conditions are concerned, since these allowed for a detailed analysis of the subsistence economy in the Bronze Age with which other regions could be compared. However, it is not special with regard to its differences in subsistence when compared to those of the other researched regions because every region showed local differences. This local variation appears to be a consistent aspect of farming in the Bronze Age and can in fact be regarded as a common feature of subsistence during this time.

It has become clear from the international comparison that the diverse exploitation strategies employed in the West Frisian subsistence economy were by no means an exception in the Bronze Age. Rather, the good preservation of remains in West Frisia has improved the visibility and recognition of practices which otherwise would not have been easily identified. West Frisia was therefore not exceptional with regard to its subsistence economy in the Bronze Age, but rather has been able to provide a basic understanding of Bronze Age subsistence due to its richness in data.

10.3 BRONZE AGE FARMING IN NORTH- WEST EUROPEAN COASTAL COMMUNITIES

Bronze Age subsistence can in general be characterised as a balanced combination of domestic and wild resource exploitation, of which the individual components complement each other in a flexible manner throughout the year.

Crop and animal husbandry form a constant system which forms the basis of the subsistence economy. Farmers need to be able to rely on the products produced, which mainly provide them with food in the form of cereals, but also meat and milk, and raw material, including bone, hide, wool, etc. Since cereals form the major staple food and crop failure is a potentially devastating phenomenon, this product needs to be produced in a reliable manner. Therefore, the basic activities related to crop husbandry are kept the same throughout the Bronze Age. Animal husbandry practices also remain similar, although the purpose of the herds seems to shift from the Middle to the Late Bronze Age in different regions. So, overall, crop and animal husbandry both seem to consist of different species and landraces/breeds, with similar basic practices; especially animals have changing purposes throughout the Bronze Age.

Hunting and gathering on the other hand, is also a constant factor of subsistence, and a more flexible system which provides a variable but essential addition to the subsistence economy throughout the year. The availability of desired wild plant and animal species changes from season to season and people exploited different resources for both raw material and dietary addition, which were not available from their own produced crops or animals. However, gaining these essential resources means that different practices are required every time, also because they need to be combinable with crop and animal husbandry practices. Hunting activities therefore range from active hunting with bow and arrow to passive hunting including the use of nets and traps, and different plant parts are collected in different seasons and at different times in order not to interfere with the activities related to crop and domestic animal production. Both hunting and gathering appear to possess a clear set of species which are always targeted, complemented by other locally available or desired species. These latter species, although different in every region, appear to belong to similar categories, such as fur animals, and migratory bird and fish species. Living in close proximity to the coast, be it freshwater or sea, means that coastal communities are able to exploit many of these species of wildlife, which are abundant in wetland environments. Furthermore, since these animals are mostly unavailable in other types of environments, they can be considered as potentially very valuable commodities for trade or exchange.
To summarize, hunting and gathering throughout the Bronze Age consisted of targeting similar species, with varying basic practices, but consistent uses for the plants and animals.

It is clear that Bronze Age subsistence could not have existed without incorporation of all four subsistence strategies. Crop and animal husbandry provided people with relatively secure production of staple foods and some basic raw materials, but could never have solely ensured healthy people, livestock, and settlements in the long-term. Hunting and gathering, although less visible as a practice, provided people with critical dietary micro-nutrients, additional sources of food during less bountiful times. It also ensured the availability of the raw material for the buildings, and almost all of the tools, equipment, clothing, and other products essential to daily life in the Bronze Age.

10.4 CONCLUSION AND FURTHER APPLICABILITY

The new results, summarized in this chapter, were only achieved by the approach presented in this thesis: by thinking things through in a logical manner and analysing data with the use of several disciplines, not by copying previous methods. This has resulted in specific new insights including, amongst others: a landscape reconstruction including available vegetation as well as the impact of farmers on it; the contribution of hunting and gathering in a farming system; a new method to analyse animal husbandry practices; and the role and composition of manure to fertilize arable fields.

The holistic approach has furthermore resulted in an integrated analysis of these different aspects related to subsistence. It has yielded a detailed understanding of the complexity of subsistence to a level which could not have been achieved by only considering single or unintegrated disciplines. In effect, a completely new image of what it means to be a farmer in the Bronze Age living in a wetland environment was created.

For example, the required skill and knowledge level of Bronze Age farmers for exploiting their surroundings has become clear: farmers needed to know what to do for every subsistence-related activity, at what time, and how this needed to occur. It required great planning skills to ensure the compatibility of different activities and to maintain their balanced interconnectedness throughout the year. It has also become apparent from the applied method that prehistoric farmers may have depended even more on wild resources than the present-day farmers observed in ethnographic parallels, as they needed to produce everything required for subsistence with the materials available in the (immediate) surroundings of the settlement. The importance and influence of the landscape was significant, providing people with resources for fulfilling basic survival needs such as food, clothing, and shelter. Living in a wetland environment provided many opportunities for exploitation, but this type of landscape is also continuously changing and challenging. Nevertheless, throughout the Bronze Age, the opportunities for both farming and hunting and gathering in a wetland environment must have exceeded the disadvantages, because people adapted to these changes rather than that they started migrating to other areas when conditions became less favourable. Staying in this wetland area meant that all subsistence strategies could be, and were practiced, in a carefully balanced manner, allowing farmers to continue their subsistence in Bronze Age West Frisia.

The approach presented in this thesis has proven to be very valuable in researching Bronze Age wetland communities. It is also potentially very valuable for research on other areas or subjects, since it is by no means restricted to the Bronze Age, to farming, or to a specific geographical location. Rather, the approach is applicable to any time period, area, or form of subsistence so long as the expectations made before the comparison with the data (*e.g.* ethnographic parallels) are chosen appropriately and possible data biases are taken into consideration.

The combination and integration of several disciplines in this thesis, related to biology and archaeology, but also ethnography, has proven to give new impulses to the research, providing new views on old subjects, which are not often attempted or observed by researchers who stay within their own respective areas of expertise. The yields of the approach presented here in my opinion greatly outweigh the debatable trouble of making oneself familiar with (the methods of) other disciplines. Even if there is a good reason not to venture into other research fields when studying a subject, the interaction with other people and integration of results is surely possible. Therefore, the results of this thesis and its approach should be considered a call for more integrated research into complex systems to allow for a better understanding of the past.

The final chapter lists the subjects which were not included in this thesis, but are of value for an even better understanding of Bronze Age subsistence in wetlands. Possible manners in which these topics could be researched when enough appropriate data becomes available are presented, with the aim of ensuring that knowledge on and research towards Bronze Age wetland communities continues to expand in the future.

11. Valorisation and recommendations for future research

In this final chapter, the results from this thesis will be weighed in terms of the possible valorisation value of the conducted research, and in terms of which steps could be taken in the future for further research on Bronze Age subsistence in wetland environments.

11.1 VALORISATION

Valorisation is about the impact that can be achieved through the transfer of scientific knowledge. This impact may include making knowledge and expertise available to other researchers as well as communicating knowledge to the general public. Examples of these two types of valorisation based on this thesis will be shortly discussed here.

11.1.1 Valorisation value

The way in which knowledge and expertise is made available to other researchers is through the presentation of the new holistic approach of this thesis, as outlined in Chapter 1 and 10. This approach has not only yielded knowledge on (the reconstruction of) the daily life of a Bronze Age farmer, but is also widely applicable to different geographical locations, time periods, and subsistence strategies with the appropriate adaptations and consideration (see Chapter 10, section 10.4).

Last but not least, this thesis has brought forth a new method for the construction and analysis of mortality profiles based on post-cranial bones. This method, Faustitas, is freely available to others to use and improve for future research on (the use of) domestic and wild animal herds.

11.1.2 Public outreach

The main manner in which knowledge based on this thesis was directly communicated to the general public was via the weblog of the project group (www.bronstijdwestfriesland.nl) and during a special open day in West Frisia.

The information produced in this thesis, especially from Chapter 8, can be very useful for archaeological open air museums. New insights into the daily life of the Bronze Age may be used in open air museums to directly transfer knowledge on food, activity, tools, clothing, and the interior of a house to the general public. The museumpark Archeon in Alphen aan den Rijn, the Netherlands, for example, has already incorporated the new view on the contribution of wild resource exploitation in Bronze Age subsistence (cf. Chapter 4 and 7) into their education programme. The Zuiderzee museum in Enkhuizen, West Frisia, which possesses a Bronze Age house reconstruction, has also included this information. Finally, the Bronze Age diet reconstruction presented in this thesis (Chapter 8) has become the topic of an exhibition in the museum Huis van Hilde in Castricum, the Netherlands, which also houses the archaeological depot of West Frisia.

11.2 RECOMMENDATIONS FOR FUTURE RESEARCH

This section attempts to outline the general important topics for future research on Bronze Age subsistence in wetland environments which could not be answered in this thesis based on the data presently available. The list presented here is by no means complete or workable under every circumstance, but provides general ways by which site excavators and scientists can work together to research these topics. First, the different topics are summarized per chapter for the chapters on subsistence (Chapter 4-8), each being followed by a number between brackets. This number is used to identify which methods can be employed to answer this topic in future research. Each chapter has its own topics and numbers. Methods are split into two categories: field research and laboratory research. Field research is sub-divided into specific methods, which are related to West Frisia in particular, but also into general methods, which could be of importance anywhere. Laboratory research is also further sub-divided into specific areas

of expertise, which can each provide a different method for analysing the remaining topics. This list of disciplines thus results in the possibility for multi-proxy, interdisciplinary analysis. Finally, a summary of the old methods and viewpoints, which are no longer deemed accurate based on this thesis is provided, followed by the new and alternative methods and viewpoints which may form the basis for further research.

For practical advice on how to sample and preserve samples for further research, see the SIKB guide for sampling (www.sikb.nl).

Chapter 4: Hunting

Remaining topics:
- Passive and active hunting techniques (1)
- Use of wild animals (2)
- Seasonality of hunting (3)
- Use of crustaceans, molluscs, amphibians, reptiles for consumption (4)

How to answer them?

Field research
- Be aware of wooden/organic objects, even though not immediately recognizable as a specific tool > *e.g.* parts of traps/nets? (1)
- Be aware of location of flint arrowheads etc. (1)
- Be aware of the presence of organic raw material, especially in wet contexts (leather, skins) (2, 4)
- Sieve multiple types of settlement context for amphibians, reptiles, molluscs, crustaceans, etc. (4)

General
- Ample sampling of building structures, and contexts on off-site locations
  - o Continue to assess the range and spread of wild animals per house and at the settlement (G1)
- Sieve several contexts on 1-2 mm sieves
  - o Continue to assess small animal remains to enable inter-site comparison with regard to the environment around settlements and use of animals (G2)

Specialist research

Zoology:
- Reconstruct fish size, it gives insight into possible catching techniques (1)
- Be aware of weapon cut marks / skinning marks / gnaw marks (pre-/post-mortem) (1,2)
- Be aware of seasonal indicators for hunting: establish age at slaughter, presence of seasonal traits (antlers), etc. (2, 3)
- Identify crustaceans, molluscs, amphibians, and reptiles to species level where possible in order to assess their potential addition to the diet (4)

Textile and leather research:
- Identify the species of animal from which the leather derives (3)

Chapter 5: Animal husbandry

Remaining topics:
- Improved gender recognition of animals (culling, import) (1)
- Location of animals (barn, shed, pen, fields, seasonality) (2)
- Use of animals (traction (oxen?), milk consumption, wool/leather) (3)
- Inbreeding/breeds (4)
- Location of pastures (5)
- Animal health (6)

How to answer them?

Field research
- Collect complete animal jaws separately for a DNA analysis and Sr isotopic research (1)
- Collect complete metacarpals separately for metric data and aDNA analysis (1, 3)
- Be aware of possible barns/partitions/kraals/pens (2)
- Collect human jaws separately for identification of milk consumption and the animal species used for milk production (3)
- Be aware of the presence of organic raw material, especially in wet contexts and near (corroded) metal objects (leather, textile!) (3)
- Collect complete skulls separately (4)
- Be aware of “empty” areas in the landscape,

and the possibility of the presence of cattle hoof prints (5)
- Sample the intestinal area, the context feature, and outside the feature when complete skeletons are uncovered to assess the health of the animal (6)

General
- Ample sampling of every house plan
o Continue to assess the range of animal species kept per household (G1)
- Sieve several contexts on 4 mm sieves
o Continue to approach actual domestic animal species ratios (G2)
- Conduct a sieving experiment of multiple closed contexts
o Continue to assess the loss of bones per sediment type (G3)

Specialist research

Zoology:
- Assess the loss of species due to sieving and sediment type (G2, G3)
- Measure the metacarpal distal breadth and plot a graph of the results (1)
- Use Faustitas on post-cranial bones to assess age at slaughter and use of the culled herd, as well as the composition of the original living herd (3)
- Assess the age based on teeth, but be aware of taphonomy (ravaging correction!), to compare with post-cranial bones (3)
- Assess the likelihood of the presence of oxen based on traction indicators and size of the animal (3)
- Be aware of differences in breeds/inbreeding (withers heights, inbreeding, horns/polled) (4)
- Be aware of specific pathologies to assess the health of the animal (6)

Entomology:
- Assess the insect species, which can provide information on the location of livestock (2) and on the health of the animal (6)

Parasitology:
- Assess the endo- and ecto-parasites related to the general health of domestic animals (6)

aDNA research:
- Analyse complete metacarpals to assess the gender of the animal, and use as a check for the metric data (1, 3)
- Analyse animal jaws to assess the gender of imported animals (in combination with isotopic research) (1)
- Try to assess difference in breed within a species, based on haplotype, especially on imported individuals (in combination with isotopic research) (4)
- Analyse specific pathological indicators (mycobacteria) to assess the general health of animals (6)

Isotopic research:
- Assess the origin of domestic animals based on Sr isotopic data (1,4)

Tooth calculus analysis:
- Analyse human tooth calculus on specific proteins to assess milk consumption and the animal species used for milk production (3)

Textile and leather research:
- Identify the species of animal from which leather derives (3)
- Identify the wool characteristics of textiles and compare with wool from contemporary sheep breeds (3)
- Assess whether the woollen textile is potentially dyed (3)

NMR/XRF microscopy:
- Assess whether the woollen textile was dyed, and if so, with which plant species (3)

Chapter 6: Crop husbandry

Remaining topics:
- Identification of activity areas in houses (1)
- Recognition of type of fertilizer applied on arable fields (2)
- Seasonality of manuring and ploughing practices (3)
- Burning practices of fields (4)
- Locations of arable fields (5)
- Cultivation of flax for fibres (6)
- Off-site locations (7)

How to answer them?

Field research
- Systematic sampling of one house plan (use of areas?) (1)

- Sieve plough layers (use/type of fertilizer) (2)
- Be aware of and sample possible manure layers (2)
- Micro-morphological soil slides (burning, ploughing circumstances, use of fertilizer?) (2, 3, 4)
- Be aware of (absence of) plough marks (5)
- Be aware of and sample organic raw material, especially from wet contexts (6)
- Extend excavations tot areas beyond the settlement, whenever possible (7)

General
- Ample sampling of every context of a house plan
  - o Continue to assess household size for new excavations (G1)
- Be aware of storage structures/containers
  - o Continue to be alert towards potential storage locations (G2)

Specialist research

Botany:
- Use frequency of presence/absence, not quantity (1)
- Apply method of Stevens (G1)
- Be aware of the possibility of stubble burning practices (4)
- Attempt to identify flax fibres (6)

Micromorphology:
- Try to identify seasonal activities such as ploughing (3)
- Be aware the possibility of stubble burning practices (4)
- Try to identify the presence or absence of tillage marks (5)

Geochemistry:
- Test the effect of different types of fertilizer on ^{15N} values(2)
- Test the ratio of digestive metabolites (sterols and stanols) to assess the origin of the fertilizer used: herbivores, omnivores, carnivores (2)

Entomology:
- Assess the insect species, which can provide information on the state and type of animal manure (2), and the state and storage of the grain (G2)
- The insect species can also provide information on specific cultivated plant species, which are not always present in the archaeobotanical record (*e.g.* pulses, legumes)

Chapter 7: Gathering

Remaining topics:
- Areas of activity in and around the house (1)
- Actual evidence for used/consumed vegetative plant matter (2)
- Impact of taphonomy on different plant parts/ uses (3)
- The potential of waterlogged material (4)

How to answer them?

Field research
- Sample multiple complete house plans (1)
- Be aware of pottery with possible food crusts (do not clean) (2)
- Collect human jaws separately for identification of root/tuber consumption (starch) (2)
- Be aware of the presence of organic raw material, especially in wet contexts (basketry, fibres, rope, textile!) (2, 4)
- Sample waterlogged contexts (2, 4)

General
- Ample sampling of building structures, also on off-site locations
  - o Continue to assess the range and spread of wild plants per house and on the settlement (G1)

Specialist research

(Ethno)botany:
- Assess the possible uses of wild plants (ethnography) and try relate them to the house plan (1)
- Assess the edibility of wild plants (ethnography) and make note of (un)charred vegetative material from those plants in house contexts (2)
- Assess the relative frequency of charred and uncharred remains per species, as well as the preservation conditions in the sampled context (2, 3)
- Assess the potential conservation of different plant parts according to their use (*e.g.* is fire included in the use? Does/Can the plant bear seed

for its eventual use?) (3)
- Assess the range of ecotypes present in waterlogged contexts: many different ecotypes may point to collecting practices and the material may be analysed as such (4)

Biochemistry and microscopy:
- Analyse food crusts in ceramics botanically to assess the processing of various vegetative plant parts, most likely for consumption (2)

Tooth calculus analysis:
- Analyse human tooth calculus on starch granules which may point to the consumption of roots/ tubers

NMR/XRF microscopy:
- Assess whether textiles were dyed, and if so, with which wild plant species (2, 4)

Chapter 8: Bronze Age Farming in West Frisia

Remaining topics:

Diet and health:
- Specific diet composition (1)
- General and specific health indications (2)
- Diseases (malaria, tuberculosis, etc.) (3)

Clothing:
- Clothing types and construction (4)

Houses:
- Inside of the house (5)

Activity:
- Structure plan (6)

How to answer them?

Field research
- Be aware of the presence of organic raw material, especially in wet contexts and near (corroded) metal objects (leather, textile!) (4)
- Be aware of tools required for the processing of fibres and the construction of clothing (4)
- Be aware of tools required the different activities related to subsistence in general (5)

General
- Continue to combine all the information on subsistence available in order to gain insight into the household (G1)
- Continue to combine all the seasonality information on subsistence available in order to gain insight into the year-cycles for domestic and wild resource exploitation (G2)
- Be aware of the fact that a structure in the field should not immediately be termed house plan, because its function may be very different (G3)

Specialist research

Biochemistry and microscopy:
- Analyse food crusts in ceramics botanically and chemically to assess the composition of meals (1)
- Analyse more wild plant species with regard to their micro-nutrient composition (1)

Tooth calculus analysis:
- Analyse human tooth calculus on several food groups to assess the range of food sources consumed (1)

Isotopic research:
- Analyse human diet with the use of carbon and nitrogen isotopes (1)

Physical anthropology:
- Assess the general health level of individuals based on stature, dental caries, enamel hypoplasia, *cribra orbitalia*, Harris lines, and (healing of) trauma (2)
- Assess specific pathologies related to disease or nutrient deficiency (*e.g.* vitamin C, iron, malaria) (2)

Entomology:
- Assess the presence of *Anopheles* mosquitoes, or their larvae, which are hosts for malaria parasites

Parisitology:
- Assess the endo- and ectoparasites related to peoples' health and present diseases (2, 3)
- Assess the presence of the parasite (*Plasmodium*), which causes malaria

aDNA research:
- Analyse specific pathological indicators (*e.g.* mycobacteria) to assess the general health of people and possibly present diseases (2, 3)

Textile research:
- Identify the wool characteristics of textiles and compare with wool from contemporary sheep breeds (4)
- Assess whether the woollen textile is potentially dyed (4)

Do's and don'ts:

subject	DO	DON'T	see:
landscape reconstruction	use off-site pollen for a landscape reconstruction (diameter of basin > 5m)	use on-site pollen to reconstruct the wider landscape	Chapter 2
subsistence reconstruction	realise that mixed farming is inherently a small-scale affair with limited numbers of livestock and limited size of arable fields	think mixed farming entails endless numbers of livestock and size of arable fields	Chapter 3
hunting	assess the role wild animals play in the subsistence economy and thus their reflection in the archaeological record	relate frequency of remains directly to importance (for subsistence)	Chapter 4
animal husbandry	use the programme Faustitas to reconstruct age and herd dynamics, including use and living herd composition	use the methods of Chaplin (1971) and Payne (1973) to reconstruct age and use	Chapter 5
crop husbandry	keep an open mind towards arable field soil enhancements, such as green manure, turf, household waste, and animal manure	assume that crop husbandry is a static practice	Chapter 6
gathering	assess the potential that vegetative wild plants parts have for the subsistence economy and thus their reflection in the archaeological record	relate frequency of remains directly to importance (for subsistence)	Chapter 7
Bronze Age farming	realise that critical vitamins can only be obtained through the frequent consumption of wild plants	reconstruct diets purely based on calories; also, don't assume that nuts and berries supply enough annual nutrients	Chapter 8

Appendix

Chapter 1

A1.1. Example of a Middle Bronze Age West Frisian house plan

Chapter 2

A1.2. Expectations of past fauna in the terrestrial habitat types in West Frisia
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Chapter 1

A1.1. Example of a Middle Bronze Age West Frisian house plan

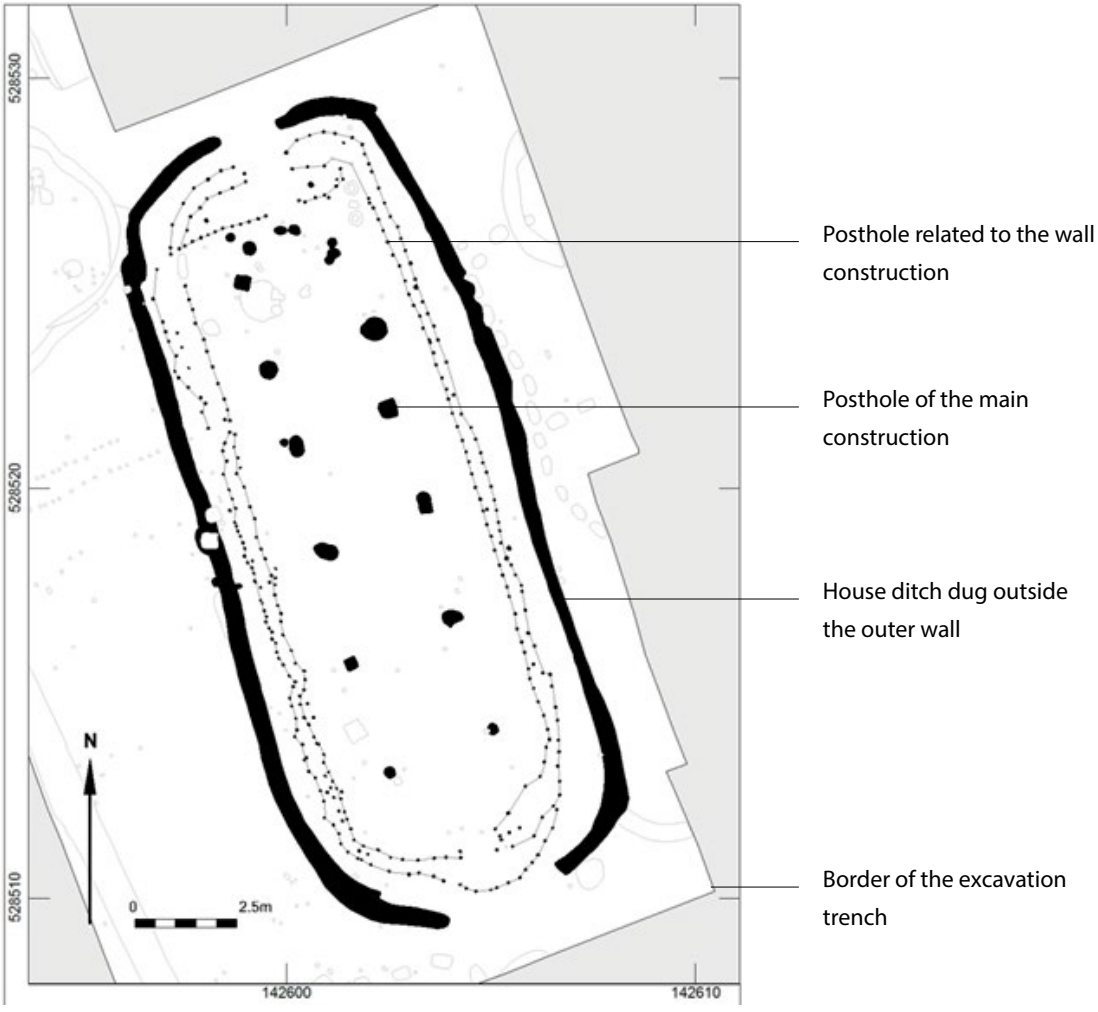


Figure A.0. West Frisian Middle Bronze Age house plan from Andijk-Noord (from: Roessingh in prep.).

