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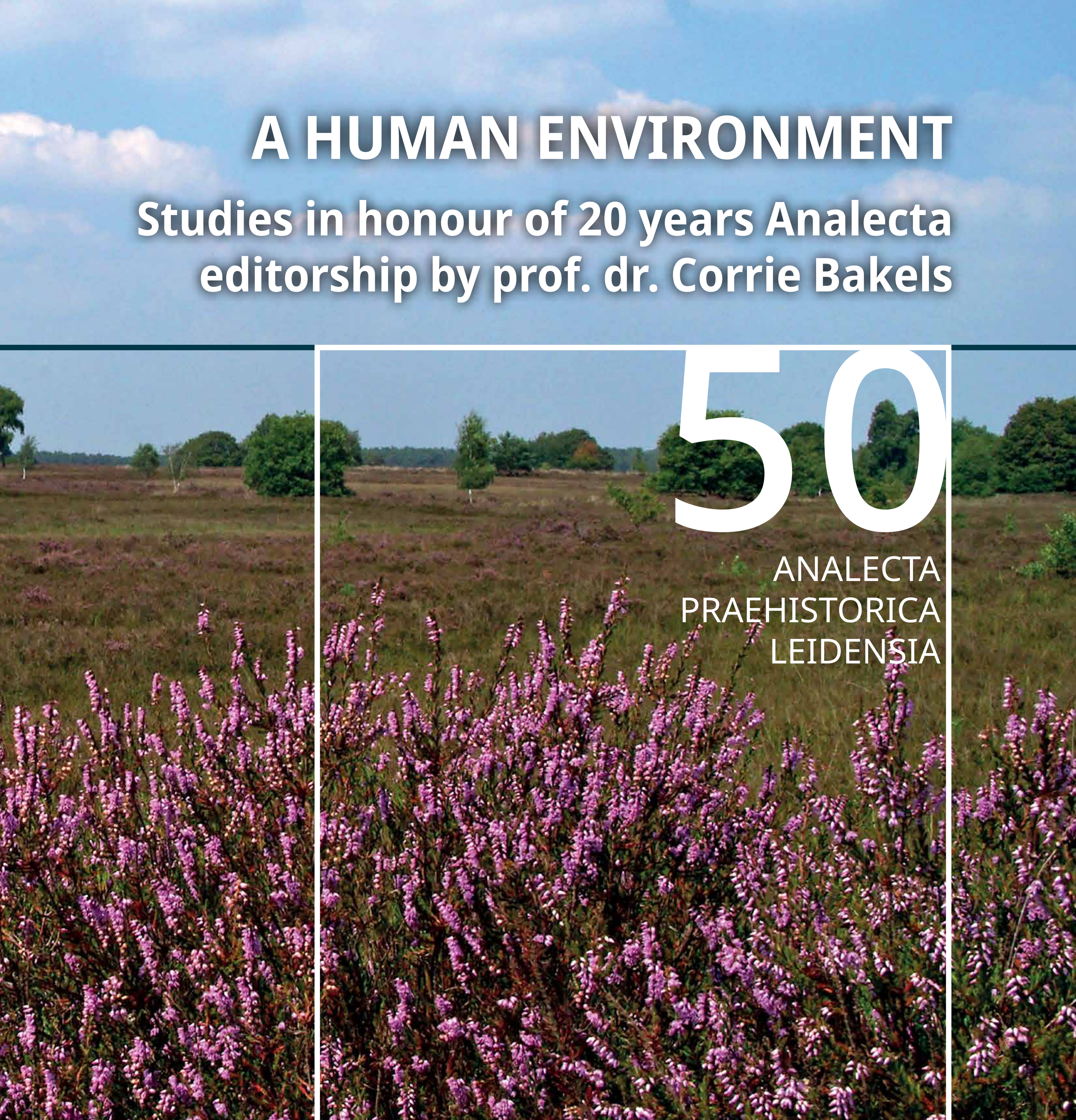
Studies in honour of 20 years Analecta editorship by prof. dr. Corrie Bakels