Chapter 2

A1.2. Expectations of past fauna in the terrestrial habitat types in West Frisia

Figure A.1. The grassland and shrub land habitats with some of their representative mammal species (Images adapted from: BN de Stem 2008 and Ecosystema 2016).

Based on what is known about the subsoil, the hydrology of that soil, and the prevailing climate during the time researched, it is possible to make predictions of the past habitat types that might have existed in West Frisia (van Zijverden in prep.). West Frisia spans 40 km from the sea coast towards inland areas, creating very broad landscape possibilities. Among the habitat types are: grassland, shrub land, forest, wetlands, and marine intertidal/coast.

These habitat types will be discussed shortly below, broadly focusing on the characteristic flora and fauna that are expected for each landscape. Water types and expectation in fresh water, brackish water and saltwater will be mentioned in a separate section further below. Some animals were not present in the Bronze Age as they were introduced at a later period, so these are mentioned in the expectation, but excluded from further research.

Possible habitats and expectations:
(info from: Burton & Assen 1976 (mammals), Birdlife International 2012 (birds), and Vissengids 2016 (fish); photos and pictures adapted from: Mixed Forest 2007; BN de Stem 2008; Wetlands 2010; Oernatuur 2011; Heumensoord 2014; Ecosystema 2016).

Grassland:
Pure grassland is treeless and most mammals that thrive here are herbivorous or insectivorous.

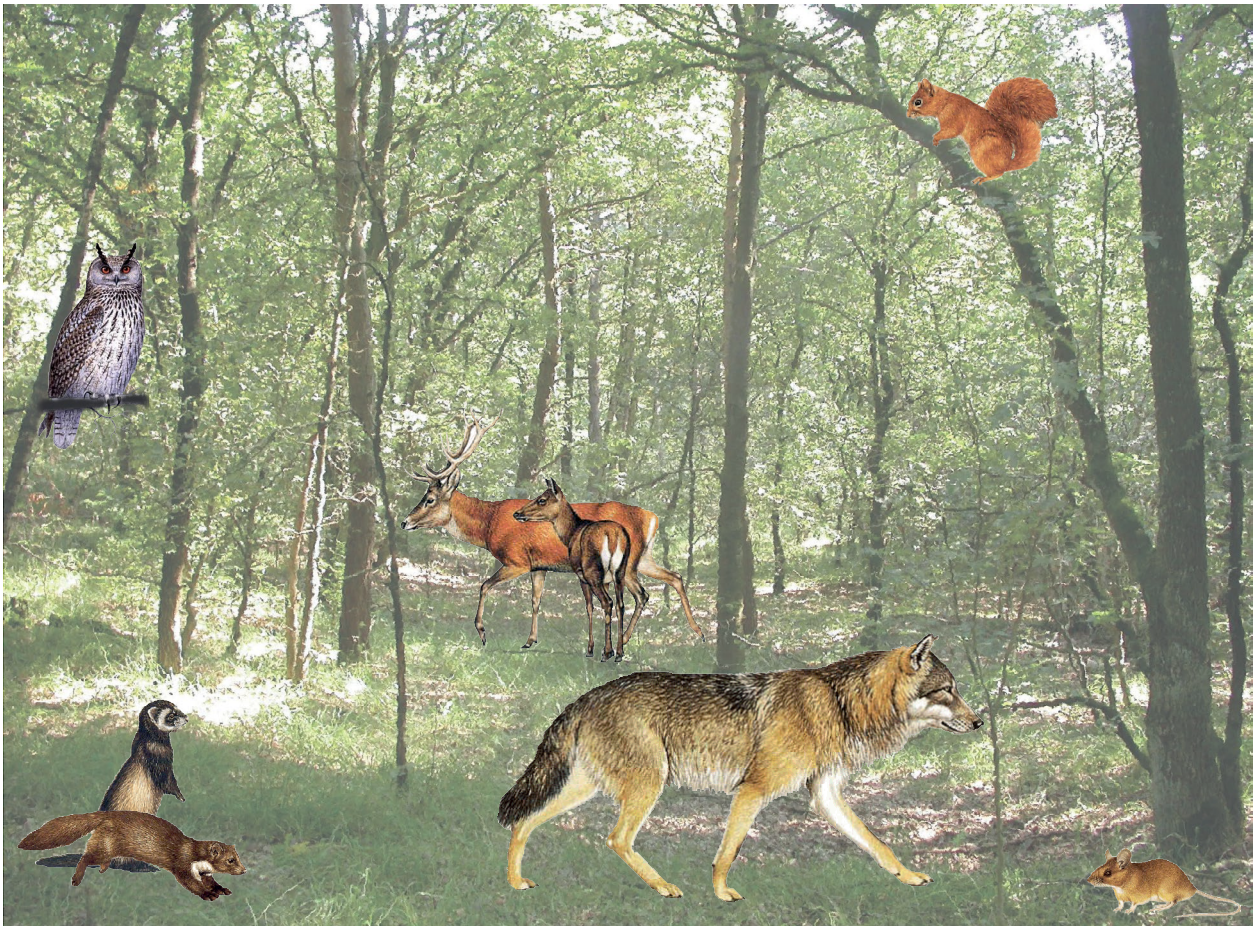


Figure A.2. The deciduous forest habitat with some of its representative bird and mammal species (Images adapted from: Heumensoord 2014 and Ecosystema 2016).

Mammals that characteristically prefer a pure grassland habitat include: common shrew (*Sorex araneus*), common vole (*Microtus arvalis*), field vole (*Microtus agrestis*), harvest mouse (*Micromys minutus*), wood mouse (*Apodemus sylvaticus*), European mole (*Talpa europaea*), and hare (*Lepus europaeus*). Based on the habitat preference, rabbit (*Oryctolagus coniculus*) belongs in this habitat and in shrub land. However, it was only introduced in the Netherlands during the Middle Ages (Gibb 1990, 115) and therefore it did not occur here in the Bronze Age. Many species of birds are expected in grasslands, so some groups have been made here. Among them are: birds of prey (*e.g.* buzzards, kites, falcons, harriers, kestrels), aquatic birds (*e.g.* ducks, geese), corvids, pipits, larks, wagtails, magpie, starling, ruff, blackbird, quail, white stork, Eurasian curlew, and northern lapwing.

The habitat grassland and its representative species can be summarized as presented in Figure A.1.

Shrub land:

Shrub land functions as the transitional area between grassland and forest. Here, grass fields are interchanged with patches of forest, consisting mostly of oak and ash, as well as patches with shrubs, such as hazel. The leaf litter produced by these patches provides ample hiding opportunities and can also provide a source of nutrients for a wider range of animals than pure grassland can. Compared to pure grassland, shrub land will harbour more carnivores.
Mammals that are expected here include: common shrew (*Sorex araneus*), pygmy shrew (*Sorex minutus*), common vole (*Microtus arvalis*), field vole (*Microtus agrestis*), harvest mouse (*Micromys minutus*), wood mouse (*Apodemus sylvaticus*), yellow-necked

Figure A.3. The mixed forest habitat with some of its representative bird and mammal species (Images adapted from: Mixed Forest 2007 and Ecosystema 2016).

mouse (*Apodemus flavicollis*), hedgehog (*Erinaceus europaeus*), hare (*Lepus europaeus*), long-eared bat (*Plecotus auritus*), weasel (*Mustela nivalis*), beech marten (*Martes foina*), wild cat (*Felis sylvestris*), badger (*Meles meles*), fox (*Vulpes vulpes*), and roe deer (*Capreolus capreolus*).

Birds that inhabit shrub land include: birds of prey, owls, warblers, finches, magpie, starling, nightingales, wrens, thrushes, doves, pigeon, tits, sparrow, cuckoo, Eurasian curlew, chiffchaff, woodpecker, woodcock.

The habitat shrub land and its representative species can be summarized as presented in Figure A.1.

Forest:

Forests can be deciduous or coniferous. Mixed forests can include either two or more dominant tree species in a deciduous forest, or a mix of deciduous and coniferous forest. For West Frisia, deciduous and deciduous mixed forest are the only two expected habitats.

Deciduous forest:

Deciduous forest are the habitat preference of amongst others the following mammals: bank vole (*Myodes glareolus*), yellow-necked mouse (*Apodemus flavicollis*), red squirrel (*Sciurus vulgaris*), horseshoe bats (*Rhinolophidae*), stoat (*Mustela erminae*), polecat (*Mustela putorius*), beech marten (*Martes foina*), badger (*Meles meles*), wild cat (*Felis sylvestris*), fox (*Vulpes vulpes*), wild boar (*Sus scrofa*), wolf (*Canis lupus*), roe deer (*Capreolus capreolus*), red deer (*Cervus elaphus*), and elk (*Alces alces*). Fallow deer (*Dama dama*) belongs in both types of forest habitats mentioned here, and occurred in the Netherlands until the last Ice Age. However, it

Figure A.4. The wetland habitat with some of its representative bird and mammal species (Images adapted from: Wetlands 2010 and Ecosystema 2016).

did not survive this period and became extinct in these regions. It was reintroduced later during the Middle Ages (Ueckermann & Hansen 1994) and therefore did not exist in the Netherlands until that time.

Mixed forest:
Mixed forests are the transitional forest between deciduous and coniferous forests. Mammals that occur in this type of forest, but not in pure deciduous forest include: pine marten (*Martes martes*), brown bear (*Ursus arctos*), several kinds of bat, and possibly lynx (*Lynx lynx*). All the other mammals that can be found here are the same as in a deciduous forest.

In both these forest habitats, the following birds can be expected are: birds of prey, owls, warblers, herons, egrets, finches, tree creepers, pigeon, dove, corvids, cuckoo, tits, woodpeckers, flycatchers, Eurasian jay, wood lark, nightingales, sparrow, Eurasian woodcock, starling, winter wren, and thrushes.

The deciduous forest and mixed forest habitats, and their representative species can be summarized as presented in Figures A.2 and A.3. Most of the species shown in these figures can exist in both types of forest mentioned above, and are not restricted to a particular forest type.

Wetlands:
Wetlands can be found in a wide range of habitat types, but four major types exist: swamp (forested wetland), marsh (herbaceous wetland), bog (acidic, peaty wetland fed by rainwater), and fen (neutral to alkaline, peaty wetland fed by groundwater). Swamps and marshes can occur in both fresh, brackish, and salt water. Bogs and fens, being fed by rain

Figure A.5. The intertidal/sea coastal habitat with some of its representative bird and mammal species (Images adapted from: Oernatuur 2011 and Ecosystema 2016).

and groundwater, respectively, can only occur in freshwater environments.

Mammals that are expected in wetland environments are: water shrew (*Neomys fodiens*), field vole (*Microtus agrestis*), water vole (*Arvicola amphibius*), nordic vole (*Microtus oeconomus*), Daubenton's bat (*Myotis daubentonii*), pond bat (*Myotis dasycneme*), mink (*Mustela lutreola*), otter (*Lutra lutra*), beaver (*Castor fiber*), and, in the summer, also elk (*Alces alces*).

As is to be expected from a rich environment such as a wetland, many birds are found here as well, including: birds of prey, warblers, sandpipers, kingfisher, aquatic birds (ducks, geese, swans), swifts, herons, owls, bitterns, egrets, plovers, terns, common coot, common moorhen, loons, common crane, gulls, wagtails, Eurasian curlew, tits, sparrow, ruff, grebes, and water rail.

The habitat wetlands and its representative species can be summarized as presented in Figure A.4.

Marine intertidal/coast:
Intertidal and coastal regions are characterised by the presence of saltwater in the near environment.

Not many mammals are expected in the intertidal and coastal regions, except for: harbour seal (*Phoca vitulina*), grey seal (*Halichoerus grypus*), dolphins, and whales.

Birds in these environments include: birds of prey, sandpipers, auk, aquatic birds (ducks, geese), stints, plovers, terns, gulls, godwits, Eurasian curlew, shag.

The habitat marine intertidal/coast and its representative species can be summarized as presented in Figure A.5.

A1.3. Expectations of fauna in the past aquatic habitat types in West Frisia

The expectations based on the geographical work by Van Zijverden (in prep.) show that the whole range of possibilities for the different water types and salinities can be expected for West Frisia, except for large rivers and mountain streams. An overview of the different aspects that can be important to a fish for its habitat is shown in Figure A.6, including the fish species that appear in each aquatic zone from the sea to the hinterland. For each fish water type mentioned in Figure A.6 a short general discussion will be provided below.

Stagnant to slow-flowing water:
Stagnant to slow-flowing water, sometimes also called the "bream zone" is characterized by relatively low amounts of oxygen and moderate to rich water, ground, and bank vegetation. It is usually found in brooks, small streams, ditches, etc.

Since this habitat type is expected for large parts of West Frisia, many fish species that thrive here can be expected, such as: sunbleak (*Leucaspius delineatus*), weather loach (*Misgurnus fossilis*), bream (*Abramis brama*), silver bream (*Abramis bjoerkna*), pike (*Esox lucius*), three-spined stickleback (*Gasterosteus aculeatus*), ten-spined stickleback (*Pungitius pungitius*), rudd (*Scardinius erythrophthalmus*), tench (*Tinca tinca*), bitterling (*Rhodeus amarus*), spined loach (*Cobitis taenia* taenia), gudgeon (*Gobio gobio*), crucian carp (*Carassius carassius*), and roach (*Rutilus rutilus*). Three-spined stickleback and roach are both non-specific in their preferences, but are most often found in this habitat. Two fish that also have a preference for this habitat are carp (*Cyprinus carpio*) and pike-perch (*Sander lucioperca*). However, these were introduced by the Romans and were not present in the Bronze Age.

(Fresh) open water:
Open water is characterized by relatively deep water with moderate to rich water and bank vegetation, but low amounts of vegetation on the ground of the water body. It contains a medium amount of oxygen on the surface, but this decreases with depth. Larger ponds and lakes are considered open water. Fish that prefer open water include: ruff (*Gymnocephalus cernuus*), ide (*Leuciscus idus*), bleak (*Alburnus alburnus*), perch (*Perca fluviatilis*), burbot (*Lota lota*), and catfish (*Silurus glanis*).

Fast-flowing water (*e.g.* rivers):
Fast-flowing water bodies are characterized by high levels of oxygen, but low amounts of vegetation. Small rivers and other fast flowing streams and brooks are considered for this habitat type. Fish expected to occur here include: ide (*Leuciscus idus*), chub (*Leuciscus cephalus*), dace (*Leuciscus leuciscus*), and stone loach (*Barbatula barbatula*).

Connection to the sea:
A connection to the sea is a broad description of habitat for fish that need to travel back and forth between fresh and saltwater for their reproduction (*i.e.* migratory fish), regardless of what other water type is used to achieve this. Therefore, a connection to the sea is an extra habitat type preference for fish that do not spend their whole life in one water type. Fish that are expected here include: eel (*Anguilla anguilla*), sturgeon (*Acipenser sturio*), mullets (*Liza spec.*), salmon (*Salmo salar*), sea trout (*Salmo trutta*), flounder (*Platichthys flesus*), shads (*Alosa spec.*), whitefishes (*Coregonus spec.*), three-spined stickleback (*Gasterosteus aculeatus*), and smelt (*Osmerus eperlanus*).

Open sea:
The open sea is characterized by highly saline water conditions with little to no plant life. In this category, only fish that live or come near the coast are discussed, or the species list would become endless. Fish that are (seasonally) expected near the coast include: grey gurnard (*Eutrigla gurnardus*), Atlantic cod (*Gadus morhua*), Atlantic herring (*Clupea harengus*), sprat (*Sprattus sprattus*), sole (*Solea solea*), stingray (*Dasyatis pastinaca*), thornback ray (*Raja clavata*), sea bass (*Dicentrarchus labrax*), and plaice (*Pleuronecta platessa*).

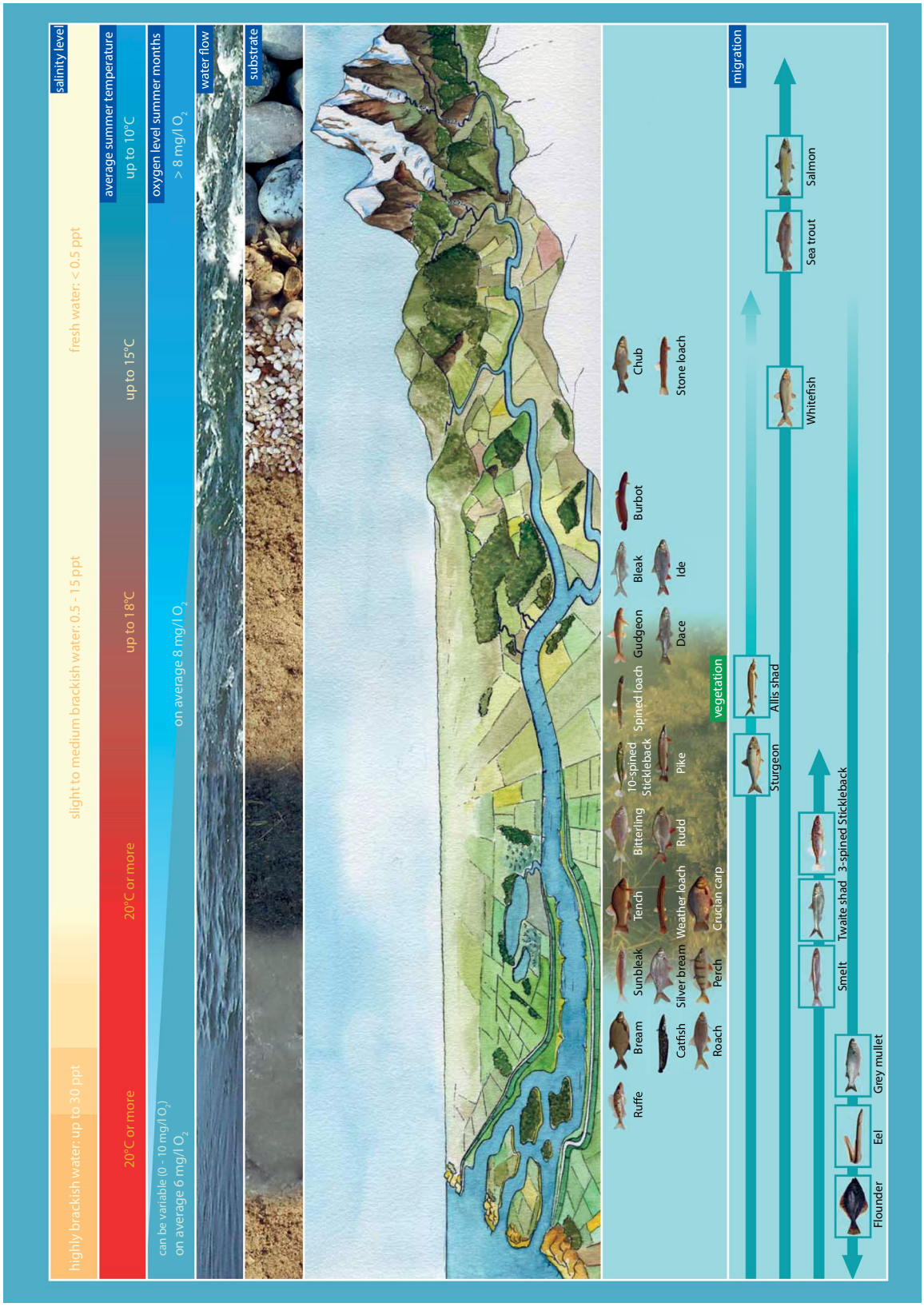


Figure A.6. Fish preferences for salinity level, temperature, oxygen level, water flow, substrate, vegetation and migration (adapted from Vissengids 2016).

Table A.1. Selected cultures that comply to the criteria set to resemble the West Frisian Bronze Age situation.