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A long slow goodbye – Re-examining the Mesolithic – Neolithic transition (5500 – 2500 BCE) in the Dutch delta

Gerrit L. Dusseldorp and Luc W.S.W. Amkreutz

During the Neolithic, Neolithic societies in the Dutch wetlands are characterised as "extended broad-spectrum hunter-gatherers". They adopted agricultural elements only gradually and wild resources continue to play an important role in subsistence. However, the exact duration of the process of neolithisation in the Dutch wetlands is debated. We analyse the taxonomic diversity of faunal assemblages from the late Mesolithic and Neolithic in the Netherlands. We demonstrate that the diversity of exploited faunal resources remains remarkably constant throughout the Neolithic. We interpret this to show that the reliance on an extended broad-spectrum economy was not a transitional phase, but was a viable economic system in its own right.

Keywords: Mesolithic, Neolithic, subsistence economy, foraging, agriculture, extended broad spectrum, Archaeozoology

1. Introduction

The adoption of agriculture in the coastal regions of North-western Europe occurred more gradually than in the interior loess belt and adjacent areas (Raemaekers 1999; Bakels 2000; 2009; Louwe Kooijmans 2007). In the Dutch wetlands, it may have taken over a millennium (*e.g.* Louwe Kooijmans 1987). It appears that Mesolithic hunter-gatherers gradually and selectively adopted elements of a farming way of life. The Early and Middle Neolithic inhabitants are proposed to have an "extended broad-spectrum" economy, including hunting, gathering and farming (Louwe Kooijmans 1993, 102-103).

However, the duration of the transitional period is contested. Proposals range from a short transition that may have been completed during the Middle Neolithic to a transition that only ended in the Early Bronze Age (compare Raemaekers 2003, 744-745; Amkreutz 2013, 435). The debate concerns when agricultural methods came to dominate the subsistence economy, but also when an agricultural way of life became central in societies' worldviews. We examine the diversity of represented animal species in Mesolithic and Neolithic faunal assemblages to determine if the extended broad-spectrum economy gave way to the exploitation of a more narrow set of mainly agricultural resources over time.

Existing approaches focus on the proportion of domestic and wild resources in the faunal spectrum of archaeological sites (*e.g.* Raemaekers 2003; also see Amkreutz 2013, 312-324). Here we focus on the diversity of represented resources to evaluate the extended broad-spectrum aspect. This complements proportional analysis of the subsistence economy. It is also less vulnerable to certain biases such as field processing (*e.g.* Faith 2007; Dusseldorp and Langejans 2013; Morin and

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Ready 2013), cultural discard patterns (cf. Sadr 2008; Huffman 2010) and taphonomic and post-depositional processes (*e.g.* excavation methods, sieving practices).

One of us, has analysed the process from an emic perspective, foregrounding lived experience and *mentalité* (Amkreutz 2013) arguing aspects of the hunter-gatherer worldview remain visible until at least 3000 BCE. Raemaekers (2019) also develops an emic perspective, arguing that in terms of societal relevance cattle and cereals had taken centre stage by 4000 BCE. Looking at changes and continuities in the diversity of faunal assemblages may also help evaluate the societal relevance of different subsistence strategies.

To study changes in the diversity of faunal assemblages, we adopt a "big-data" approach. We compiled a database of Late Mesolithic and Neolithic assemblages from the Netherlands, which we analyse in terms of taxonomic richness (*i.e.* the number of represented species) as a function of assemblage size. We demonstrate that a diverse spectrum of resources is exploited throughout the Neolithic, suggesting the uptake of an agricultural way of life was a very gradual process.

2. Background

2.1 Ecological background

Neolithic bone assemblages from the Netherlands are virtually only known from wetland settings. These were not marginal areas and communities in the Late Mesolithic-Neolithic succession clearly focused on them (Amkreutz 2013, ch. 7, ch. 9; also see Raemaekers 2019). Our emphasis lies with these communities in the Lower Rhine Area delta region between the Scheldt in the south and the Elbe in the north. With respect to food and raw materials these wetlands are among the richest areas hunter-gatherers inhabit (Van de Noort and O'Sullivan 2006; Nicholas 2007a; 2007b), explaining why they could afford to be selective compared to upland communities in their uptake of elements from an agricultural subsistence economy (Amkreutz 2013, 427).

The Lower Rhine delta comprises different zones with varied characteristics. From east to west these include a riverine area with extensive Pleistocene upland, an extensive freshwater peat marsh interspersed with riverine elements, levees, lakes and Pleistocene river dunes ('donken') (Verbruggen 1992; Louwe Kooijmans 1993; Westerhof *et al.* 2003; Amkreutz 2013). Further west there are salt marshes dissected by creeks, followed by tidal flats and coastal barriers with low dunes and wide estuaries. Further north in the IJsselmeer basins and south in the Scheldt valley water was an equally dominant factor (Crombé *et al.* 2011; Ten Anscher 2012; Schepers 2014). Site-based faunal and botanical research indicates habitation of a wide range of settings (*e.g.* Bakels 1986; Out 2009b; Amkreutz 2013, 298; Schepers 2014). In general a difference in subsistence strategies may exist between freshwater (riverine and freshwater peat districts) and coastal wetlands (Zeiler *et al.* 2011).

The area was subject to temporal changes as well. Cycles of transgression and regression first precipitated an inland coastline shift until 4000 cal BCE resulting in peat growth and an eastward shift of the entire system of beach barriers, lagunas and peat marsh. Around the turn of the 5th millennium BCE this reversed due to the drop in relative sea level rise and resulted in increased freshwater influence and outward extension of the beach barriers (Van Gijssel and Van der Valk 2005; Vos and Kiden 2005). Marine incursions and peat growth made certain landscapes uninhabitable. Additionally, changing river systems and seasonal changes in habitability, such as flooding of important sites (cf. Schepers 2014) greatly influenced people's lives.

To hunter-gatherers, the stable uplands afforded very different foraging opportunities than these dynamic wetlands. The Holocene fauna lacks megafauna that play a key role in landscape engineering (Crégut-Bonnoure 1995, 233; Von Koenigswald 2007, table 29.1). In the dense forests covering the loess and coversand landscapes, available prey biomass was low, mainly consisting of red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*) and wild boar (*Sus scrofa*) (Delpech 1999, also see Binford 2007). These "infertile uplands" (Svenning 2002), were covered by closed forest during the Mesolithic. Small-scale agricultural activity resulted in a gradual opening up during the Neolithic, and a largely open character by the Late Neolithic (Van den Brink and Paulussen 2013, 21).

The herbivore biomass of the wetland regions was larger, as vegetation was more open in places (Zeiler 1999; Svenning 2002). Some herbivores were adapted to wetland settings (*i.e.* aurochs (*Bos primigenius*) and elk (*Alces alces*)) (Hall 2008). Moreover, beaver (*Castor fiber*) and otter (*Lutra lutra*) were present in large numbers. Additionally, the wetlands were characterised by the presence of rich fish and fowl stocks, and more abundant edible plant foods (see overview in Amkreutz 2013).

Clearly the wetland and upland landscapes merged into each other, yet in general, the biodiver-

Figure 1: Exploited food remains from Hardinxveld (Polderweg and De Bruin). Note typical wetland resources such as otter and beaver skulls (elevated at back), fish vertebra and grey seal jaw (center right) as well as waternuts, (front right). Photo: National Museum of Antiquities, Leiden.

sity in the 'upland' regions is lower. The wetlands on the other hand offered less ideal circumstances for animal husbandry and crop cultivation (see Bakels 1988; Dusseldorp and Amkreutz 2015). Within the wetland group geographic difference and temporal change intersected with the traditions and choices of the communities living there (*e.g.* Louwe Kooijmans 2009; also see Amkreutz 2013, ch. 7-9). It appears that both the wetland ecology, and its inhabiting societies therefore favoured an extended broad spectrum economy.