		Relative dependency on subsistence strategy (total = 10)				
Neighbourhoods						
Cultural code	Cultural group	gathering	hunting	fishing	animal husbandry	crop husbandry
A08c	Sukuma	0	0	0	3	7
A08e	Hehe	0	1	0	3	6
A10b	Ruanda	0	1	0	3	6
A10e	Nyoro	0	1	1	2	6
A19c	Tallensi	1	0	0	2	7
A24e	Luo	0	1	1	2	6
A25b	Nandi	0	0	0	5	5
C01d	Kafa	1	1	0	2	6
C15a	Basques	0	0	2	3	5
C23a	Albanians	0	0	0	4	6
C24c	Hutsul	0	1	1	4	4
E12a	Lepcha	0	1	0	3	6
E13b	Bhil	1	1	1	2	5
N24b	Tarahumara	1	1	0	3	5
average		0,29	0,64	0,43	2,93	5,71

		Relative dependency on subsistence strategy (total = 10)				
Hamlets						
Cultural code	Cultural group	gathering	hunting	fishing	animal husbandry	crop husbandry
A03e	Sotho	1	1	0	3	5
A23b	Otoro	0	2	0	2	6
C02a	Amhara	0	0	1	3	6
C03c	Dilling	1	1	0	3	5
C20b	Cheremis	0	0	2	3	5
C25b	Cherkess	0	1	0	4	5
E10b	Monguor	0	0	1	3	6
E15d	Coorg	0	1	1	2	6
average		0,25	0,75	0,63	2,88	5,50

Table A.1.(Continued) Selected cultures that comply to the criteria set to resemble the West Frisian Bronze Age situation.

		Relative dependency on subsistence strategy (total = 10)				
Villages						
Cultural code	Cultural group	gathering	hunting	fishing	animal husbandry	crop husbandry
A03d	Venda	1	1	0	2	6
A09b	Kikuyu	0	0	0	3	7
A13b	Katab	2	1	1	1	5
A18a	Bambara	2	0	1	2	5
A19a	Songhai	0	0	2	3	5
A19b	Dogon	2	0	0	2	6
A23a	Fur	0	0	1	3	6
C01b	Konso	0	0	0	2	8
C02b	Tigrinya	0	0	0	3	7
C04c	Kanembu	0	0	1	3	6
C07a	Riffians	0	1	1	3	5
Co7b	Kabyle	0	0	0	3	7
C07d	Tunisians	0	0	1	2	7
C11b	Druze	0	0	0	1	9
C12a	Turks	0	0	1	4	5
C12b	Kumyk	0	0	0	3	7
C13a	Greeks	0	0	1	3	6
C14a	Imp. Romans	0	0	2	2	6
C15b	Spaniards	0	0	0	3	7
C15c	Brazilians	0	1	1	2	6
C16a	Fr. Canadians	0	0	1	2	7
C18a	Dutch	0	0	1	3	6
C21a	Czechs	0	0	0	3	7
C21b	Lithuanians	0	0	1	4	5
C22b	Bulgarians	0	0	0	2	8
C23b	Hungarians	0	0	1	2	7
C24a	Russians	0	0	0	3	7
C24b	Ukrainians	0	0	1	3	6
C25a	Armenians	0	0	0	3	7
C25c	Khevsur	0	1	1	3	5
E09b	Manchu	0	0	1	2	7
E12d	Lolo	0	1	0	3	6
E13d	Pahari	0	0	0	4	6
E13e	Gujarati	0	0	1	2	7
E16c	Kol	1	0	0	2	7
average		0,23	0,17	0,60	2,60	6,40

Chapter 4

A1.4. Selected cultures as a parallel for the West Frisian Bronze Age based on the ethnographical work by Murdock (1981).

Selection criteria (Table A.1 and Figure A.7)

1. The subsistence economy should consist for at least 56-65% of both crop and animal husbandry (combined value of 6 or higher).
2. The type and intensity of agriculture should consist of intensive agriculture on permanent fields, using fertilization, crop rotation, or other techniques to ensure a short to no fallow period. In addition, cereal grains should form the main crops (Ic).
3. The settlement patterns should be either neighbourhoods of dispersed family homesteads (N), separated hamlets with permanent single communities (H), or compact and relatively permanent settlements (V).
4. The type of animal husbandry should be mainly bovine animals (B), or sheep/goat (S). In addition, milking (m) could be an option, but is not necessarily a prerequisite (o).

Cultures that meet the set criteria and their dependency on the different subsistence strategies, sorted by the size of the settlement

Chapter 5

A1.5. Characterization of the Bronze Age domestic animal species cattle, sheep, pig, dog, and horse.

Cattle

Cattle (*Bos taurus*) in the Bronze Age were very different from present-day cattle. In fact, there is no real modern equivalent. In his dissertation, Gerard IJzereef has reconstructed the size and weight of Bronze Age cattle (IJzereef 1981). Bronze Age cattle were small, with an average

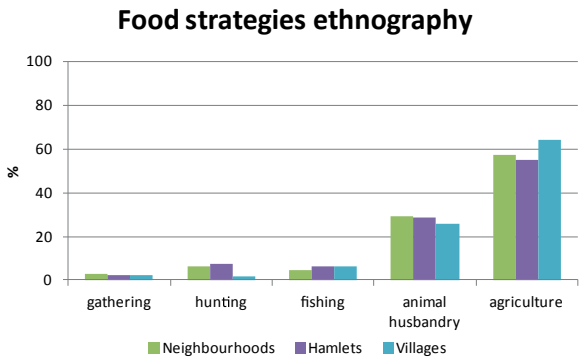


Figure A.7. Summary of the average values for the contribution of the different subsistence strategies for the selected cultural groups from Table A.1, for the different sizes of settlements.

withers height of 109 cm (IJzereef 1981, 55), and an average weight of 175 kg (IJzereef 1981, 60). Both male and female animals were horned, with the exception of one find from Enkhuizen Haling, where a hornless skull (*i.e.* born without horns, not dehorned) was uncovered (van der Jagt 2014, 59).

A recent cattle breed that slightly resembles Bronze Age cattle is for example Dexter cattle (see Figure A.8). Although this cattle breed has a similar withers height to Bronze Age cattle, the weight and overall proportions are different. Bronze Age cattle were more slender in relation to their size (Figure A.9).

The small size of Bronze Age cattle is the result of continuous diminution in size since the Neolithic, which continued well into the Iron Age (Filean 2006 and references therein). This phenomenon can have various reasons. Small cattle might be the result of inbreeding (*e.g.* Sutherland 1956), or a conscious selection of smaller individuals by the farmer. Farmers might prefer small cattle for several reasons. For example, small cattle are more manageable and more efficient producers, especially on small-scale farms. For their size, small cattle produce more meat and milk than their larger

Figure A.8. Dexter cattle (Photo by author at the farm of A. Slagter, Wolvega).

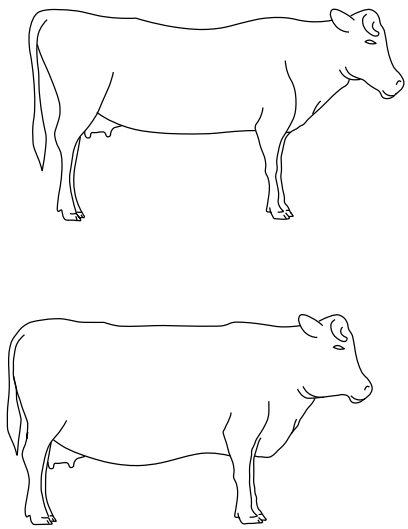


Figure A.9. Differences in build between Bronze Age cattle (left, from: IJzereef 1981, 66, Fig. 26), and modern Dexter cattle (right); average withers height of both breeds lies around 110 cm.

counterparts for the amount of nutrition they need, especially when grazed on pasture (Long *et al.* 1975). However, having smaller cattle does not lead to a reduction in labour time.

No matter the size of an animal, the number of animals kept is the deciding factor for the amount of work to be done.

Sheep

West Frisian Bronze Age sheep (*Ovis aries*) were also small, with a withers height of on average 62.3 cm and an average weight of 27.4 kg, although the weight is an approximation (IJzereef 1981, 98). Both males and females were horned; no hornless individuals were encountered anywhere in West Frisia. It is unknown whether sheep in the Bronze Age shed their wool which would have allowed plucking, or whether they needed to be periodically sheared. IJzereef has concluded from his measurements that sheep from Bovenkarspel Het Valkje resembled either Merino-type sheep, the terpschaap, the Drents Heideschaap or Shetland sheep based on several characteristics (IJzereef 1981, 95, 101). However, these comparisons are merely morphological, and no hard conclusions should be drawn solely based on this data, as the centuries of human breeding selections may have changed the phenotypical characteristics of the sheep. IJzereef however, does not mention the possibility that Soay-type were kept in West Frisia.

This is remarkable, since Soay sheep, from the island of Soay in the St. Kilda archipelago (UK), are usually seen as the living descendants of prehistoric domestic sheep and would therefore most closely reflect the type of sheep kept by people from north-western Europe during the Bronze Age.

However, based on the type of sheep and wool uncovered in the Northern Netherlands, Soay sheep might not have been the sheep breed kept in the Bronze Age in West Frisia, or indeed north-western Europe.

A wild population of Soay sheep consists of dark-coloured (sometimes with a pale belly)

Figure A.10. Examples of yarn balls found in the Emmererfscheidenbog in Drenthe in the north-eastern Netherlands (Photos by author at the Drents Museum in Assen, Drenthe).

individuals that shed their wool once a year (Clutton-Brock & Pemberton 2004), which can be hand-plucked during moult. Conversely, many Bronze Age archaeological wool finds from the Netherlands (Vons-Comis 1990, 183; Butler 1979, 122-4; Schlabow 1974: 193, 207-8; van der Sanden 1998, 131-41; van der Sanden 2002, 141) as well as throughout Europe (*i.e.* Scandinavia, Hallstatt in Austria, and the Balkans), actually lack pigmentation and have very different fibre characteristics from Soay wool (Ryder 1983, Rast-Eicher & Jorgensen 2012). Finds related to wool include yarn balls (such as in the Emmererfscheiden bog in Drenthe, the Netherlands; Figure A.10), sheepskins, and produced textiles, and based on these objects, many processing stages could be researched.

Wool lacking pigmentation only occurs on the underside of wild Soay sheep, and, as an interview with a wool sheep breeder has brought to light, wool from the belly of a sheep is of the lowest quality, surpassed only by leg wool (pers. comm. B. Stikkers). First of all, belly wool is often present in such small amounts, that a large amount of sheep would have been needed to create a piece of clothing. In addition, this wool is of low quality because sheep lie on their belly, which can result in dirtying and felting of the wool. Therefore, this wool would not be preferable to use for garments in general, let alone undergarments, such as was discovered in the Emmererfscheiden bog in Drenthe, the Netherlands (Vons-Comis 1990). Further research has even indicated that the Soay sheep type with the pale underside might be a recent result of cross-breeding (Gratten *et al.* 2010, 213).

The fibre characteristics of the wool finds are also different from Soay wool, which has been shown by Rast-Eicher & Jorgensen (2012) for Scandinavia and Central Europe, and by Mrs. Stikkers for the Dutch finds. Based on fibre characteristics, the possibility of Soay sheep being in the Netherlands during the Bronze Age is rejected as well (pers. comm. B. Stikkers). She thinks a more likely candidate would be short-tailed northern breeds that naturally shed their wool annually. Rast-Eicher and Jorgensen also propose that wool in the Bronze Age was acquired by plucking, which they base on the presence of hair follicles, since these are absent after shearing (Rast-Eicher & Jorgensen 2012, 1231).

If the sheep kept in the Bronze Age in Europe were indeed not Soay, it remains unclear which sheep breeds were likely candidates. Based on a comparison between Bronze Age sheepskins and textiles, Rast-Eicher and Jorgensen indicate that several sheep breeds must already have existed in the Bronze Age throughout Europe (Rast-Eicher & Jorgensen 2012, 1233-4, 1240). Still, it remains uncertain where we should place Bronze Age sheep from the Netherlands in this image.

Interestingly, DNA research in which several sheep breeds were analysed for their ancestry, has shown that sheep have a varied ancestry. This research furthermore seems to imply that Dutch sheep resemble Northern European sheep breeds more than those of Central Europe (Kijas *et al.* 2012, 3-4).

Dr. Lenstra from the University of Utrecht, who cooperated in this DNA project with Kijas, suggests that a panmictic population (*i.e.* a large population in which all individuals are potential partners) of prehistoric sheep, consisting of geographical local varieties may have existed (pers. comm. H. Lenstra), which might be seen as breeds.

Another result from this DNA project was that a sheep with the primitive characteristics of the Drents Heideschaap (*i.e.* horns, composition of hair/wool) has existed in the northern Netherlands for at least 4000 years (Kijas *et al.* 2012; pers. comm. H. Lenstra).

When all the above results based on the wool from Drenthe, the sheep bone characteristics of West Frisian sheep, and the general DNA research are combined, the most likely candidate for sheep kept in the Northern Netherlands is the Drents Heideschaap-type (Figure A.11). This sheep has similar physical characteristics to the West Frisian sheep types proposed by IJzereef (*i.e.* build, male and female have horns, etc.), has existed in the Netherlands for a very long time, and has fleece characteristics that are compatible with the archaeological wool finds (*i.e.* yarn balls and textiles).

Figure A.11. The proposed modern sheep breed equivalent of Bronze Age West Frisian sheep: the Drents Heideschaap (adapted from: Fryslansite 2015).

Since no finds of woollen textiles from West Frisia have (yet) emerged, there cannot be conclusive evidence that the Drents Heideschaap-type sheep also existed there in the Bronze Age. However, since there is evidence for a connection between West Frisia and the eastern part of the Netherlands (cf. Chapter 5), it can be assumed that a Drents Heideschaap-type sheep could have been present in West Frisia as well.

Pig

Pigs (*Sus domesticus*) in West Frisia did not resemble present-day pigs. They were large and still showed similarities to wild boars based on several bone measurements (IJzereef 1981, 81). This also means they would most likely have had more hair than present-day pigs, and probably had similar colour patterns to wild boar.

A possible explanation for this "wild" aspect of the pigs was given by IJzereef. He postulates that: "(…) tame females mated, deliberately or spontaneously, with wild males" (IJzereef 1981, 81). This constant supply of new genes would greatly diminish the risk of inbreeding, which would normally be very high when low numbers

Figure A.12. Domestic pigs and piglets roaming freely around Romanian settlements on the banks of the Danube delta. Since these pigs interbreed with wild boar, piglets show a combination of pink domestic pig skin with the characteristic boar piglet stripe pattern (photo courtesy of: P. Valentijn).

of pig are kept. Baeté & Vandekerkhoven similarly indicated 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 were kept in the settlement, preventing the interbreeding with wild female boars (Baeté & Vandekerkhoven 2001, 9).

An example of such an extensive pig keeping practice was witnessed by the author in the Danube delta in Romania (Figure A.12), where "domestic piglets", which roamed freely outside settlements with domestic females, possessed the characteristic stripe pattern of wild boar piglets.

Dog

Dogs (*Canis familiaris*) in the Bronze Age were of varying size and build, ranging from medium-sized relatively frail statured dogs to large dogs with a strong build (*i.e.* withers height: 48-65 cm; IJzereef 1981, 107). Modern dog breeds comparable to these measurements include the pointer, the sheepdog (IJzereef 1981, 104), and the German shepherd dog (Figure A.13).

Horse

Similar to Bronze Age cattle, the horse (*Equus caballus*) during this time is also of small stature. Although exact calculations on size were not possible based on the West Frisian data, finds from Denmark suggest a withers height of around 133 cm (Nyegaard 1996, 48), which is comparable to present-day ponies. This withers height can be found in the small Steppe horse/pony and several pony breeds such as the New Forest pony (Figure A.14).

A1.6. Liver fluke in West Frisia

For sheep in a wet environment many diseases can pose a threat, but liver fluke infection is often considered one of the worst. A figure of the life cycle of liver fluke is shown in Figure A.15.

Although both cattle, humans, and pigs can be infected (Lenton & Behm 2000, 201; Boray & Murray 1999, fig.1), liver fluke infections are known to eliminate up to 40% of sheep flocks at a time (Njau *et al.* 1988).

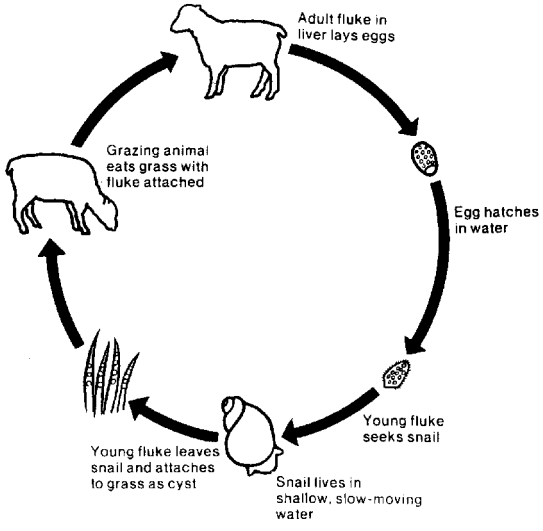
The question is whether liver fluke infection could be one of the reasons for the overstocking practice observed in West Frisia (cf. Chapter 5). In order to answer this question, it first needs to be ascertained that the liver fluke existed in the Bronze Age. Indeed, eggs of liver fluke (*Fasciola hepatica*) have been found in human and cattle remains at a Late Neolithic site at Karsdorf in Southern Saxony Anhalt, Germany (Dittmar & Teegen 2003), so it surely must have existed in the Bronze Age.

Besides mammal hosts, a liver fluke needs another – intermediate – host, a snail. The most well-known host snail for liver fluke is Galba truncatula (= Lymnea truncatula) (Lenton & Behm 2000, 202). In addition, recent research in Belgium has indicated that the snail *Radix balthica* (= *R. peregra* = *R. ovata*) can also fulfil this role (Caron *et al.* 2014). Both these molluscs are found, in very high numbers, at sites such as Bovenkarspel and Westwoud (IJzereef 1981, 129; Buurman 1996, 150).

Finally, the liver fluke needs an appropriate habitat in which to lay its eggs after parasitizing the snail and before being ingested by a mammal. This habitat is characterized by the presence of

Figure A.13. Examples of modern dog breeds which match the Bronze Age dog sizes found at Bovenkarspel; left: pointer; middle: sheepdog; right: German shepherd dog (from: Webbrittannica n.d.; Knowledgebase n.d.; German Shepherd Information n.d.).

Figure A.14. Modern horse and pony breeds with a comparable withers height to the Bronze Age horse; left: Steppe horse; right: New Forest pony (from: Mongolian Derby 2013 and Keyassets 2013).



To the left: Figure A.15. Liver fluke life cycle (from: ACGA n.d.).

slow moving water and specific aquatic vegetation. The fish remains have given indications for ample appropriate liver fluke habitats in and around the settlement (cf. Chapter 2, section 2.4.1), and plant remains indicate that aquatic plants and plants bordering small streams were also present (Chapter 2, section 2.3.4). Summarizing, all the factors needed for liver fluke to thrive were available at the sites of West Frisia. The high number of potential casualties to this and other diseases may have caused people to overstock sheep in West Frisia.

A1.7. Faustitas: a new method to construct a mortality profile from archaeological bone material and interpret past herd use and dynamics

1. Introduction

Zooarchaeology aims at understanding past human-animal interactions, including the use of animals by humans. This understanding is achieved by careful examination of bone material from excavated archaeological sites and subsequent analyses. The main analyses performed to elucidate past use of animals are sex and age determination based on individual bones. From the sex and age ratios within the bone assemblage the composition of the culled (*i.e.* killed) herd is reconstructed. The age composition in particular can be used to deduce the culling selections and the exploitation of the herd by past humans.

The age of animals can be determined based on both teeth and post-cranial bones. Teeth can provide information on the age of a slaughtered animal by analysing eruption and wear of dental elements. However, although teeth provide more precise information on age-at-death, post-cranial bone material is often well represented in the archaeological record, therefore providing a large(r) dataset for analysis and interpretation.

Post-cranial bones provide information on age based on the epiphyseal part of the bone, which becomes fused when the bone has completed its growth. This fusion occurs at a different age for each epiphysis, and for each animal species. When epiphyseal fusion, or lack thereof, is recorded in archaeological bone material, this can therefore signify a minimum or maximum age at death. Ideally, all the dental and post-cranial bone elements from all individual animals are retrieved during excavation, so that the combination of identified ages from teeth and bones can provide exact ages at slaughter. However, such finds are very rare. Instead, usually the entire bone assemblage of an excavated site, which consists of an unknown combination of elements from different individuals, is used for the age determination analysis. From this collection of bones, a slaughter pattern, or general mortality profile is constructed.

The mortality profile based on epiphyseal fusion data of post-cranial bones is often constructed with the method described by Chaplin (1971). Thereafter, the method of Payne (1973) is employed to interpret the possible past uses of a herd based on the mortality profile. Both methods have been practiced for over 40 years in the zooarchaeological research field. However, after a critical re-evaluation of their methodology, the present study has shown that these basic methods, and the subsequent interpretation of bone material, should be rethought and revised (section 2.1).

In addition, a new method is presented for the interpretation of post-cranial bone material to ensure that this large dataset is used correctly, and to its full potential. This new method is called Faustitas, named after the Roman goddess protecting livestock and herds.

Faustitas is a user-friendly Open Source online programme for cattle and sheep age data which allows the user to construct an improved mortality profile and interpret past herd characteristics based on raw post-cranial bone data. The new mortality profile is constructed by a method which removes internal data biases, and has the option to evaluate the potential effects of taphonomy on the original dataset (section 3.1). Furthermore, Faustitas enables the user to enter this new mortality profile data in a simulation to reconstruct past herd dynamics. Reconstructed past herd dynamics include: 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 live herd.

Although Faustitas is by no means restricted to any particular time period, the benefits of this new programme will be demonstrated here based on Bronze Age bone data from the area of West Frisia, the Netherlands.

2. Theory and calculation

2.1 The method of Chaplin

In his method, Chaplin (1971) calculates percentages of fused and unfused bones for each age group in order to establish the age ratios of animals within a bone assemblage (Chaplin 1971, 129-33). In order to test the validity of Chaplin's method, a fictive dataset of twelve complete cattle skeletons was used, of which the ages of the animals were known *a priori*. Age groups obtained by applying Chaplin's method to this dataset could thus be compared with the known age classes to identify similarities or differences in outcome.

The known age dataset consisted of twelve cattle skeletons, divided into four equal age groups ranging from 0-4 years. Each age group in turn consisted of three individuals of varying ages within that group. The expected outcome of calculations based on this dataset should therefore ideally match the four equal age groups of 25% each.

The twelve cattle skeletons were subsequently assumed to be complete archaeological finds, from which all post-cranial bones, which could provide information on age, were retrieved and analysed by the method of Chaplin. The results of this analysis can be observed in Figure A.16. It is clear that the results obtained do not resemble the expected equal ratios of age groups, even under the applied ideal archaeological circumstances. Most likely, an even more pronounced under- and over-representation occurs of the different age groups in actual archaeological bone assemblages. Although the method of Chaplin has formed the basis for research towards reconstructing mortality profiles based on archaeozoological data, several inherent aspects of this method have hindered the interpretation of what is observed in the resulting graph. It is in fact very difficult to evaluate whether the observed age

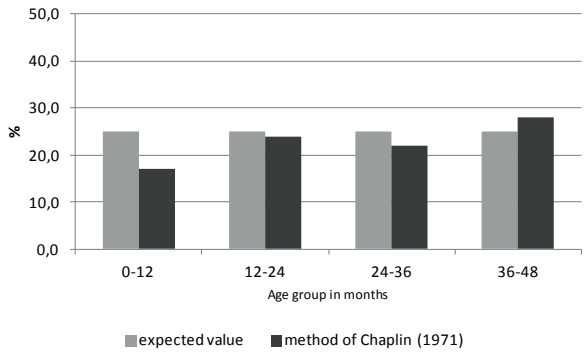


Figure A.16. Expected age group ratios (grey) versus calculated age group ratios based on the method of Chaplin (dark grey).

differences in the resulting mortality profile derive from aspects of the raw data, from calculations, or from actual past human practices, since they could also be the result of internal data biases, underlying mathematical procedures, and implicit assumptions. This will be researched next.

The mathematical procedures employed by Chaplin include the calculation of percentages of fused and unfused bones per age group, and the subtraction of these values from each other to obtain the age data for each specific age group (Chaplin 1971, 179-80). This methodology is based on the implicit assumption that the total number of fused and unfused bones on average would represent the age composition of the herd at a certain time. The reasoning continues in a further implicit assumption that each subsequent age group should contain less individuals than the previous, since in every age group individuals are lost to slaughter. This assumption is made clear by the fact that percentages of age groups are subtracted from each other. In cases where subsequent age groups contain more instead of less individuals than the last age group, Chaplin's method results in producing negative values for certain age groups. This type of irrational outcome underlines the inability of this method to deal with different types of culled herd composition. In a dead/culled herd composition, age group ratios may in fact vary widely in size depending on the use of the herd and the selections of humans made on it (Cribb 1985, 87-8). So, although in essence Chaplin's assumption of subsequent age groups becoming smaller due to

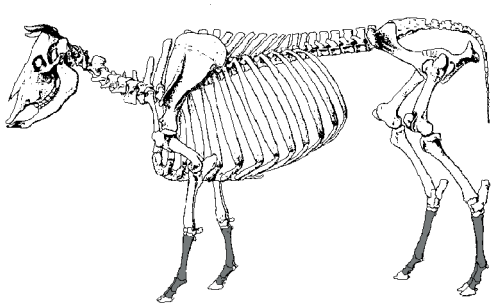


Figure A.17. Overview of a cattle skeleton indicating post-cranial bones which occur more than twice in dark grey (i.e. metapodia, which includes both metacarpal and metatarsal bones; and the 1st and 2nd phalanx).

slaughter practices is not wrong, it is only applicable when examining a live herd at a certain moment in time, not the dead reflection of it.

A final important aspect of the method of Chaplin negatively affecting the construction of the mortality profile and its interpretation is the lack of correction for internal biases which are always present in raw post-cranial bone data. First of all, calculations on epiphyseal fusion data obtained from post-cranial bones do not consider the number of times a bone was originally present in the body. For example, cattle phalanges have a higher chance of being uncovered relative to tibias, since phalanges occur at a ratio of 4:1 in the cattle skeleton. This means that the age group to which they belong (*i.e.* 1-2 years; Table A.4) will become relatively over-represented (Figure A.17).

A second bias which exists in the bone data is related to the unequal number of bones which can provide information on age. For instance, only two cattle bones can inform about the age of 0-1 year, whereas seven bones represent ages three and up (Table A.4). For a fair interpretation of the data, both of the above internal biases should be removed.

The third bias is the result of taphonomy: taphonomical processes greatly affect a bone assemblage prior to excavation, either by pre- or post-depositional processes. These processes cause some bones to be absent more often than others from the eventual uncovered assemblage. Although not all taphonomical effects can be identified or corrected for in a bone assemblage, at least one property of bone does allow for such a correction: density.

Bones from young and sub-adult individuals are not yet (all) fused and these unfused bones possess a lower density in comparison to fused bones from older animals. This aspect of young bone results in a gross under-representation of young(er) animals in a bone assemblage (Munson 2000), and is further exacerbated by the presence of ravaging dogs or pigs on a settlement (section 3.1). In order to most closely approach the original age ratios of animals in a bone assemblage, therefore, a correction for these taphonomical processes is required before further calculations are performed.

Faustitas corrects for all three biases presented above, producing a more mathematically accurate mortality profile based on post-cranial bones. This accuracy allows for the possibility to research past human practices without the unwanted influence of noise deriving from data biases.

2.2 The method of Payne

In his article, Payne (1973) discusses several optimal age-at-death mortality distribution graphs for meat, milk, and wool production, which are compared to mortality profiles to deduce the past use of a herd or flock. In practice however, these optimal graphs have proven far from optimal for several reasons. Firstly, the assemblage of bones recovered from a site seldom falls within just one of the use categories described by Payne, hindering the interpretation of multiple uses of a herd. Furthermore, these mixed uses of herds are very hard to interpret based on static data such as a mortality profile, and, finally, for many time periods it is not assumed that production of a herd was optimal at all.

Since the publication of the method of Payne, several researchers have discussed the (applicability of) ageing methods (*e.g.* Steele 2005; Twiss 2008), but these have mainly been focused on dental data. In addition to these discussions, other authors have shown that the optimal graphs presented by Payne are not realistic for comparative purposes (*e.g.* Cribb 1985; 1987; Munson 2000). Both Munson and Cribb

remark that, based on ethnographical parallels, most animals are slaughtered well before they reach 15 months of age (Cribb 1985; 1987; Munson 2000, 395-6). This observation is in stark contrast to the optimal slaughter age assumed by Payne of 18-30 months. Cribb furthermore identifies an important problem fundamental to all zooarchaeological interpretations: it is very hard to reconstruct dynamic processes (*e.g.* herd use) from their static reflections (*i.e.* mortality profile) in the archaeological record (Cribb 1985, 81 and references therein). In order to accommodate this inherent problem and improve the interpretation of past herds, Cribb has developed a simulation. This simulation attempts to identify the underlying dynamic properties of a herd which ultimately result in the mortality profile (Cribb 1984; 1985; 1987). The mortality profile therefore becomes an input of a simulation rather than a direct means of comparison to elucidate the past use of the herd or flock. As mentioned, Cribb has been able to show the invalidity of Payne's optimal graphs by comparing its assumptions with observed ethnographical and historical data (Cribb 1985, 88-90). Sadly, Cribb's simulations of actual zooarchaeological data never quite matched with his expectation based on these ethnographical and historical parallels. However, this mismatch was most likely not due to inadequacy of the simulation programme, but rather because Cribb had employed mortality profile data based on the method of Chaplin, with its inherent disregard of the effect of internal biases and taphonomy on the data.

Since Faustitas does incorporate corrections for the aspects related to the construction of the mortality profile discussed above (section 2.1), the method of Cribb is now applicable to zooarchaeological data as well. By incorporating Cribb's method, Faustitas therefore allows for the simulation of past dynamics. In this manner, information on long-term viability, use potential, and composition of the original live herd based on post-cranial bone material can be obtained.

3. Material and methods

3.1 Faustitas: mortality profile

The mortality profile in Faustitas was constructed based on epiphyseal fusion data of post-cranial bones, which was recorded based on the method of Habermehl (1975). The threshold for the number of bones (*i.e.* fused, unfused, and fusing) in a zooarchaeological complex before application of the new method is 100 (cf. Hambleton 1999, 39). The removal of internal data biases was achieved by correcting for the frequency of specific bones present in the skeleton, as well as for the number of bones which could inform about a certain age group (section 2.1). After these corrections, the resulting values were used further to calculate the number of bones per age group (*e.g.* 1-2 years), and fusing category (*i.e.* category 1: unfused bones and fusing bones, category 2: fused bones) (Table A.2).

First, for the calculation of bones in a certain age group based on fused bones, the oldest age identifiable by bones (excluding vertebrae) was regarded as the upper limit of the data. Therefore, the following method was applied: when a younger age contained more bones than the consecutive older age(s), the total number of bones of the older age(s) was subtracted from this value. Hypothetically, an age of older than 42 months consists of 16 bones. When the age of older than 36 months consists of 20 bones, 16 of these bones could possibly be explained by the age of older than 42 months as well, but four do indeed reflect individuals of an age older than 36 months to 42 months. In the instance that the age of older than 36 months contains less than 16 bones (cf. Table A.2), all these bones could possibly also belong to the age of older than 42 months, and in this case the age of older than 36 months after subtraction is assigned a value of zero. The age of older than 24 months is calculated similarly, by subtracting the values of the categories after subtraction of older than 42 months (16 bones) and from older than 36 months (zero bones) from the 48 bones present in the older than 24 months category, resulting in 32 bones left for this age after subtraction.

By calculating in this manner for all ages, minimum values for each age are obtained.

Where the category of unfused and fusing bones is concerned, the opposite calculation was applied, since here, the youngest age forms the lower limit of the data. Apart from unborn individuals, which

Table A.2. Example of the corrections made on number of bones for each relative age (older and younger than a certain number of months), based on unfused and fusing, and fused post-cranial bones.

age (months)	unfused and fusing bones	unfused and fusing bones after subtraction	age (months)	fused bones	fused bones after subtraction
< 10	0	0	> 7	6	0
< 15	1	1	> 12	59	0
< 18	1	0	> 15	65	17
< 20	8	7	> 20	1	0
< 24	0	0	> 24	48	32
< 30	10	2	> 36	2	0
< 36	2	0	> 42	16	16
< 42	3	0			
< 48	4	0			
TOTAL	**10**	**10**		**65**	**65**

are not included in this method, animals cannot be younger than zero years of age. So, when an older age of unfused and fusing bones consists of more bones than the previous age(s), values are subtracted and the resulting value again reflects the minimum number of individuals which can be explained by the bones for this age. Note that Faustitas thus produces the most cautious representation of the mortality profile, in that no use is made of percentages, and that calculations cannot result in negative values.

The final mortality profile is obtained by dividing the resulting values of the two bone categories per age after subtraction, containing the data of fused and unfused/fusing bones. This division also incorporates a final correction for the varying age breadths present in each of the fusion age groups. These groups differ in the number of months they represent: 0-1 year is represented by bones of 7-10 months (3 months), whereas 2-3 years is represented by bones of 24-36 months (12 months) (Table A.4). By applying this last correction, the mortality profile is, as much as possible, corrected for internal biases present in the data.

The final and different type of bias which can be present in the data, which results from external factors, is taphonomy. A correction for this phenomenon is, however, only partially possible due to the multitude of contributing factors. Several authors have, however, provided guidelines for when and how a correction can be achieved (Binford & Bertram 1977; Munson 2000; Munson & Garniewicz 2003). The zooarchaeological record can be severely affected by the presence of dogs and/or pigs at a site due to a high chance of the occurrence of ravaging (*i.e.* the destruction of bones by gnawing). Ravaging has an especially large effect on small bones and bones of low density (Munson 2000), meaning that young animals (*i.e.* younger than two years, but especially younger than one year of age) are most susceptible to such and other degradational processes. This high susceptibility inherently results in a large under-representation of young animals in ravaged assemblages and thus the eventual mortality profile. The effects of ravaging can be recognized in an assemblage by the ratios of certain bones. When the ratio of total number of distal ends (high density) versus proximal ends (low density) of humeri is

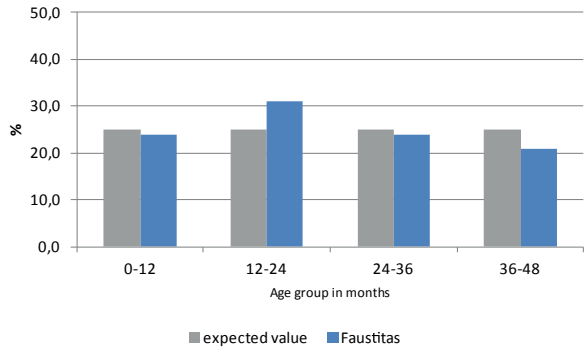


Figure A.18. Expected age group ratios (grey) versus calculated age group ratios based on Faustitas (dark blue).

higher than 4.7:1, taphonomical processes have definitely affected an assemblage (Munson 2000). Therefore, a ravaging correction, as proposed by Munson (Munson 2000, 400 and references therein), can be applied to the calculated mortality profile in Faustitas (Figure A.20) when the presence of pigs and/or dogs on a site can be presumed, and the ratio of the distal and proximal ends of humeri are within the ravaging range.

3.2 Faustitas: simulation

The simulation used in Faustitas (Figure A.21) is derived from the work of Cribb (Cribb 1984; 1985; 1987). Although based on the same assumptions, the simulation presented in Faustitas has undergone slight technical adjustments in comparison with the original simulation. Cribb allowed the user to enter several variables related to livestock mortality and birth rates, but neglected to mention how these variables resulted in the single simulation solution he presented. Indeed, a re-iteration of Cribb's simulation has shown that based on this type of data, there is always more than one solution for the entered variables. In the simulation in Faustitas, this aspect is made transparent and instead, the user can make deliberate decisions based on all simulation results, and choose which data should be incorporated in the final conclusion. Additionally, because some of the variables are dependent on each other, only two variables need to be entered in Faustitas (*i.e.* expected mortality of adults (mA) and birth rate (B) based on ethnographic parallels), which are subsequently used for the simulation of the other variables. The various different outcomes of the simulation are portrayed both in table and graph form, in which all the variables are shown. In order to ensure graphical clarity, the possible uses for herds are only shown in table form. The results of the simulation can be compared to the expected birth rate and mortality values of each age group (0-1 years, 1-2 years, and > 2 years) to arrive at indications for past herd use. Finally, the simulation can be applied to any animal husbandry situation and time period, as long as underlying assumptions are adjusted accordingly.

3.3 West Frisian data

The data used to exemplify the use of Faustitas derives from the excavated Bronze Age site Bovenkarspel Het Valkje, the Netherlands, which yielded large amounts of zooarchaeological material (IJzereef 1981). This site was occupied from ca. 1600-750 BC, but only the Dutch Middle Bronze Age B (1500-1000 BC) will be considered here. People in this time period can be characterised as small-scale mixed subsistence farmers with small, self-sustaining herds (Chapter 5). Ethnographical parallels used for the simulation input were obtained from several sources from around the world (birth rate: Mukasa-Mugerwa 1989; Negassa & Jabbar 2008; mortality rates: Dahl & Hjort 1976; Fall 1982; Muma *et al.* 2009; Fiore *et al.* 2010; Inamdar 2012).

The data presented here has been analysed as part of the research project "Farmers of the Coast", funded by the Netherlands Organisation for Scientific Research (NWO).

4. Results and discussion

The validity of Faustitas was tested in a similar manner as the method of Chaplin, with the aid of the fictive cattle dataset (section 2.1). Furthermore, the archaeological Bronze Age dataset from Bovenkarspel was tested with Faustitas, and the results compared with the outcomes based on the methods of Chaplin and Payne.

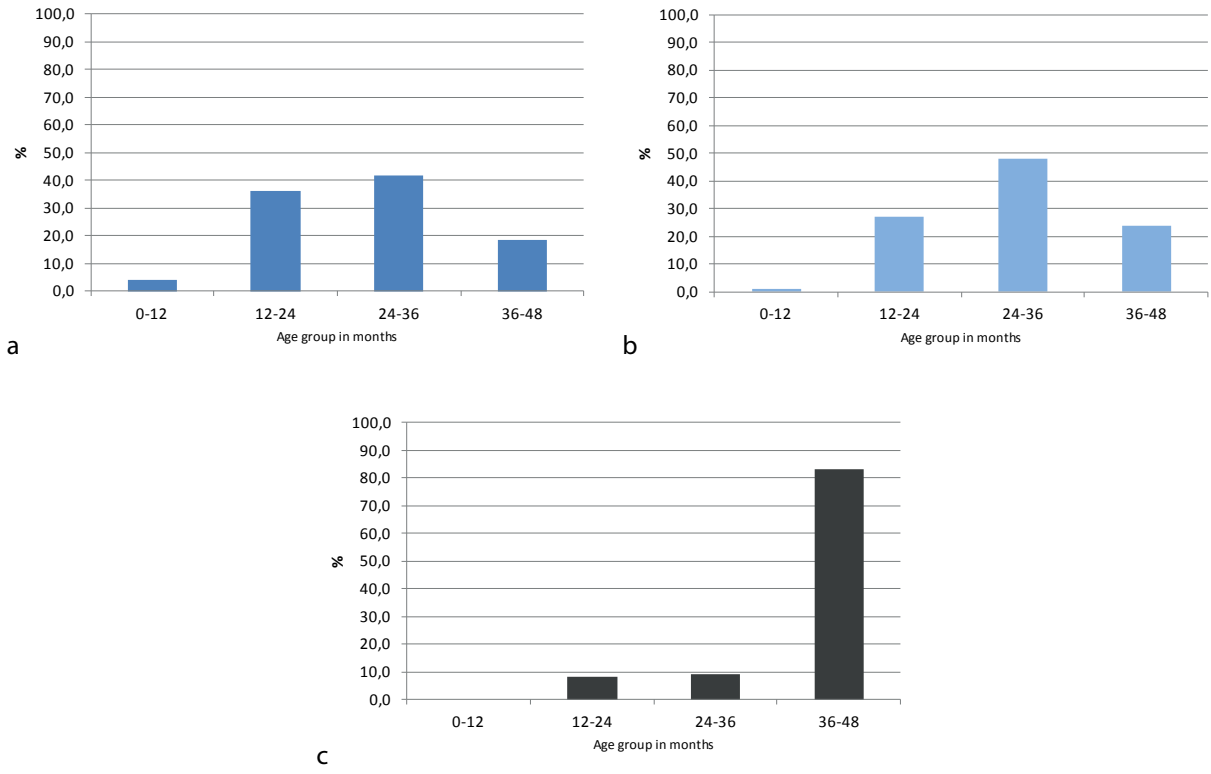


Figure A.19 Mortality profile for cattle from Bovenkarspel Het Valkje for the Dutch Middle Bronze Age B situation (1500-1000 BC) based on: a. Faustitas with ravaging correction; b. Faustitas without ravaging correction; c. Chaplin (1971).

4.1 From Chaplin to Faustitas

The fictive cattle data used to test the validity of the method of Chaplin (section 2.1) was also entered into Faustitas (Figure A.18). The results in Figure A.18 can be regarded as mathematically correct because all possible internal biases of the data were removed, and will no longer have affected the ratios observed (cf. section 3.1). Therefore, the results can now more accurately be related to past human practices than was possible based on the method of Chaplin. Thus, Faustitas presents an improved methodological step for zoological research and subsequent archaeological interpretation. What is clear from Figure A.18 is that the resulting age groups approach the expected equal age ratios of 25% in a different manner than the method of Chaplin, and that especially the youngest age group is better matched by Faustitas. Some differences can still be observed between age groups in Figure A.18 (*i.e.* an over-representation of 1-2 year old individuals), but since this will be a constant aspect of the Faustitas method (unaffected by biases as much as possible) these can be taken into consideration during interpretation.

Because of the few remaining internal properties of the underlying relative bone data (*i.e.* older than and younger than), it is not possible to arrive at a perfect match. More research might be employed in the future to test the internal dynamics of the new method and improve its matching qualities further (section 5 Conclusion and future prospects).

4.2 Ages of Bronze Age cattle

Cattle bone data from Bovenkarspel (Table A.4). was analysed using Faustitas. An additional correction for ravaging was applied, since the humerus distal:proximal ratio was very high (*i.e.* 8.7:1; threshold: 4.7:1). This ratio indicates that taphonomical processes will have severely affected the bone material, removing all but a few young

Table A.3. Faustitas simulation model input and output for Bronze Age cattle from Bovenkarspel Het Valkje, the Netherlands.

Ethnographical model input	Value	Meaning
Birth rate	0.2-0.7	0.2-0.7 young born annually per female
Expected mortality young (0-1 year)	0.1-0.6	10-60% young die annually
Expected mortality immature (1-2 year)	0.1-0.2	10-20% immature die annually
Expected mortality adult (> 2 year)	0.1-0.3	10-30% adults die annually
Mortality profile model input		
No. of bones	619	total number of bones with age determination
Target mortality young	0.04	mortality young based on mortality profile Faustitas
Target mortality immature	0.36	mortality immature based on mortality profile Faustitas
Target mortality adult	0.60	mortality adults based on mortality profile Faustitas
Simulation output		
Growth rate	1.08	8% annual growth of the herd
Birth rate	0.48	0.48 young born annually per female
Simulated mortality young	0.03	3% young died annually
Simulated mortality immature	0.27	27% immature died annually
Simulated mortality adult	0.16	16% adults died annually
Potential for meat production	0.17	potential of the simulated herd for meat production
Potential for milk production	0.13	potential of the simulated herd for milk production

animal bones from the original assemblage (cf. Munson 2000; section 3.1). The mortality profile of the West Frisian data is shown in Figure 19a, with Figure 19b added to show the effect of the ravaging correction. As a contrast, the mortality profile based on the method of Chaplin is shown in Figure 19c. The mortality profile produced by Faustitas shows the slaughter of animals of mainly 1-3 years old, whereas Chaplin's method resulted in the almost exclusive slaughter of animals older than 36 months. This comparison between the figures clearly signifies the importance of the removal of internal biases in the data as well as external taphonomical effects.

Animals younger than one year are nearly absent from both assemblages. This is surprising, since high numbers of dead young animals are always expected for this particular animal husbandry situation; unwanted youngstock is slaughtered and high natural mortality of young animals occurs within these types of farming communities (*i.e.* small-scale farmers with self-sustaining herds; section 3.3). Therefore, in

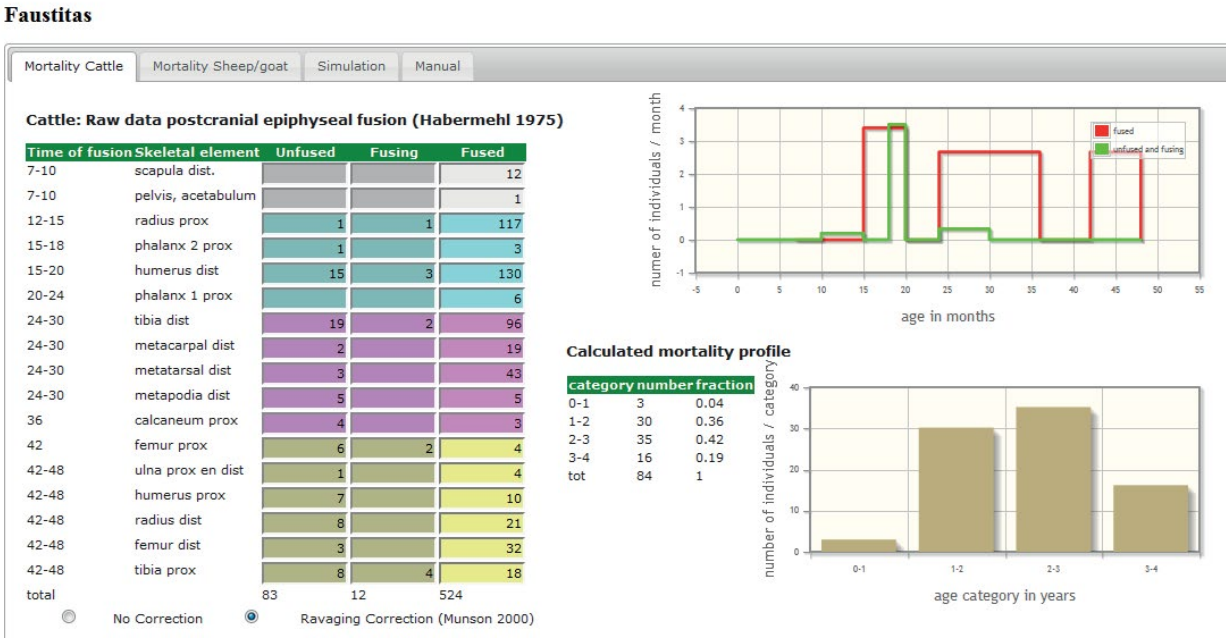


Figure A.20. Screenshot of the raw data input page for the construction of the mortality profile.

this case, the absence of dead young animals might be related to the very high impact of taphonomy on the original assemblage rather than other factors (section 4.4 Further discussion). When very few remains are present, even the application of the ravaging correction can no longer aid their visibility. Clearly, this example emphasizes the importance of a continuous comparison between expected and observed data as a vital aspect in the interpretation of past animal husbandry practices.

4.3 Use of Bronze Age cattle herds

The mortality profile produced by Faustitas, as well as additional ethnographical data on birth rate and mortality rates were used as input for the simulation of past herd dynamics. A summary of the ethnographical input to the simulation (cf. section 3.3), the mortality data from the reconstructed mortality profile (Figure 19a), and the resulting simulation output information is shown in Table A.3.

For the Bronze Age, it is assumed that flocks were self-reproducing units (Chapter 5). Therefore, the growth rate of the herd is expected to be higher than one, or else the herd would be declining in size on an annual basis. Based on this assumption (*i.e.* only growth rates higher than one were included), the values of the output of the simulation (Figure A.21) were averaged.

Table A.3 shows that the simulation based on the Middle Bronze Age cattle data has resulted in different kinds of information about the past herd. Based on the assumptions made, the herd's growth rate was 1.08 (*i.e.* 8%) and the birth rate 0.48, both of which are characteristics of healthy herds (cf. Cribb 1987, 403). The simulated mortality values of the different age groups have resulted in values which are mostly in the range of the expected values based on ethnographic parallels (Table A.3: compare simulation output with ethnographical input). The mortality of young animals however, lies slightly below the observed values in small-scale farming communities, and the mortality of immature animals is slightly higher than was expected based on ethnographic examples. These differences may be related to taphonomical processes affecting the original bone assemblage or to the application of a different animal husbandry practice than was expected for this time period and location (section 4.2; section 4.4 Further discussion). Still, the potential for meat and milk production of the herd is comparable to the expectation and does

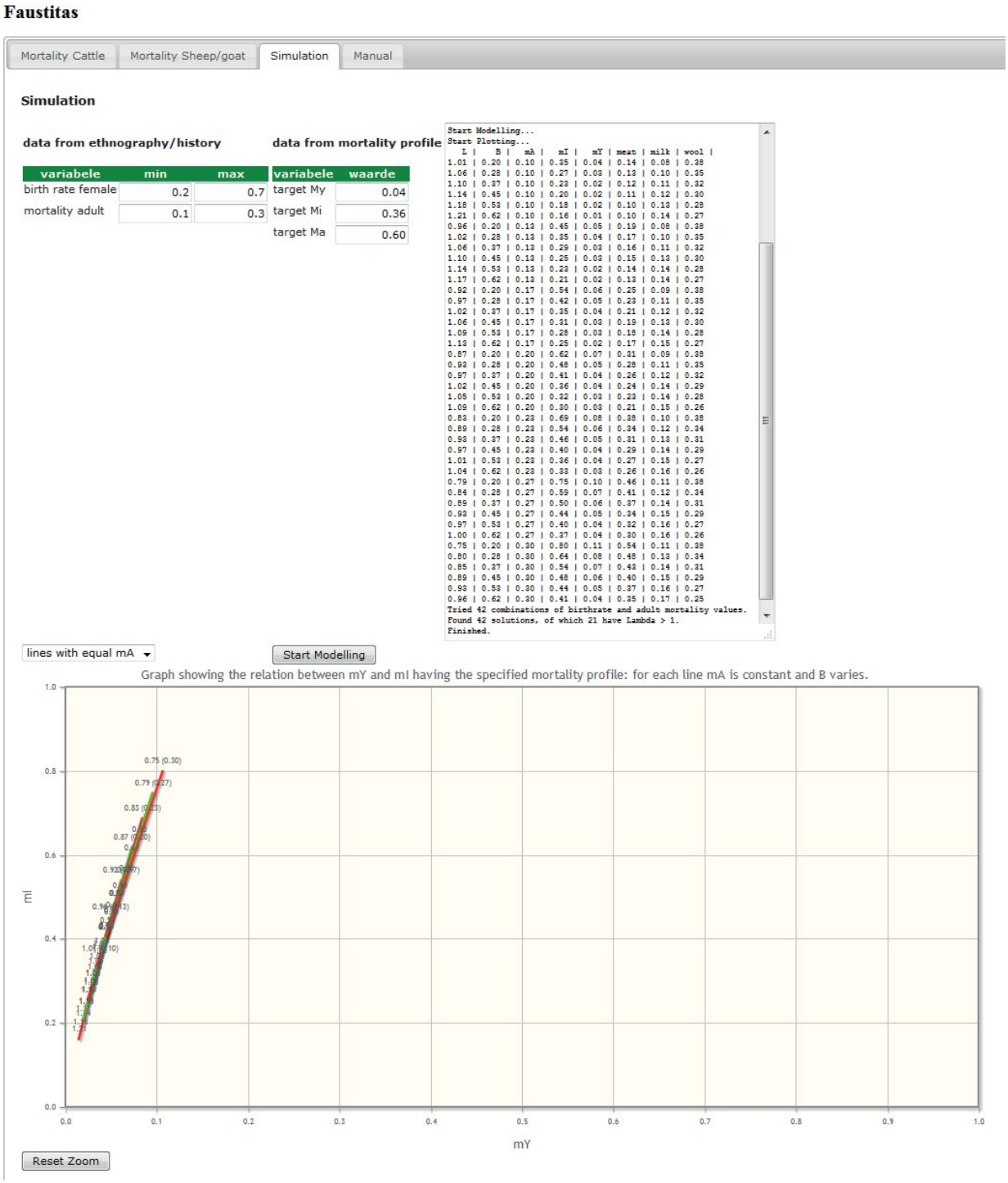


Figure A.21. Screenshot of the input page for the simulation of past herd dynamics.

concur with what is observed in parallel small-scale farming communities: the exploitation of animals for multiple purposes is preferred over specialisation towards a single use (Schiere & Kater, 2001). This result is in contrast with conclusions drawn based on Payne's method, which would have resulted in a herd used for traction (Payne 1973, 284, figure 3; Hambleton 1999).

Finally, the composition of the original live Bronze Age herd based on the simulated data also agrees with live herd compositions observed in small-scale farming communities (*e.g.* Lehloenya *et al.* 2007, 220-1), consisting of around 58% adults (> 2 years), 17% immature (1-2 years), and 25% young (< 1 year) animals (data not shown). Therefore, the cattle herds in Bronze Age West Frisia can be considered to have been healthy growing herds with the potential for the exploitation of multiple uses, concurring with the expected small-scale animal husbandry practices for this area (Chapter 5).

4.4 Further discussion on the use of Faustitas

Faustitas has shown its potential for the interpretation of past use of herds by people. Although the example used in this research was based on Bronze Age data, it must be emphasized that Faustitas can be applied to any archaeological bone dataset, as long as the basic prerequisites regarding number of bones and applied fusion identification method are met (section 3.1). Indeed, different assumptions and ethnographic or historical parallels will be required for different studies, but the simulation remains applicable regardless.

Alternatively, only the mortality profile may be of interest to the researcher, without using the simulation. For example, if no (self-sustaining) herds are expected in a certain situation, because animals are being bought individually or imported, expectations for growth rate and mortality rates of the total herd will be different or even not applicable. Past uses of these animals may however still be made clear through the application of only the mortality profile part of Faustitas (Figure A.20). In some cases, subsequent interpretation based on simulation is not therefore required for answering certain research topics. When it is applied however, the simulation of past herd characteristics should always occur on a tentative basis because the model and its output are built upon many assumptions. The Bronze Age example shown in this research interprets past herd properties based on 619 bones which could reflect 500 years of animal husbandry practices. Animal husbandry itself is a dynamic process, which can change annually depending on both internal and external factors, thus affecting the composition and use of the herd. Rather than providing definitive answers, the simulation results and their interpretation should therefore be regarded more as providing indications for possible use and practice, as well as forming a source for generating new ideas about past herds. New ideas and hypotheses resulting from the simulation could be re-tested by adjusting the target mortality profile data and by running a consecutive simulation accordingly.

Faustitas uses post-cranial bone data to identify slaughter ages, but a final remark must also be made regarding the interpretation of ages based on dental information. Although often regarded as a more reliable aging method due to its more specific age categories in comparison to bone material, the same, if not more taphonomical effects occur on jaws of young individuals (Munson 2000; Munson & Garniewicz 2003). Young animals can therefore be similarly highly under-represented in the dental record. A ravaging correction should thus actually also be applied to this type of age data, where appropriate (cf. section 3.1), in order to remove possible biases present before interpretation (cf. Munson 2000). After such corrections, post-cranial bone and dental data should be more comparable, and perhaps may even become complementary when interpreting mortality profiles.

5. Conclusion and future prospects

Faustitas is a considerable step forward for zooarchaeological research because it allows for the interpretation of past animal use by people on a much more mathematically correct basis than ever before. Internal biases in the data are removed and taphonomical processes can be taken into consideration before a mortality profile is constructed. Furthermore, more insight is gained in past herd characteristics

time of fusion in months (Habermehl 1975)	skeletal element and side of fusion	unfused	fusing	fused
		n	n	n
7-10	scapula distal	-	-	12
7-10	pelvis, acetabulum	-	-	1
12-15	radius proximal	1	1	117
15-18	phalanx 2 proximal	1	-	3
15-20	humerus distal	15	3	130
20-24	phalanx 1 proximal	-	-	6
24-30	tibia distal	19	2	96
24-30	metacarpus distal	2	-	19
24-30	metatarsus distal	3	-	43
24-30	metapodia distal	5	-	5
36	calcaneum proximal	4	-	3
42	femur proximal	6	2	4
42-48	ulna proximal and distal	1	-	4
42-48	humerus proximal	7	-	10
42-48	radius distal	8	-	21
42-48	femur distal	3	-	32
42-48	tibia proximal	8	4	18
	Total	83	12	524

Table A.4 Cattle bone data from Bovenkarspel Het Valkje, Middle Bronze Age B (1500-1000 BC).
Ravaging ratio: (humerus distal:humerus proximal) 148/17=8.7

by being able to examine underlying dynamic processes of the live herd, which will ultimately have resulted in the dead reflection uncovered in the zooarchaeological record. Herd characteristics which can be researched include birth rate, growth rate (*i.e.* long-term viability), and potential uses of the herd for meat, milk, and/or wool production. Still, many more steps can and should be taken to ensure that zooarchaeology continues to advance as a research field in the future. The internal dynamics of the Faustitas method could be tested to a higher degree in order to ensure model and simulation robustness. Furthermore, the matching qualities of the method need to be tested in more detail to further

Table A.5. Grazing requirements on grassland pasture only of the different West Frisian domestic animal species based on 6DSE/ha (after: van Gool et al. 2000).

Dry Sheep Equivalent	Number of animals/ha	Animal/ grassland pasture required
Cattle (Dexter): 4 DSE	1.5 cattle/ha	1 cattle/0.7 ha
Sheep: 1 DSE	6 sheep/ha	1 sheep/0.2 ha
Goat (average): 1.55 DSE	3.9 goats/ha	1 goat/0.3 ha
Horse (pony): 5 DSE	1.2 horses/ha	1 horse/0.8 ha

decrease the likelihood of results occurring due to coincidence, for example by generating 100 random populations rather than one (cf. section 4.1).

Faustitas can also be further improved by extending its use: several additional features can be added in the future to accommodate a wider range of research possibilities. First of all, the model could be extended by adding an option to include post-cranial bone data based on the method of Silver (1969). Furthermore, options such as the potential of a cattle herd for traction purposes may be included.

Additional simulation options developed by Cribb include the possibility to investigate the effect of long-term changes of variables (*e.g.* birth rate) on herd composition and use, allowing the user to investigate the effects of changing animal husbandry practices over time. Another additional simulation option includes the incorporation of the effect of periodical negative events (*e.g.* disease) on a herd to test its ability to withstand said events and remain viable in the long-term (Cribb 1987, 389).

A final addition to Faustitas might include the incorporation of more animal species to accommodate the research towards more types of animal groups, which may be either wild or domestic animal species. In this manner, both animal husbandry and hunting practices may be researched (cf. Steele 2003).

Ultimately, whether additions are made or not, Faustitas, just as in Roman times, will continue to ensure the protection of livestock and herds, although now within the realm of zooarchaeological interpretation. The programme Faustitas will eventually become available as an open-access website at the Leiden University website. Until that time, anyone interested can contact the author for access to the program at: faustitasmethod@gmail.com.

Table A.6. Grazing requirements on 2/3 grassland and 1/3 woodland pasture of the different West Frisian domestic animal species based on 1 GVE/4 ha (after: by Baeté & Vandenkerkhoven 2001).

Groot Vee Eenheid/ Large Livestock Unit	Animal/grassland and woodland pasture (2.3; 1/3) required
Cattle (Dexter): 0.8 GVE	1 cattle/3.2 ha
Sheep: 0.2 GVE	1 sheep/0.8 ha
Goat (average): 0.3 GVE	1 goat/1.2 ha
Horse (pony): 1.0 GVE	1 horse/4.0 ha

A1.8. Calculation of grazing requirements

Calculating required pasture per animal species on grassland pasture only

In order to calculate the required pasture per animal, the stocking rate for these grazing grounds need to be calculated first. Stocking rates can be expressed as DSE (Dry Sheep Equivalent) values, which means the amount of food consumed by a sheep that is not pregnant. Other species will have proportionally

higher or lower values when consuming more or less food than a dry sheep.

Under grassland pasture conditions on clayey soils (which is assumed for the West Frisian situation), 6 Dry Sheep Equivalents can graze on 1 ha (van Gool *et al.* 2000). This means that the values from Table A.5 should be kept in mind for grazing on grassland pasture only for the sizes of the domestic animal species kept in West Frisia (see A1.4).

Calculating required pasture per animal species on grassland and woodland pasture combined
Since woodland pasture can form a part of the grazing grounds of some animals as well, calculations were also made to include this pasture type.

In the article by Baeté & Vandenkerkhoven (2001), GVE (Groot Vee Eenheden; Large Livestock Units) values are used instead of DSE values. The GVE value of sheep in this article is set at 0.2 (Baeté & Vandekerkhoven 2001, 22). This value was proportionally translated into the values of the other animal species, based on the DSE values of van Gool *et al.* (2000).

Based on the article by Baeté & Vandenkerkhoven (2001, 21), grazing for most animals occurs at 2/3 grassland pasture, 1/3 forest pasture when vegetation is to remain the same. West Frisian soils are considered rich in nutrients, meaning that:

Stocking rate forest on rich soils: 1 GVE/ 10ha
Stocking rate grassland on rich soils: 1 GVE/ 1 ha

Under the stocking rate of 2/3 grassland pasture and 1/3 forest pasture, grassland will, in terms of nutrition (see stocking rate above), therefore be able to support 1 GVE/0.7 ha, and woodland 1 GVE/3.3 ha, resulting in a total of 1 GVE/4.0 ha for the combination of grassland and woodland.

Therefore, the stocking rate for 2/3 grassland pasture and 1/3 forest pasture: 1 GVE/ 4ha.

In addition, 17.5% (0.7/4.0) of the total calculated acreage of grassland and woodland will thus consist of nutrient-rich grassland pasture, because a smaller area is required to obtain sufficient nutrients. The other 82.5% (3.3/4.0) will consist of the relatively nutrient-poor woodland pasture.

The resulting GVE values for the different West Frisian domestic animal species can be seen in Table A.6.

Calculating required total pasture per household for different grazing scenarios
The total acreage of required per household is calculated based only on the article by Baeté & Vandekerkhoven, because their values for required grassland pasture only are very comparable to those obtained from van Gool *et al.* (compare Table A.5, column 3 and Table A.6, column 1).

Herd size per household:
5-8 cattle
5-15 sheep/goat (75% sheep, 25% goat)
1 horse

Scenario 1: Grassland pasture only (Baeté & Vandekerkhoven 2001):
Cattle: 4.0-6.4 ha
Sheep: 0.8-2.3 ha
Goat: 0.4-1.1 ha
Horse: 1.0 ha +
Minimum: 6.1 ha
Maximum: 10.8 ha

Scenario 2: Grassland and Woodland for goat only, other species on grassland (Baeté & Vandekerkhoven 2001):
Cattle: 4.0-6.4 ha
Sheep: 0.8-2.3 ha
Goat: 1.5-4.5 ha
Horse: 1.0 ha +
Minimum: 7.3 ha (6.0 ha grassland, 1.3 ha forest)
Maximum: 14.2 ha (10.5 ha grassland, 3.7 ha forest)

Scenario 2: Grassland and Woodland for all species (Baeté & Vandekerkhoven 2001):
Cattle: 16.0-25.6 ha
Sheep: 3.0-9.0 ha
Goat: 1.5-4.5 ha
Horse: 4.0 ha +
Minimum: 24.5 ha (4.3 ha grassland, 20.2 ha forest)
Maximum: 43.2 ha (7.6 ha grassland, 35.6 ha forest)

Figure A.22. Emmer wheat (Figure from: Educational Technology Clearinghouse 2011).

Figure A.23. Hulled barley (photo courtesy of C.C. Bakels).

Chapter 6

A1.9. Characterisation of the West Frisian cultivated crop species and the ard

Emmer wheat

Emmer wheat (*Triticum dicoccum*) is one of the principal food crops in prehistoric Europe, being adaptable to diverse climates and altitudes. It is a hulled wheat crop, which means that its grain kernels are enclosed by glumes that remain attached to the kernel when ripe. In emmer wheat, two kernels ripen within each spikelet (Figure A1.22; Zohary & Hopf 2012, 39-40). Processing emmer wheat kernels requires extra steps to remove the glumes and prepare them for human consumption.

Barley

Hulled barley (*Hordeum vulgare* var. *vulgare*) and naked barley (*Hordeum vulgare* var. *nudum*) are other main food crops of prehistoric Europe, which can withstand poorer soil conditions than emmer, including moderate aridity, lower amounts of soil nutrients, and low levels of salinity (Zohary & Hopf 2012, 51-2). Kernels of six-rowed barley, the species present in Bronze Age West Frisia, appear in triplets on either wide of the awn (Figure A.23). Similar to hulled wheat species, the processing of kernels of hulled barley requires extra steps to remove the glumes when their ultimate use is for human consumption, whereas this is not required for naked barley to the same extent.

Figure A.24. Broomcorn millet (from: Forestry Images n.d.).

Figure A.25. Linseed/flax (from: Southeast Farmpress 2013).

Broomcorn millet
Broomcorn millet (*Panicum miliaceum*) is a food crop that can withstand the harshest environmental conditions, including high temperatures, poor soils, and severe aridity (Zohary & Hopf 2012, 69). It is a crop that has a short growing season and which grows best during the warm summer months. Broomcorn millet is cultivated as a food crop, and its small seeds are situated in panicles (Figure A.24). When ripe, the husked seeds are prone to shattering (*i.e.* falling from the panicle to the ground), which can lead to considerable harvest losses. In addition, crops tend to lodge (*i.e.* lie flat on the ground) when rains occur to often towards the end of the growing season. For human consumption, broomcorn millet seeds first need to be de-husked.

Linseed/flax
Linseed/flax (*Linum usitatissimum*) is a crop that can provide both oil-containing seeds and fibres for the production of linen textiles (Zohary & Hopf 2012, 101). Usually, specialisation towards one use occurs, because fibres are of lower quality when seeds are ripe and vice versa, but crops grown for both purposes also exist (Figure A.25). The seeds can be pressed to obtain a high-quality edible and/or lighting oil. For obtaining the fibres, stems are harvested before the seed is mature and they are further processed by drying the stems, letting them rot in water to allow the decomposition of the stem tissue, and subsequently separating the wanted fibres through pounding and combing.

The ard
Prehistoric ploughs are plough that cut the soil, rather than turn the soil. They are collectively called ards, and exist in several different types and sizes (for overviews, see Tegtmeier 1993; Fries 1995). For West Frisia, it is assumed that the Donnerup ard type, an Early Bronze Age ard uncovered in the Donneruplund bog near Velje, Denmark (Figure A.26), is the ard type used for cultivation.

A1.10. Calculation of the turn radius of a cattle pair with ard

The turning radius of a cattle pair and ard can be calculated to gain insight into the approximate distance between subsequent furrows and radius of turning points at the edge of an arable field. When calculating this turning radius, the cattle pair and ard can be compared to a modern vehicle (Figure A.27)

The plough mark that is preserved in the soil, is represented by the turning radius of the plough, which in this case is the circle formed by the inner cattle plus half the length of the yoke (Figure A.28).

When the length of the ard is considered the same as the distance between the axles of a vehicle (since the middle of the yoke and the ard point in the soil are the turning points), w = 2 m (Aborg & Bowen 1960: 145). The turning angle of the cattle pair is unknown and is therefore varied between 10 and 30 degrees, so α = 10, 20 or 30. From these values r can be calculated according to the following formula:

$r=w/\sqrt{(2-2*\cos(2*\alpha))}$ (Davdata 2016)

$r_{a=10}$=1.83m, $r_{a=20}$=1.54m, $r_{a=30}$=1.01m

Adding to these values half the width of the yoke (*i.e.* 0.75m) means that the turning radii lie around 2.59m, 2.29m, and 1.76m. This means that the turning diameter of an ard lies somewhere between 3.5 and 5 metres, depending on the angle at which the cattle can turn whilst attached to the yoke and ard.

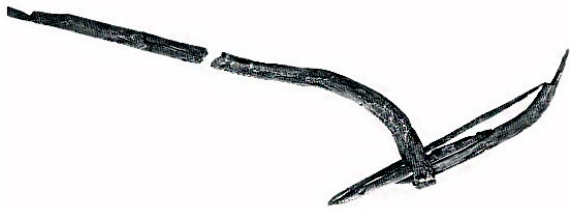


Figure A.26. Prehistoric plough, or ard, which cuts the soil, but does not turn it. The West Frisian ards were most likely similar to this example, uncovered in a bog in Donneruplund, Velje, Denmark (from: Denmark's history 2014).

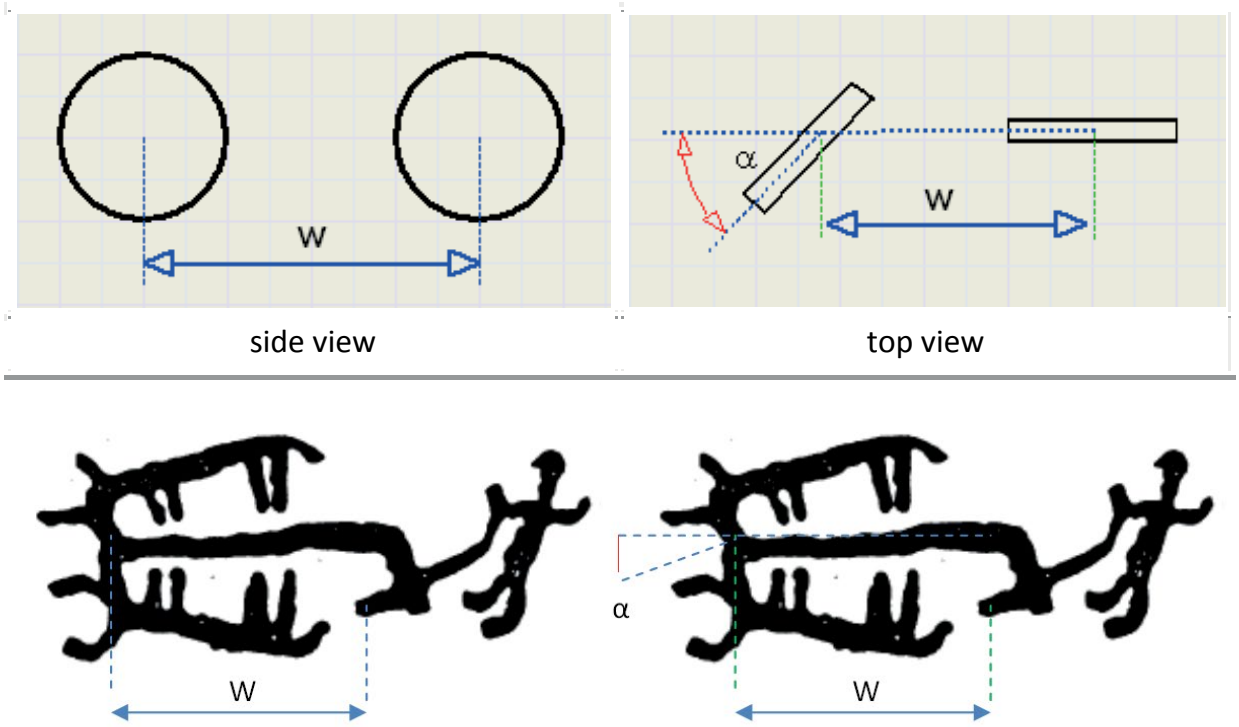


Figure A.27. Comparison of a modern vehicle and a Bronze Age cattle pair and ard for the calculation of the turning radius. Above: W represents the distance between the two axles (*i.e.* wheels or the distance between yoke and ard share), α the turning angle of the front turning point (*i.e.* front inner wheel or inner cattle in yoke) (from: Davdata 2016). Below: Scandinavian rock art depicting a cattle pair with plough and human (from: Fredsjö 1956, Figure 35); indicated are the distance W and the possible turning angle α.

A1.11. Identifying manuring practices in West Frisia based on 15N isotope analysis

The West Frisian Bronze Age fields, manured or not manured: a preliminary report on the $\delta^{15}N$ values of charred grain

Corrie Bakels

1. Introduction

Several proxies may provide information regarding the question whether fields were manured in the past, but there is one direct approach available, through the measuring of the $\delta^{15}N$ values of charred grain. The spreading of solid animal dung on fields enhances the $\delta^{15}N$ in the crop (Kanstrup 2011). Slurry or artificial fertilizer do not produce this effect, but as those kinds of fertilizer are not considered to have been used in prehistory the method may prove valuable in the case of the Bronze Age.

2. Material and methods

2.1 Archaeological material

For the first trials reported on in this contribution charred grain from eight West Frisian features was chosen *i.e.* Bovenkarspel-Het Valkje find numbers 7, 10 and 105, Enkhuizen-Haling find number 23, Twisk find numbers 1-1-19 and 1-1-20 and Westwoud find number 4 and 39/4. The first six are dated Middle Bronze Age, the last two Late Bronze Age. Except for Enkhuizen-Haling all finds came from the research conducted by Buurman (1996). The Enkhuizen-Haling site was excavated by ARCHOL BV and its botanical material retrieved by E. van Hees from the Faculty of Archaeology, Leiden University (van der Linde *et al.* 2014).

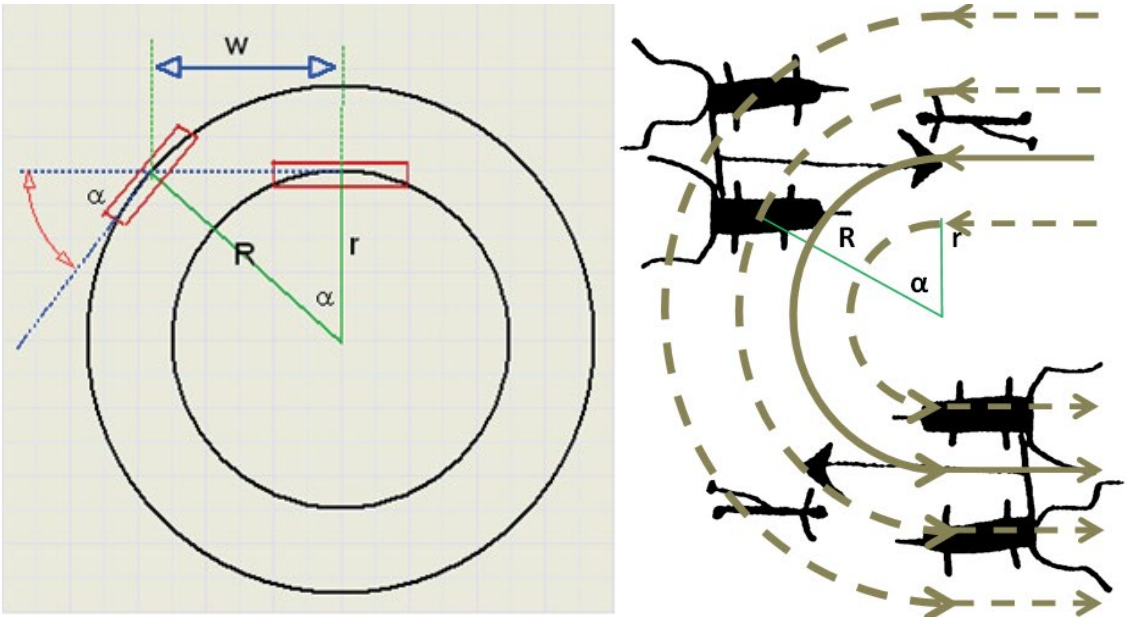


Figure A.28. Variables required to arrive at the turning radius. W represents the distance between the two axles, α the turning angle of the front turning point, R the radius of the front turning point, and r the radius of the back turning point (from: Davdata 2016. Left: calculation variables; right: example of a turning radius with a cattle pair and plough (rock art) (after: Payne 1948, plate V.2).

As the main cereals grown in West Frisia were emmer wheat (*Triticum dicoccum* Schübl.) and hulled barley (*Hordeum vulgare* L.), both species were selected for the analysis. The Bovenkarspel-Het Valkje features provided both, the others one kind of grain. All in all 11 samples were available for analysis (Table A.7).

From each sample subsamples were taken to be sent to the Centre for Isotope Research at Groningen, the Netherlands. Subsamples comprised 10-20 grains, but in the case of Enkhuizen-Haling only seven specimens were available (see table).

All grains were free from remnants of rachises and glumes, as chaff is reported to give a different $\delta^{15}N$ signal (Bogaard *et al.* 2007; Bol *et al.* 2005).

In Groningen the subsamples were treated by the acid-base-acid (ABA) method, ground and their $\delta^{15}N$ values established.

2.2 Providing baselines

$\delta^{15}N$ values of prehistoric crops are meaningless if they cannot be compared with $\delta^{15}N$ values of crops grown without any manure. The baseline value is not a single, fixed value but is influenced by the substrate and the kind of crop (see for instance Bateman *et al.* 2005; Högberg 1997).

To provide the best possible baselines, both emmer wheat and hulled barley were grown in tubs filled with West Frisian sandy clay, dug from an off-site prehistoric horizon, 120cm below the present surface. This clay was not polluted by modern fertilizers.

The plastic tubs were placed on concrete tiles to avoid contact with modern soil and protected by a large cage from the activities of cats and birds (Figure A.29). The whole experiment was set up in a part of the Hortus Botanicus at Leiden closed to the general public.

Table A.7. The samples and the results.

Locality	Date	crop	N specimens	$\delta^{15}N$
Bovenkarspel-Het Valkje 7	Middle Bronze Age	emmer wheat	10	9.65
Bovenkarspel-Het Valkje 7	Middle Bronze Age	hulled barley	10	13.50
Bovenkarspel-Het Valkje 10	Middle Bronze Age	emmer wheat	20	9.57
Bovenkarspel-Het Valkje 10	Middle Bronze Age	hulled barley	20	12.72
Bovenkarspel-Het Valkje 105	Middle Bronze Age	emmer wheat	12	10.00
Bovenkarspel-Het Valkje 105	Middle Bronze Age	hulled barley	12	9.63
Enkhuizen-Haling 23	Middle Bronze Age	emmer wheat	7	11.63
Twisk 1-1-19	Middle Bronze Age	emmer wheat	12	6.61
Twisk 1-1-20	Middle Bronze Age	naked barley	12	8.16
Westwoud 39/4	Late Bronze Age	emmer wheat	12	10.30
Westwoud 4	Late Bronze Age	hulled barley	12	9.13
Recent experiment	recent	emmer wheat in nitrogen	15	3.31
	recent	emmer wheat in air	15	3.30
	recent	hulled barley in nitrogen	15	3.26
	recent	hulled barley in air	15	2.40

Figure A.29. Growing grain for baselines in tubs.

The experiment will last two years as it is the intention to sow summer and winter varieties of emmer wheat and hulled barley, and to do this twice to avoid the influence of a possible bad summer or winter. The first sowings took place in the spring of 2014 and this crop provides the results discussed below. The emmer wheat was provided by ARCHEON at Alphen aan den Rijn, the Netherlands but came originally from Italy. The summer barley was obtained from the firm Vreeken.

The grain was harvested in the beginning of August and charred for two hours at a temperature of 2500 °C. This temperature was chosen because Fourier Transform Infrared Spectrography (FTIR) conducted by A. van Hoesel showed that the prehistoric grain had become charred at temperatures between 2300 °C and 2700 °C. Experimental work by Kanstrup *et al.* (2012) have shown that a heating time of two hours is sufficient. Charring was conducted in two kinds of atmosphere, in a flow of nitrogen and in an environment with a limited access to air.

The charred grain was sent to Groningen and treated in the same way as the Bronze Age grain.

3. Results and discussion

The results are presented in Table A.7 and Figure A.30.
It is obvious that the $\delta^{15}N$ values of the grain grown for the baselines are much lower than those obtained for the Bronze Age grain. Whether the grain was charred in a nitrogen or air environment does not seem to matter. The value for barley charred in air is lower than that for barley charred in nitrogen, but in another experiment where baselines were obtained for sandy soil, this effect is the other way round thus it may be assumed that the difference falls within the normal range. The samples Bovenkarspel-Het Valkje 7 and 10 were obtained from features close to each other and it is quite possible that they originate from the same crop. If so, the size of a batch, 10 or 20 grains, does not seem to lead to a difference in the obtained values.

Values for Middle Bronze Age emmer wheat vary between 6.6 and 11.6. The Late Bronze Age Westwoud does not stand out but falls within this range. The baseline is 3.3. Values for Middle Bronze Age barley vary between 8.2 and 13.5. Again Late Bronze Age Westwoud does not differ. The baseline is 2.4-3.3. The question is whether the enhancement in $\delta^{15}N$ is due to manuring with animal dung. Although the climate during the Bronze Age was slightly different from the present one, the varieties of the emmer wheat and barley were probably not the same as the, unknown, Bronze Age ones, and the baselines provided by one season only, the δ^{15N} values of the prehistoric grain is still considered to be the result of some external agent. This might be animal dung, but this explanation brings another problem *i.e.* the presence of a sufficient large number of cattle and/or sheep to produce dung in larger quantities. In her chapter 6 Y. van Amerongen states that animal manure was most likely not produced in the required amount on the small-scale farms of West Frisia. If so, some other agent has to be looked for.

A1.12. Calculation of available storage space in the attic of West Frisian houses

Here, it is calculated what the approximate storage area on attics in West Frisian houses may have been (Figure A.31). When it is assumed that storage could only occur on a platform on the cross frames (which can support the weight), the measurements for an average West Frisian attic are as follows: b = 1.5m, h = 3.0m, l = 20.0m (Roessingh in prep.), so V equals 45m^3.

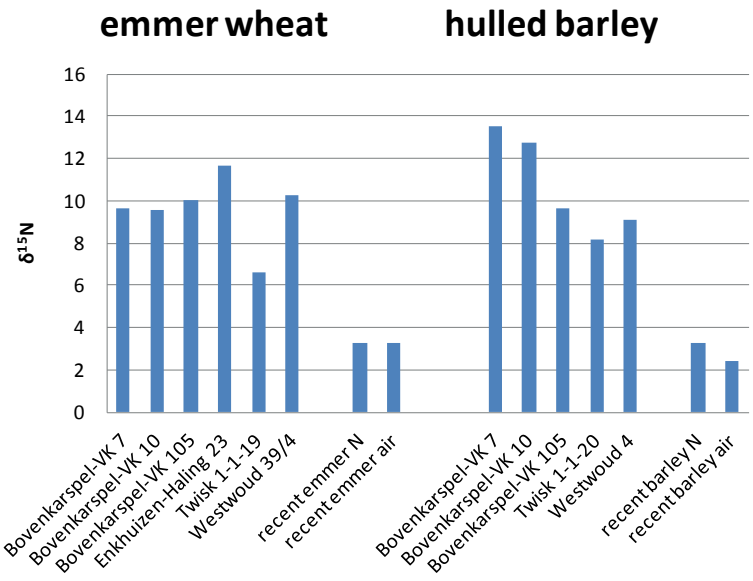


Figure A.30. $\delta^{15}N$ values (Y-axis) of the grain.

Chapter 8

A1.13. Calculation of the required area per household for habitation, and crop and animal husbandry (i.e. total human impact on the environment).

Settlement area

Only grassland pasture:

Per household (and partially derived from Gregg's calculations):

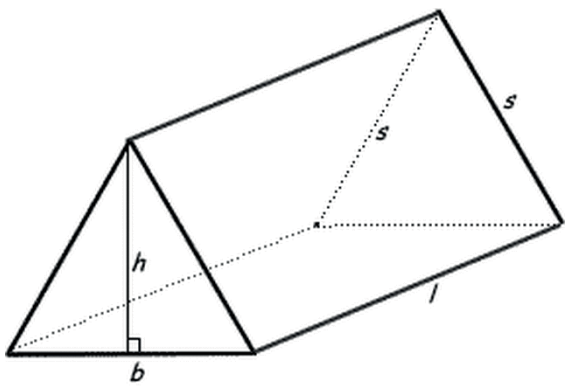


Figure A.31. Volume calculation of a triangle: Volume: V = ½ * (bh) * l

Grassland pasture = 6.1-10.8 ha (see A1. 1.7 above)
Meadow = 3.4 ha (Gregg's value/6)
Woodlot = 7.8 ha (Gregg's value/6)
Village, including houses, outbuildings, and gardens = 0.75 (Gregg's value/6)
Arable fields + fallow fields = 3.6-5.4 ha (1.8 ha per household, 1-2 year fallow)
+
Minimum = 21.65 ha = 0.22 km^2
Maximum = 28.15 ha = 0.28 km^2

Grassland and woodland pasture (2/3 grassland, only goat woodland):

Per household (and partially derived from Gregg's calculations):

Grassland pasture = 6.0-10.5 ha (see see A1. 1.7 above)
Woodland pasture = 1.3-3.7 ha (see see A1. 1.7 above)
Meadow = 3.4 ha (Gregg's value/6)
Woodlot = 7.8 ha (Gregg's value/6)
Village, including houses, outbuildings, and gardens = 0.75 (Gregg's value/6)
Arable fields + fallow fields = 3.6-5.4 ha (1.8 ha per household, 1-2 year fallow)
+
Minimum = 22.85 ha = 0.23 km^2
Maximum = 31.55 ha = 0.32 km^2

A1.14 Science-based artist impression of the reconstructed Middle Bronze Age West Frisian landscape

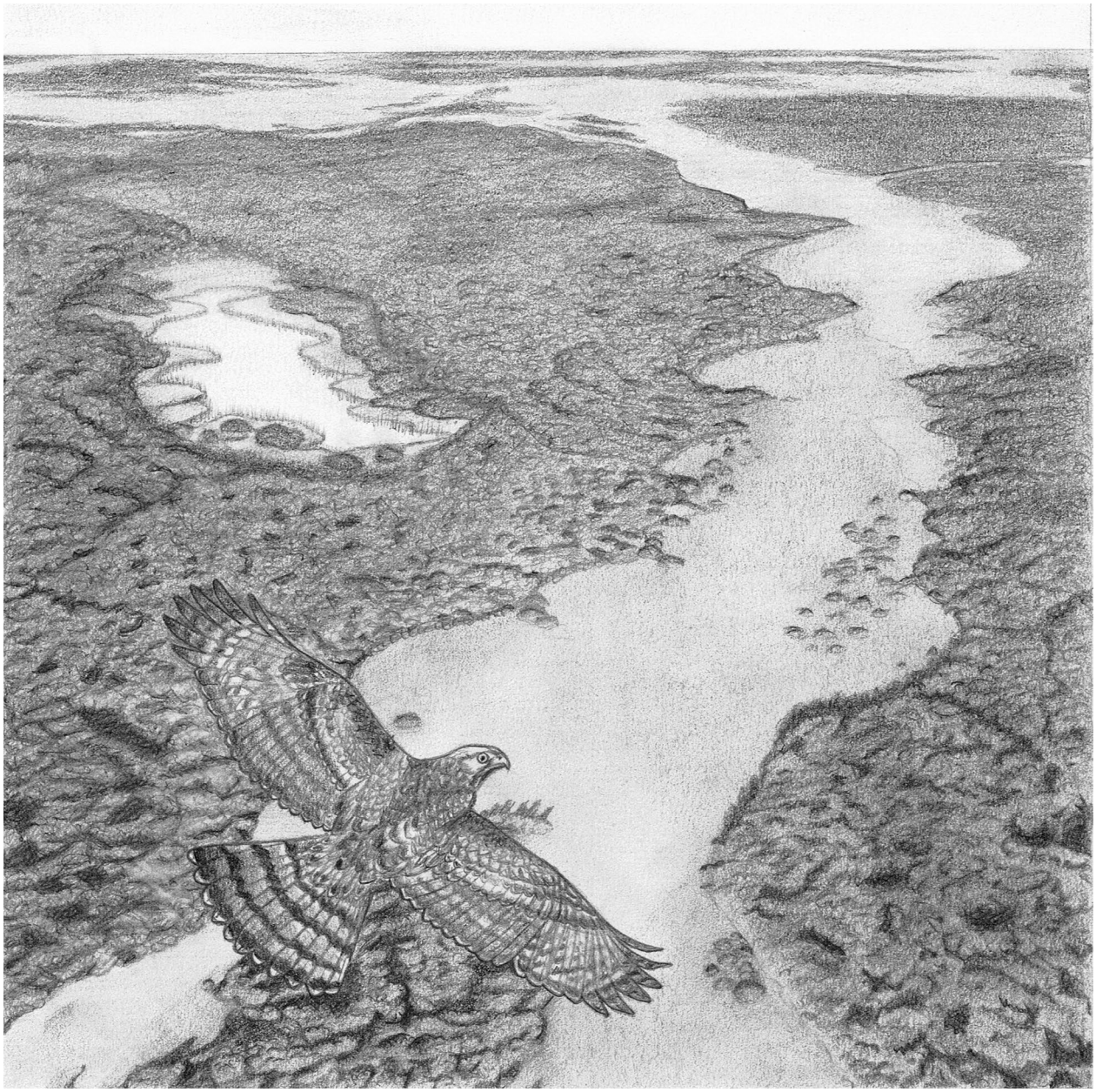


Figure A.32. Reconstructed Middle Bronze Age landscape based on zoological and botanical remains from sites, as well as soil characteristics of West Frisia

A1.15. Calculation of dietary requirements according to adaptations made to the work of Gregg (1988)

Table A.8. Table 60 from Gregg 1988: Farmer resource proportions (% of annual diet) under low red deer densities

resource	red deer	roe deer	boar	fish	beaver	small game	plants	livestock	milk	crops
	3.4	0.5	3.3	2.0	0.2	1.9	2.8	15.3	7.7	62.9

Table A.9. Table 61 from Gregg 1988: Farmer monthly resource fractions, all livestock (% of annual total)

Resource	sept	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug
red deer	8.5	8.0	6.5	7.5	15.0	14.0	15.0	6.5	4.0	3.5	5.5	6.0
roe deer	7.5	7.5	7.5	9.5	12.5	11.5	12.0	8.5	6.0	5.5	5.5	6.5
boar	7.5	7.5	13.5	13.5	12.0	10.0	10.0	4.0	4.0	5.5	6.0	6.5
fish+small game	14.0	3.0	2.0	2.0	1.5	2.0	3.5	7.0	25.0	14.0	13.0	13.0
beaver	0	0	0	20.0	20.0	20.0	20.0	20.0	0	0	0	0
plants	12.0	10.0	7.0	5.0	5.0	5.0	5.0	7.0	10.0	10.0	12.0	12.0
livestock	5.7	7.2	7.2	7.2	7.2	12.4	14.5	14.0	7.3	5.9	5.7	5.7
milk	9.0	0	0	0	0	0	16.0	16.0	16.0	16.0	14.0	13.0
crops	8.2	8.2	8.2	8.2	8.2	8.2	8.6	8.6	8.2	8.2	8.6	8.6

Table A.10. Appendix F from Gregg (1988): Farmer monthly resource fractions, all livestock (% of annual total), low red deer densities (% of monthly diet)

Resource	sept	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug
red deer	3.6	3.4	2.7	3.2	6.3	5.9	0	0	0.9	1.5	2.2	2.4
roe deer	0.4	0.4	0.4	0.5	0.7	0.6	0	0	0.3	0.3	0.3	0.3
boar	3.0	3.0	5.4	5.4	4.8	4.0	0	0	0	2.2	2.3	2.5
fish	3.5	0.7	0.5	0.5	0.4	0.5	0	0	6.2	3.5	3.1	3.1
beaver	0	0	0	0.4	0.4	0.4	0	0	0	0	0	0
small game	3.4	12.8	12.3	12.0	9.4	0.9	0	0	0.2	0.2	2.7	3.2
birds	0	0	0	0	0	0	0	0	0	0	0	0
plants	4.1	3.4	2.4	1.7	1.7	1.7	0	0	0.9	3.4	3.9	3.9
livestock	10.6	13.4	13.4	13.4	13.4	23.1	25.8	24.9	13.6	11.0	10.1	10.1
milk	8.5	0	0	0	0	0	14.3	14.3	15.0	15.0	12.5	11.6
cereal	62.9	62.9	62.9	62.9	62.9	62.9	62.9	62.9	62.9	62.9	62.9	62.9

Table A.11. Adapted farmer resource proportions (% of annual diet) based on the West Frisian situation (pulses and legumes are grouped under wild plants, since these crops are not cultivated in West Frisia).

resource	red deer	roe deer	boar	fish	beaver	small game	plants	livestock	milk	crops
	3.4	0.5	3.3	2.0	0.2	1.9	5.7	15.3	7.7	60.0

Table A.12. Raw monthly resource percentages for the West Frisian situation (including shortages and surpluses).

Resource	sept	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug
red deer	0.2890	0.2720	0.2210	0.2550	0.5100	0.4760	0.5100	0.2210	0.1360	0.1190	0.1870	0.2040
roe deer	0.0375	0.0375	0.0375	0.0475	0.0625	0.0575	0.0600	0.0425	0.0300	0.0275	0.0275	0.0325
boar	0.2475	0.2475	0.4455	0.4455	0.3960	0.3300	0.3300	0.1320	0.1320	0.1815	0.1980	0.2145
fish	0.2800	0.0600	0.0400	0.0400	0.0300	0.0400	0.0700	0.1400	0.500	0.2800	0.2600	0.2600
beaver	0	0	0	0.0400	0.0400	0.0400	0.0400	0.0400	0	0	0	0
plants	0.6840	0.5700	0.3990	0.2850	0.2850	0.2850	0.2850	0.3990	0.5700	0.5700	0.6840	0.6840
livestock	0.8721	1.1016	1.1016	1.1016	1.1016	1.8972	2.2185	2.1420	1.1169	0.9027	0.8721	0.8721
milk	0.6930	0	0	0	0	0	1.2320	1.2320	1.2320	1.2320	1.078	1.0010
crops	4.9200	4.9200	4.9200	4.9200	4.9200	4.9200	5.1600	5.1600	4.9200	4.9200	5.1600	5.1600
SUM	8.0231	7.2086	7.1646	7.1346	7.3451	8.0457	9.9055	9.5085	8.6369	8.2327	8.4666	8.4281
surplus/ shortage	0.1769	0.9914	1.0354	1.0654	0.8549	0.1543	-1.3055	-0.9085	-0.4369	-0.0327	0.1334	0.1719
half of value above	0.0885	0.4957	0.5177	0.5327	0.4275	0.0772	-0.6528	-0.4543	-0.2185	-0.0164	0.0667	0.08595

Table A.13. Final monthly resource percentages for the West Frisian situation.

Resource	sept	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug
red deer	0.2890	0.2720	0.2210	0.2550	0.5100	0.4760	0	0	0.1360	0.1190	0.1870	0.2040
roe deer	0.0375	0.0375	0.0375	0.0475	0.0625	0.0575	0	0.0425	0.0300	0.0275	0.0275	0.0325
boar	0.2475	0.2475	0.4455	0.4455	0.3960	0.3300	0	0	0	0.1652	0.1980	0.2145
fish	0.2800	0.0600	0.040	0.0400	0.0300	0.0400	0	0	0.5000	0.2800	0.2600	0.2600
beaver	0	0	0	0.0400	0.0400	0.0400	0	0.0400	0	0	0	0
small game	0.1769	0.9914	1.0354	1.0654	0.8549	0.1543	0	0	0	0	0.1334	0.1719
plants	0.6840	0.5700	0.3990	0.2850	0.2850	0.2850	0	0	0.3516	0.5537	0.6840	0.6840
livestock	0.8721	1.1016	1.1016	1.1016	1.1016	1.8972	2.2185	2.1420	1.1169	0.9027	0.8721	0.8721
milk	0.6930	0	0	0	0	0	1.2320	1.2320	1.2320	1.2320	1.0780	1.0010
crops	4.9200	4.9200	4.9200	4.9200	4.9200	4.9200	5.1600	5.1600	4.9200	4.9200	5.1600	5.1600

Table A.14. Farmer monthly resource fractions for the West Frisian situation.

Resource	sept	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug
red deer	3.5	3.3	2.7	3.1	6.2	5.8	0.0	0.0	1.7	1.5	2.2	2.4
roe deer	0.5	0.5	0.5	0.6	0.8	0.7	0.0	0.5	0.4	0.3	0.3	0.4
boar	3.0	3.0	5.4	5.4	4.8	4.0	0.0	0.0	0.0	2.0	2.3	2.5
fish	3.4	0.7	0.5	0.5	0.4	0.5	0.0	0.0	6.1	3.4	3.0	3.0
beaver	0.0	0.0	0.0	0.5	0.5	0.5	0.0	0.5	0.0	0.0	0.0	0.0
small game	2.2	12.1	12.6	13.0	10.4	1.9	0.0	0.0	0.0	0.0	1.6	2.0
plants	8.3	7.0	4.9	3.5	3.5	3.5	0.0	0.0	4.3	6.8	8.0	8.0
crops	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0
livestock	10.6	13.4	13.4	13.4	13.4	23.1	25.8	24.9	13.6	11.0	10.1	10.1
milk	8.5	0.0	0.0	0.0	0.0	0.0	14.3	14.3	15.0	15.0	12.5	11.6
Monthly contribution of subsistence strategies												
animal husbandry	19.1	13.4	13.4	13.4	13.4	23.1	40.1	39.2	28.6	26.0	22.7	21.8
hunting	9.2	18.9	21.2	22.6	22.7	12.9	0.0	1.0	2.0	3.8	6.3	7.2
fishing	3.4	0.7	0.5	0.5	0.4	0.5	0.0	0.0	6.1	3.4	3.0	3.0
crop husbandry	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0
wild plant gathering	8.3	7.0	4.9	3.5	3.5	3.5	0.0	0.0	4.3	6.8	8.0	8.0

Table A.15. Micro-nutrient composition of different Bronze Age food sources and diets based on well-being. Also the amount of required food per food category is noted.

	emmer/ barley mix (50/50)	raw milk	beef	farmer's diet (emmer/ barley, beef, and milk)	farmer's diet, no milk	wild plants (greens)	full diet (farmer's diet + wild plants)	fish (eel)
Amount of required food:	**750g**	**200 ml**	**110g**			**100g**		**50 g**
Micro-nutrient:								
Vitamin A (ug)	3	9	0	12	3	94	106	522
Vitamin C (mg)	0	0	0	0	0	122	122	1
Folate (ug)	94	3	2	99	96	unknown	99	8
Iron (mg)	121	0	22	143	143	12	155	0
Zinc (mg)	136	1	59	196	195	6	201	1

Dietary requirements based on calories

By using the Table A.11 and the same farmer monthly resource fractions as Gregg (Table A.9), the following monthly resource percentages were obtained for the West Frisian situation (Table A.12):

In addition, the sum of all the resource percentages per month was calculated (Table A.12), which was used in accordance to the work of Gregg (1988, chapter 7) to assess whether there were surpluses or shortages during each month. These surpluses and shortages were then used to calculate the possibly required additional food from wild resources, such as wild plants, boar, red deer, fish, and roe deer during certain months (Gregg 1988, 186).

The results of these calculations can be observed in Table A.13.

The values from Table A.13 were finally re-calculated to arrive at the farmer monthly resource fractions (Table A.14). These values were used to evaluate the availability of resources in West Frisia throughout the year, as well as to calculate the contributions of each subsistence strategy based on calories (Table A.14 bottom rows).

Dietary requirements based on well-being

Several sources were consulted to arrive at the dietary requirements based on well-being (see references in Chapter 8, section 8.3.1). First of all, the recommended critical micronutrient intake values for people consuming a staple diet based on cereals were researched. Then, calculations were made of the nutrient composition of a farmer's diet (consisting of emmer/barley mix, beef, and milk). Finally, nutrient composition calculations were made of the food groups lacking in the farmer's diet, but which are essential for well-being. Using all this information, the following values for the different food sources for a healthy diet were obtained (Table A.15) Ultimately, the required food amounts from Table A.15 were combined with the monthly availability to arrive at the monthly dietary composition throughout the year, based on well-being (Table A.16).

Table A.16. The required amounts of food (in g) per food group, in proportion to the availability throughout the year (cf. Table A.14).

	sept	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug
wild plants	100	100	200	200	200	200	100	100	100	100	100	100
game	55	110	110	110	110	55	55	55	55	55	55	55
fish	25	25	50	50	50	50	25	25	25	25	25	25
milk	200	200	0	0	0	0	200	200	200	200	200	200
domestic meat	110	55	55	55	55	110	110	110	110	110	110	110
crops	750	750	750	750	750	750	750	750	750	750	750	750

Table A.17. Calculations made to arrive at an estimation of the importance of the different subsistence strategies in the Bronze Age.

	Murdock 1981 selections			**average**	**+ 56% Ertuğ**		
subsistence strategy	**Neighbour hoods**	**Hamlets**	**Villages**	**food**	**subsistence**		
wild plant gathering	2.86	2.50	2.29	3	7	14	14
hunting	6.43	7.50	1.71	5	5	10	10
fishing	4.29	6.25	6.00	6	6	11	11
animal husbandry	29.29	28.75	26.00	28	28	14	25
crop husbandry	57.14	55.00	64	59	59	29	40
TOTAL	100	100	100	100	104	78	100

A1.16. Estimating the importance of the different subsistence strategies in the Bronze Age

The relative importance of each of the subsistence strategies in the Bronze Age was estimated by several assumptions based on the results in this thesis, as well as ethnographical parallels. First of all, it is assumed that plants and animals, especially wild varieties, do not necessarily only contribute to subsistence in terms of consumption. Raw material obtained from these (wild) sources is also very important for the creation of tools, clothing, and shelter (cf. Chapter 4, 7, and 8). Their overall contribution to subsistence should therefore be increased with respect to farming strategies, which contribute less in the form of raw materials.

Second, in terms of consumption, the various food categories contribute more than just calories. In fact, food groups such as wild plants are essential to remain healthy, but are not consumed in comparable large quantities to for example cereals, which form the staple food. Therefore, when health is considered, which is essential for subsistence, the wild plant food group must increase in importance with respect to instances where only calories are considered (cf. Chapter 7 and 8).

Third, in every researched selected culture based on the work by Murdock (1981), crop husbandry always contributes most to subsistence, followed by animal husbandry. It is assumed that this was also the case in the Bronze Age.

The following calculations were made to arrive at the estimation:
The average values of Figure A.7 were employed as a starting point (Table A.17, column 5). Subsequently, the work of Ertuğ was used as an indication of the importance of wild plant gathering when not solely performed for consumption. She indicates that 56% of the wild plants is not collected for consumption (Ertuğ 2004, 165), so 56% importance was added to wild plant gathering (Table A.17, column 6). The resulting total percentage was logically higher than 100%, so the other strategies needed to be adjusted accordingly.

Since it is assumed that wild plants and animals in the new model for Bronze Age farming in general should increase in importance with respect to crops and domestic animals (see above), values for wild plant gathering, hunting, and fishing were multiplied by two, whereas farming strategies were divided by two (Table A.17, column 7). Finally, since the total was now less than 100, the values for farming were again raised according to their relative importance and ratios, under the assumption that crop husbandry is always more important than animal husbandry in small-scale mixed farming communities (Table A.17, column 8).

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Nederlandse Samenvatting

HET WILDE WEST-FRIESLAND:

Het wilde West-Friesland: de bijdrage van zowel geproduceerde als uit het wild verkregen voedings- en grondstofbronnen aan het Bronstijd bestaan.

De nieuwe aanpak die in dit proefschrift wordt gebruikt in de re-evaluatie van de oude en nieuwe West-Friese data heeft veel profijt gehad van de integratie van zowel mijn achtergrond in de biologie als de archeologie. De combinatie van deze onderzoeksrichtingen heeft ervoor gezorgd dat er een volledig interdisciplinaire aanpak naar de bestaanseconomie kon plaatsvinden. Dit werd bereikt door het principe van het onderzoeksveld van de systeembiologie toe te passen op het complexe systeem dat het boerenbedrijf heet, maar ook door een verwachting op te stellen voor de verschillende praktijken waarna pas vergeleken wordt met de archeologische data. Tenslotte is het bewust zijn van en corrigeren voor de potentiële impact van interne en externe data biases van belang geweest, omdat deze de daaropvolgende archeologische interpretatie van menselijk handelen in het verleden kunnen beïnvloeden.

Zoals gezegd omvat mijn biologische achtergrond onder meer de kennis van en ervaring met de systeembiologie, waarbij individuele genen, eiwitten en metabolieten van een organisme eerst apart worden onderzocht. Daarna worden de resultaten van deze onderzoeken gecombineerd om meer inzicht te krijgen in de werking van het gehele organisme. Deze unieke aanpak is ook gebruikt om het complexe systeem van het boerenbedrijf te onderzoeken. Eerst zijn de onderdelen waaruit een dergelijk bedrijf kan bestaan onderzocht. Deze onderdelen zijn akkerbouw, veeteelt, jagen en het verzamelen van wilde planten, maar dit zijn slechts de middelen waarmee men zijn bestaan opbouwt. De eigenlijke bestaanseconomie, echter, is een dynamisch en complex systeem dat bestaan uit vele met elkaar in contact staande onderdelen die beïnvloed worden door factoren zoals omgevingsomstandigheden, tijd en sociale condities. Daarom zijn de resultaten van de analyses van de verschillende onderdelen gecombineerd om het boerenbedrijf in zijn geheel te onderzoeken. Het landschap is op een vergelijkbare manier onderzocht, waarbij alle beschikbare omgevingsindicatoren (zoals biologische informatie over planten- en diersoorten) gebruikt en gecombineerd zijn om het landschap als een geheel, een ecosysteem, te onderzoeken.

Door het bestaan op deze manier te bestuderen zijn vele nieuwe inzichten in de complexiteit en interconnectiviteit van zowel de akkerbouw en veeteelt als de natuur verkregen.

Dit proefschrift heeft niet alleen betrekking op wat er archeologisch is aangetroffen, maar vooral ook op wat er logischerwijs kan worden verwacht binnen een Bronstijd boerenbedrijf. Deze verwachting is met name gebaseerd op vastgelegde informatie van etnografische studies naar hedendaagse boerengemeenschappen die verondersteld worden vergelijkbaar te zijn met de Bronstijd situatie. De etnografie is een belangrijke en nuttige bron gebleken om basisactiviteiten gerelateerd aan het boerenbedrijf en het exploiteren van de natuur te identificeren. Deze insteek is anders dan wanneer etnografische voorbeelden worden gebruikt voor de vergelijking en verklaring van culturele fenomenen. De vastgestelde basisactiviteiten bleken in verschillende delen van de wereld vergelijkbaar te zijn, onafhankelijk van hun geografische locatie, het klimaat, en de tijdsperiode, waardoor zij als een goede basis voor de vergelijking met het verleden worden beschouwd.

Met name praktijken die (bijna) onzichtbaar zijn binnen de archeologie, zoals het eten van wilde planten, zijn op deze manier herkend en juist deze

activiteiten zijn het meest essentieel gebleken om een gezond boerenbestaan te leiden.

Door ten slotte het proces achter elke voedselstrategie te onderzoeken zijn meerdere problemen rond praktische aanpak en wetenschappelijke redeneringen gebaseerd op (gebrekkige) bio-archeologische datasets ontdekt. Voor beide type problemen zijn nieuwe methoden en invalshoeken geïntroduceerd waarbij zoveel mogelijk met de effecten van tafonomie op zowel botanische als zoölogische archeologische assemblages rekening is gehouden. Dit resulteerde in een dataset welke zoveel mogelijk unbiased is. Net als bij biologisch onderzoek is deze dataset vervolgens vergeleken met de verwachting die vooraf voor elk onderdeel van de bestaanseconomie/het landschap is opgesteld. Verschillen of overeenkomsten die waargenomen zijn op basis van deze vergelijking kunnen zo een duidelijker beeld scheppen van menselijke activiteit in het verleden, wat de hoofddoel van archeologisch onderzoek is.

Een nieuw model voor het Bronstijd boerenbedrijf in West-Friesland

Het Bronstijd boerenbedrijf in West-Friesland was een kleinschalig gemengd boerenbedrijf en bestond uit een combinatie van vier voedselstrategieën, namelijk akkerbouw, veeteelt, jagen en het verzamelen van wilde planten. De verbouwde granen waren emmertarwe, bedekte gerst, lijnzaad en gierst op akkers met een totale oppervlakte van 1-3 ha per huishouden. De aanwezige huisdieren waren rund, schaap, geit, varken, paard en hond, al bezat niet elk huishouden alle soorten. Kuddes waren klein, een kenmerk van het gemengd boerenbedrijf, en bestonden uit maximaal 5-8 runderen, 10-15 schapen/geiten en 3 varkens. De wilde dieren en planten in de omgeving waren overvloedig beschikbaar en divers van aard, wat verklaard kan worden door het feit dat er zich vele landschapstypen aanwezig waren zoals bos (nat en droog), struikgewas, graslanden, wetlands en de kust.

De beschikbare voedselstrategieën werden gebruikt om in de basisbehoeften te voorzien van het bestaan: voedsel, drinkwater, kleding, onderdak en vuur. Hiervoor werd de omgeving van de nederzetting geëxploiteerd voor zowel geproduceerde als in het wild beschikbare grondstof- en voedselbronnen. Deze exploitatie had een aanzienlijke impact op het landschap, omdat een huishouden gemiddeld 0,3 km^2 aan grond nodig had om alle benodigdheden voor het bestaan te verkrijgen. Deze impact op de omgeving was met name in de Midden Bronstijd groot, door zowel mens en vee als wilde dieren. Het West-Friese Midden Bronstijd landschap kan dan ook worden gekarakteriseerd als dichtbevolkt. Echter, zelfs onder deze druk waren er bossen aanwezig in vele delen van het landschap.

In de Late Bronstijd nam de hoeveelheid bewoonbaar land af door toenemende algehele vernatting van het landschap en het aantal mensen en vee dat in West-Friesland woonde zal daarmee ook zijn afgenomen. Boeren die wel in de omgeving bleven wonen beoefenden nog steeds alle vier de vormen van exploitatie, maar er waren wel lichte veranderingen in akkerbouw en veeteelt als aanpassing aan de veranderingen in het landschap. Jagen en verzamelen bleven echter dezelfde stabiele en flexibele toevoeging aan het bestaan leveren als in de Midden Bronstijd.

Het dieet van de Bronstijdboeren zal hebben bestaan uit een basis van granen, gevolgd door vlees (van zowel gedomesticeerde als wilde dieren), melk, wilde planten en vis. De vegetatieve delen van wilde planten (alles behalve de zaden), zijn essentieel geweest om in een dergelijk graandieet de benodigde cruciale vitaminen A en C te leveren, welke beiden niet (makkelijk) uit andere voedselbronnen zijn te verkrijgen. Vlees van wilde dieren en vis zullen ook zeer belangrijke toevoegingen aan het dieet hebben gevormd in tijden wanneer vlees van gedomesticeerde dieren niet beschikbaar was. Jagen en verzamelen waren dus essentiële elementen van het Bronstijddieet, ondanks dat hun reflectie in het archeologische vondstenbestand betrekkelijk beperkt is.

Dat West-Friese Bronstijdmensen zeer goed in staat waren om een relatief gezonde levensstijl te hebben wordt duidelijk aan de hand van hun hoge gemiddelde lichaamslengte en hun vermogen om te herstellen

van letsel. Er zijn maar minimale aanwijzingen voor periodieke voedingsstoftekorten, die mogelijk gerelateerd kunnen worden aan tijden van algehele voedselschaarste zoals de winter.

Resten van kleding zijn niet gevonden in West-Friesland, maar, op basis van gelijktijdige vondsten, kan verondersteld worden dat de West-Friese Bronstijdgarderobe zal hebben bestaan uit een combinatie van kledingstukken van linnen en wol, maar ook kleding gemaakt van huiden en pelzen. Het is goed mogelijk dat textiel ook geverfd werd in Bronstijd West-Friesland, aangezien textiel uit deze periode vaak geverfd blijkt te zijn en omdat West-Friesland meerdere potentiële verfplanten heeft opgeleverd in de botanische assemblages van huisplaatsen.

Huizen in West-Friesland werden vooral gebouwd van hout, maar de binnenkant van deze huizen is nooit echt gereconstrueerd. Echter, gebaseerd op zowel de verwachting als de vondsten van voorwerpen gerelateerd aan activiteiten voor het bestaan is het duidelijk geworden dat huizen zeker niet leeg waren. West-Friese huizen zullen verschillende plekken in het huis hebben gehad waar opslag plaatsvond, kleding werd gemaakt, werd gekookt, gereedschap werd vervaardigd, werd geslapen en gegeten, en waar vee stond. Voor de productie van bijna al deze gereedschappen en uitrusting die nodig zijn op een nederzetting zullen grondstoffen uit wilde planten en, in mindere mate, wilde dieren onmisbaar zijn geweest. Deze onmisbaarheid onderstreept opnieuw het belang van deze natuurlijke grondstoffen voor het bestaan, onafhankelijk van hoeveel overblijfselen er van deze organismen uiteindelijk bij de opgraving en uitwerking aan het licht zijn gekomen.

Huizen in West-Friesland zien er op het eerste gezicht erg vergelijkbaar uit op elke site, maar in Bovenkarspel Het Valkje zijn er wel verschillen tussen huizen ontdekt, zowel gerelateerd aan de grootte van de huishoudens die in huizen woonden als aan de functie van de huizen. Zo zijn er kleine en grote huishoudens geïdentificeerd die significant verschilden in de samenstelling van de verschillende huisdieren die werden gehouden, onafhankelijk van de grootte van het huis zelf. Daarnaast heeft een analyse van de verschillende samenstellingen van botanische macroresten uit deze huizen aangetoond dat huisplattegronden beter gebouwplattegronden kunnen worden genoemd. Er kunnen namelijk verschillende functies van gebouwen zijn zoals alleen een woonhuis, alleen een stal, of een combinatie van woonhuis en stal binnen één gebouw, het zogenaamde woonstalhuis.

Elk seizoen van het jaar moet zijn besteed aan andere activiteiten om aan de verschillende grondstoffen te komen. In de herfst werden waarschijnlijk de schapen van in toenemende mate natter wordende gebieden naar de hogere, drogere gebieden gebracht. Deze periode was ook de paartijd van alle runderen, schapen en geiten. Op de akkers zal er nu bemest zijn (met zowel vaste dierlijke mest, huishoudelijk afval, etc.) en geploegd om de velden klaar te maken voor het zaaien in de volgende lente. De exploitatie van grondstoffen uit het wild zal hebben plaatsgevonden in de vorm van het jagen op grofwild, trekvogels en –vissen, en het verzamelen van vruchten, zaden, noten en bessen. In de winter werden kwetsbare en kostbare huisdieren waarschijnlijk binnen gehouden om ze te beschermen tegen het slechte weer en roofdieren, terwijl het overige vee buiten bleef. Varkens hadden nu hun paartijd. De akkers zullen grotendeels met rust zijn gelaten, al kon de tweede keer ploegen om het zaaibed voor te bereiden bij gunstig weer al tegen het eind van de winter plaats hebben gevonden. Aangezien de winter voor de gebruikelijke buitenactiviteiten op de boerderij een rustige periode was, werd dit seizoen waarschijnlijk vooral besteed aan het herstellen en maken van gereedschap en uitrusting. Daarnaast zal er ook tijd zijn geweest voor het actief bejagen van grofwild, het passief jagen op pelsdieren met vallen, en, aan het eind van de winter, voor het vangen van trekvogels en –vissen. Gedurende de hele winter waren wortels en knollen beschikbaar als de belangrijkste bron van voedsel afkomstig van wilde planten.

In de lente werd het vee dat binnen stond tijdens de winter waarschijnlijk weer naar buiten gelaten en samen met het overige vee naar de graaslanden gebracht. De meeste diersoorten zullen nu jongen hebben gekregen, waardoor melk beschikbaar werd. Overbodige en ten dode opgeschreven dieren zullen

met name tijdens dit seizoen zijn afgemaakt en verwerkt voor (latere) consumptie. Jacht op grofwild zal beperkt zijn gebleven in dit seizoen doordat er een overvloed aan geproduceerde voedselbronnen zoals vlees en melk beschikbaar was. In deze periode zullen er echter wel eieren van wilde vogels beschikbaar zijn geweest, net als visproducten, welke niet op de nederzetting beschikbaar waren. Wilde planten kwamen op in dit seizoen, waardoor jonge scheuten en bladeren ook beschikbaar waren als aanvullende voedselbron.

In de zomer graasde het vee waarschijnlijk op verschillende gebieden in het landschap en in de late zomer konden dieren weer gedekt worden. Op de akkers zal er nu gewied zijn en, later in de zomer, geoogst. Na de oogst kon het vee grazen op de stoppelvelden of werden de oogstresten afgebrand. De jacht op watervogels was een potentieel vruchtbare onderneming in de zomer, aangezien door de rui vele soorten watervogels voor langere periode niet konden vliegen. Onderdelen van wilde planten die beschikbaar zullen zijn geweest in de zomer zijn eerst de groene delen, dan de zaden, gevolgd door vruchten, noten en bessen.

In de Late Bronstijd zorgden periodieke overstromingen van het landschap ervoor dat bepaalde gebieden onbegaanbaar werden voor exploitatie in de winter. Zoals gezegd kon de resulterende verminderde hoeveelheid geschikte grond minder mensen, vee en wilde dieren dan in de voorgaande periode herbergen, iets wat ook zijn weerslag kende in de akkerbouw- en veeteeltpraktijken. Gewassen werden minder ver verwerkt opgeslagen, wat waarschijnlijk gerelateerd is aan het feit dat er door de verslechterende weersomstandigheden minder tijd was om de oogst binnen te halen en/of minder mensen beschikbaar waren om te helpen. Er was ook een verandering van strategie binnen de veeteelt, waarbij werd ingezet op een verhoogd productiepotentieel voor vlees en melk. Deze strategie had echter tot gevolg dat de kudde op de lange termijn een minder gezonde samenstelling kreeg.

Deze veranderingen geven aan dat mensen zich aanpasten aan de veranderende omstandigheden in hun omgeving en niet wegtrokken naar andere gebieden om deze veranderingen te ontlopen. West-Friese boeren zijn dus gedurende de hele Bronstijd zelfvoorzienend gebleven door geproduceerde voedsel- en grondstofbronnen en die uit het wild te combineren om in hun levensonderhoud te voorzien in een dynamisch landschap.

Is West-Friesland bijzonder?

West-Friesland wordt vaak gezien als een regio in Nederland die bijzonder en afwijkend is binnen de Bronstijd, omdat onderdelen van de bestaanseconomie niet overeenkomen met andere gebieden van Nederland. Resultaten die op basis van de analyses in dit proefschrift (Hoofdstuk 4-7) nieuw zijn in vergelijking met voorgaande onderzoeken zijn onder andere dat veeteelt kleinschalig was en dat het vee hoogstwaarschijnlijk voor zowel vlees als melk werd gehouden, zonder dat daarbij sprake is van specialisatie in één van de twee richtingen. De twee hoofdsoorten binnen de verbouwde granen zijn bedekte gerst en emmertarwe, waarbij er in de Late Bronstijd meer een verschuiving naar tarwe lijkt te ontstaan ten koste van gerst. Het is ook duidelijk geworden dat de aanwezigheid van grote huishoudens op de nederzetting van Bovenkarspel in de Midden Bronstijd een uitzondering is binnen West-Friesland. Ten slotte is aangetoond dat de natuur geëxploiteerd werd door het jagen op wilde dieren en het verzamelen van wilde planten. Hierbij is vastgesteld dat er in verhouding weinig fruit en noten aanwezig waren op de nederzettingen, maar dat juist de groene en ondergrondse delen van planten essentieel waren voor het bestaan.

De vergelijking van West-Friesland met andere Nederlandse regio's (Texel, Kennemerland, Noordwijk, Haaglanden, Hattemerbroek, het westelijk rivierengebied en het oostelijk rivierengebied) en Europese gebieden (Denemarken, zuidelijk Zweden en Zwitserland) heeft dit gebied in perspectief geplaatst. Er zijn wel veel van de aspecten van het West-Friese bestaan anders dan in de andere regio's, maar alle onderzochte sites vertonen lokale variatie. Beschikbare gewassen en veerassen lijken verschillend te zijn in elke regio, zowel in samenstelling als in onderlinge verhoudingen. Sommige van de waargenomen verschillen zijn

pas aan het licht gekomen door gebruik van de methoden toegepast op de rijke West-Friese data. Daardoor zijn er pas interregionale verschillen in eigenschappen van kuddes en gebruiksdoeleinden van vee aan het licht gekomen. In West-Friesland werd waargenomen dat runderen voor zowel vlees als melk werden gehouden, terwijl in andere regio's juist meer een trend was in de richting van vlees (oostelijk rivierengebied) of melk (Denemarken). Naast verschillen in veel van de onderzochte bestaansstrategieën tussen de regio's zijn er ook overeenkomsten waargenomen, maar deze zijn dus pas duidelijk geworden na de reconstructie van praktijken op basis van de West-Friese data. Zo heeft de analyse van oogstverwerking het bijvoorbeeld mogelijk gemaakt om verschillende groottes van huishoudens te identificeren in zowel West-Friesland en Denemarken en een verschuiving naar kleinere huishoudens in de Late Bronstijd te herkennen in beide regio's. Daarnaast is vastgesteld dat andere akkerbouwpraktijken ook hetzelfde waren in veel regio's, zoals zaaitijd, oogsthoogte en algemene groeicondities op de akkers. Jagen en verzamelen lijken in alle regio's constante factoren te zijn geweest die gedurende de gehele Bronstijd aan het bestaan bijdroegen. De vaakst aangetroffen grote zoogdieren lijken in elke regio bejaagd te zijn, onafhankelijk van klimaat, geografische locatie en tijdsperiode. Deze "basis set" van dieren werd verder aangevuld met lokaal voorkomende of gewenste dieren die verschilden per regio maar in dezelfde categorieën zijn in te delen zoals pelsdieren, trekvogels en trekvis. Het verzamelen van wilde planten geeft een vergelijkbaar beeld weer als jagen. Er werd ook een "basis set" van wilde planten verzameld, die verder werd aangevuld met lokaal beschikbare of gewenste planten. Deze lokale planten lijken in vergelijkbare gebruikscategorieën te vallen, ook al zijn de soorten verschillend. Plantengebruiken die in alle regio's zijn waargenomen zijn onder andere die voor vezels, als bedmateriaal, voor mandenmaken en voor kleurstof. Andere toepassingen, die zowel in Nederland als in Scandinavië zijn teruggevonden zijn gebruik voor tannine, zeep, afweermiddel en dakdekking.

Zowel jacht als verzamelen zullen het hele jaar hebben plaatsgevonden waarbij verschillende dier- en plantensoorten in verschillende seizoenen zijn geëxploiteerd om grondstoffen te verkrijgen en het bestaan aan te vullen.

Er kan dus worden gesteld dat West-Friesland als speciaal kan worden beschouwd als het om de uitstekende bewaarcondities gaat. Deze omstandigheden liggen tenslotte ten grondslag aan de mogelijkheid om een gedetailleerde analyse van de bestaanseconomie in de Bronstijd uit te voeren waarmee andere regio's kunnen worden vergeleken. West-Friesland is echter niet bijzonder als het op het eerste gezicht afwijkende Bronstijdbestaan daar met andere regio's wordt vergeleken, aangezien elke regio lokale verschillen laat zien. Deze lokale variatie lijkt een consequent aspect te zijn van het boerenbedrijf in de Bronstijd en kan dus eigenlijk worden gezien als een algemeen kenmerk van het bestaan in deze periode.

De internationale vergelijking heeft duidelijk gemaakt dat de diversiteit aan exploitatiestrategieën die is gebruikt in de West-Friese bestaanseconomie zeker geen uitzondering was in de Bronstijd. De goede conservering van resten in West-Friesland heeft eerder de zichtbaarheid en herkenning van praktijken verbeterd die anders niet gemakkelijk geïdentificeerd hadden kunnen worden. West-Friesland was dus niet uitzonderlijk met betrekking tot de bestaanseconomie in de Bronstijd, maar heeft door de rijkheid aan data een fundamentele basis gelegd om de Bronstijd bestaanseconomie beter te begrijpen.

Het Bronstijd boerenbedrijf in Noordwest-Europese kustgemeenschappen

Het Bronstijdbestaan kan in het algemeen worden gekarakteriseerd als een evenwichtige combinatie van het gebruik van geproduceerde en in het wild verkregen grondstoffen, waarvan de individuele componenten elkaar op flexibele wijze gedurende het jaar aanvulden. Akkerbouw en veeteelt vormden een constant systeem dat de basis was van de bestaanseconomie. Boeren moesten kunnen rekenen op hun geproduceerde producten, die ze voorzag van voedsel in de vorm van granen, maar ook vlees, melk, en grondstoffen zoals bot, huiden, wol, etc. Aangezien granen het stapelvoedsel vormden en misoogsten

een potentieel zeer verwoestend fenomeen konden zijn, moesten deze producten op een betrouwbare manier worden geproduceerd. Daarom werden de activiteiten gerelateerd aan akkerbouw gedurende de Bronstijd hetzelfde gehouden. Veeteeltpraktijken bleven ook vergelijkbaar, al lijkt het gebruik van kuddes tussen de Midden en Late Bronstijd te verschuiven in verschillende regio's. In het algemeen leken akkerbouw en veeteelt beiden dus gebaseerd op verschillende soorten en rassen, maar met vergelijkbare onderliggende praktijken; met name dieren hadden wisselende doeleinden in de Bronstijd.

Jagen en verzamelen waren ook constante factoren in het bestaan, maar zij vormden samen een flexibeler systeem dat een variabele maar essentiële toevoeging aan de bestaanseconomie gaf gedurende het jaar. De beschikbaarheid van gewenste wild planten- en diersoorten veranderde van seizoen tot seizoen en mensen exploiteerden verschillende bronnen voor grondstoffen die zij niet konden verkrijgen van hun eigen gewassen en vee. Het feit dat grondstoffen zo wisselend beschikbaar waren betekende dat men telkens op andere manieren moest jagen/verzamelen, ook omdat deze activiteiten gecombineerd moesten kunnen blijven worden met het boerenbedrijf.

Jachtactiviteiten varieerden daarom van actief jagen met pijl en boog tot passief jagen met het gebruik van netten en vallen, en verschillende plantendelen werden in verschillende seizoenen en op verschillende tijdstippen verzameld. Zowel de jacht als het verzamelen lijken een duidelijke set van soorten als doelwit te hebben die werden aangevuld met lokaal beschikbare of gewilde soorten.

Doordat men dicht in de buurt van de zee of van meren woonde, betekende dit dat kustgemeenschappen de mogelijkheid hadden om veel van deze wilde soorten, die in zulke landschapstypen veelvuldig aanwezig zijn, te bemachtigen. In andere gebieden waren deze soorten planten en dieren wellicht minder beschikbaar, waardoor zij potentieel waardevolle ruilmiddelen of handelswaar vormden.

Samengevat kan dus worden gesteld dat jagen en verzamelen gedurende de gehele Bronstijd bestonden uit vergelijkbare geselecteerde soorten, met variërende onderliggende basispraktijken, maar dezelfde doeleinden voor de verkregen diersoorten.

Het is duidelijk dat het Bronstijdbestaan niet zou kunnen hebben functioneren zonder de integratie van alle vier de bestaansstrategieën. Akkerbouw en veeteelt voorzag mensen van een relatief zekere productie van stapelvoedsel en een aantal basisgrondstoffen, maar het kon er niet voor zorgen dat mensen, vee en de nederzetting op een gezonde manier bleven functioneren op de lange termijn. Jagen en verzamelen, ook al was dit minder zichtbaar als praktijk, gaf mensen toegang tot benodigde essentiële micronutriënten, aanvullend voedsel in tijden van schaarste en grondstoffen voor huizen en bijna al het gereedschap, de uitrusting, kleding en andere producten die onmisbaar waren in het dagelijks leven in de Bronstijd.

Conclusie en verdere toepasbaarheid

De nieuwe resultaten die samengevat zijn in dit hoofdstuk, zijn alleen behaald door toepassing van de aanpak gepresenteerd in dit proefschrift: door logisch nadenken en het analyseren van data met gebruik van verschillende onderzoeksdisciplines, niet door het nadoen van vorige methodes. De holistische aanpak heeft geresulteerd in een geïntegreerde analyse van deze verschillende aspecten gerelateerd aan het bestaan. Het heeft een gedetailleerd begrip van de complexiteit van het bestaan gegeven tot op een niveau dat bij het gebruik van slechts één of ongeïntegreerde disciplines niet mogelijk was geweest. Er is dus een compleet nieuw beeld ontstaan van wat het betekende om een Bronstijdboer te midden van een relatief natte leefomgeving.

Het is bijvoorbeeld duidelijk geworden dat een Bronstijdboer over veel kennis en kunde moest beschikken om zijn omgeving te exploiteren: boeren moeten weten wat ze moeten doen voor elke bestaans-gerelateerde activiteit, op welk moment en hoe dit moet gebeuren. Er waren grote planningsvaardigheden nodig om te verzekeren dat de verschillende activiteiten compatibel konden worden uitgevoerd en om hun evenwichtige verbondenheid door het jaar heen te waarborgen.

Het is ook duidelijk geworden dat prehistorische boeren mogelijk meer afhankelijk waren van wilde grondstoffen dan hedendaagse boeren in etnografische parallellen. Bronstijdboeren moesten namelijk alles wat ze nodig hadden voor hun bestaan zelf produceren uit de beschikbare materialen in de (nabije) omgeving van de nederzetting. Het belang en de invloed van het landschap was groot, omdat het mensen voorzag van de grondstoffen voor het vervullen van de basisbehoeften om te overleven zoals voedsel, kleding en onderdak. Het leven in een omgeving bestaande uit wetlands gaf vele kansen voor exploitatie, maar een dergelijk landschap zorgt ook voor een constante verandering en uitdaging. Niettemin zullen de voordelen van zo'n landschap voor het uitoefenen van akkerbouw, veeteelt, jagen en verzamelen landschap in de Bronstijd zwaarder hebben gewogen dan de nadelen, omdat mensen zich aanpasten aan deze veranderingen en niet wegtrokken naar andere gebieden toen de omstandigheden in West-Friesland verslechterden. Het blijven wonen in dit type landschap betekende dat alle bestaansstrategieën nog steeds konden en ook werden beoefend, op een uitgebalanceerde manier die boeren de mogelijkheid gaf om in de Bronstijd in hun bestaan te kunnen blijven voorzien.

De aanpak van dit proefschrift heeft bewezen een waardevolle bijdrage te vormen voor het onderzoek naar Bronstijd kustgemeenschappen wonende aan zowel zout- als zoetwaterlichamen.

Het is ook een potentieel zeer waardevolle aanpak voor onderzoek in andere gebieden of van andere onderwerpen, aangezien het zeker niet beperkt is tot de Bronstijd, tot het boerenbedrijf of een specifieke geografische locatie. De aanpak is juist toepasbaar op elke tijdsperiode, elk gebied en elke vorm van bestaan zolang de verwachtingen die voor de vergelijking met de data worden gemaakt (etnografische parallellen) maar op de goede manier worden gekozen en rekening wordt gehouden met eventuele biases in de data.

De combinatie en integratie van de verschillende disciplines in dit proefschrift, gerelateerd aan biologie en archeologie maar ook etnografie, heeft nieuwe impulsen gegeven aan het onderzoek en een nieuwe kijk op oude onderwerpen opgeleverd; iets wat niet geprobeerd of geobserveerd wordt wanneer onderzoekers slechts binnen hun eigen vakgebieden blijven werken.

Daarom moeten de resultaten van dit proefschrift en de aanpak beschouwd worden als een oproep om meer geïntegreerd onderzoek te doen naar complexe systemen om het verleden beter te leren begrijpen.
Het laatste hoofdstuk geeft een overzicht van de onderwerpen die geen onderdeel uitmaakten/konden uitmaken van dit proefschrift, maar die wel belangrijk zijn voor een beter begrip van het Bronstijdbestaan in wetland gebieden. Er worden mogelijke manieren aangedragen waarop deze onderwerpen onderzocht kunnen worden wanneer er genoeg geschikte data beschikbaar komt in de toekomst. Dit heeft tot doel om te verzekeren dat kennis over en onderzoek naar de Bronstijd gemeenschappen in wetland omgevingen zich uit blijft breiden in de toekomst.

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About the Author

Yvonne van Amerongen was born in 1987 in Voorburg, the Netherlands. From 1999 to 2005 she went to the gymnasium (pre-university education including Latin and classical studies) at the Interconfessioneel Makeblijde College in Rijswijk. In 2005 she started studying Biology in at Leiden University in the direction of Molecular and Cellular Biology, from which she graduated cum laude in 2010. Her doctoral thesis was involved with two studies. The first dealt with the theoretical and qualitative control of metabolites in a Chinese medicinal plant recipe with the aid of High-Performance Liquid Chromatography-UV (HPLC-UV) and Liquid Chromatography-Mass Spectrometry (LC-MS). The second was involved with the identification of lipids in the zebrafish brain with Proton Nuclear Magnetic Resonance (^{1}H NMR) and in vivo magnetic resonance spectroscopy (MRS). The goal was to compare its brain lipid composition with the human brain and therefore test the validity of the zebrafish as a test animal for Alzheimer and Parkinson's disease in humans, and this research has resulted in an article. In 2011 she started studying Archaeology as her second Master's degree at Leiden University in the directions Prehistory of North-Western Europe and Archaeobotany, from which she graduated in 2012. Her doctoral thesis was concerned with the identification, analysis, and interpretation of the charred botanical remains from a Linearbandkeramik (LBK) settlement excavated in Stein, the Netherlands.In 2011 she applied for a PhD position in the NWO-funded Farmers of the Coast project at the Faculty of Archaeology, Leiden University. Throughout her PhD she followed many extracurricular courses, published several articles, and presented multiple papers at both national and international conferences. She's currently working as a palaeo-ecologist on a project basis, but also continues to pursue a scientific career.