2.2 Archaeological background

The loess and coversand uplands in the southern Netherlands witness a relatively quick transition to agricultural societies (Amkreutz 2013; Dusseldorp and Amkreutz 2015). We have argued this is partly caused by these landscapes being relatively more suitable for agriculture than foraging (Dusseldorp and Amkreutz 2015). The wetlands were less suitable for agriculture; smaller areas for fields were available and in some regions grazing was limited (Bakels 1988; Amkreutz 2013; Dusseldorp and Amkreutz 2015). Moreover,

Culture	Chronology	Characteristics
Late Mesolithic	Up to 5000 BCE	Broad-spectrum hunter-gatherers in the wetlands
Early Swifterbant	5100/5000-4500 BCE	Pottery production in the wetlands; broad-spectrum hunter-gatherers
Middle-Late Swifterbant	4500-3800/3400 BCE	Livestock, cultivars introduced in wetlands; "extended broad-spectrum" hunter-gatherers (cf. Louwe Kooijmans 1993)
Hazendonk	3800/3400 BCE	"Extended broad-spectrum" farmers; farming thought to increase in economic importance (cf. Raemaekers 2003)
Vlaardingen	3400-2500 BCE	"Extended broad-spectrum" farmers, related to Stein group further inland.
Funnel Beaker Culture	3400-2900 BCE	Farming communities on uplands in N. Netherlands (Pleistocene till deposits). Associated with megalithic structures.
Single Grave	2900-2500 BCE	Farming communities, but intensive use of other resource in coastal and wetland areas
Bell Beaker	2500-2000 BCE	

Table 1: Chronological overview of cultural entities across the Late Mesolithic and Neolithic periods.

the area may have been unsuited to some of the crop plants and livestock species such as sheep/goat would be vulnerable to liver fluke (Louwe Kooijmans 1987).

In the wetlands, Late Mesolithic hunter-gatherers give way to the so-called Swifterbant culture (table 1). Both Mesolithic and early Swifterbant societies subsisted on a very broad range of wild resources to which the latter added pottery (figure 1). From the Middle phase of the Swifterbant culture, domestic animals and cereals are found at sites. The date of adoption of the earliest domesticates is debated as previously reported specimens from Brandwijk appear to be younger than originally thought (Çakirlar *et al.* in press). At De Bruin, early domestic animals are present during phase 3, prior to 4450 BCE (Mol and Louwe Kooijmans 2001; Oversteegen *et al.* 2001). However, numbers are small; transport of domestic remains to the site from elsewhere is likely (Louwe Kooijmans 2007; 2017). Domestic crops appear slightly later at *e.g.* Swifterbant S3 and P14 (Out 2008; Amkreutz 2013; Dusseldorp and Amkreutz 2015). Raemaekers and colleagues have shown that small-scale cereal cultivation also took place, even though the area was previously thought unsuitable (Bakels 1988; Cappers and Raemaekers 2008; Huisman and Raemaekers 2014; also see Out 2009a). However, wild animals remain present in large numbers (Zeiler 1997; Raemaekers 2003; Amkreutz 2013).

During the subsequent Hazendonk period, farming becomes more important and in the Vlaardingen period some faunal assemblages are clearly dominated by cattle (Louwe Kooijmans 2009; Bulten and Stokkel 2017). However, wild mammals remain important at many sites and foraging plays an important role until the early Bronze Age (Zeiler 1997; Fokkens *et al.* 2016).

Based on the foregoing, a specific wetland formula combining small-scale agricultural activities with foraging, *i.e.* an extended broad-spectrum economy continues well into the Late Neolithic. In the coastal dunes, some cattle-dominated assemblages occur. Elsewhere, however, communities remain characterized by a varied spectrum at what are clearly living sites (*e.g.* Amkreutz 2013). During the Late Neolithic Single Grave Culture in wetland settings, evidence still abounds for an intensive use of a variety of wild resources (*e.g.* Zeiler and Brinkhuizen 2012; 2013), probably increasingly exploited in a logistical system.

3. Materials and Methods

Against the ecological and cultural background introduced above we explore the diversity of Dutch Late Mesolithic and Neolithic faunal assemblages as a function of their size (Grayson 1991; Grayson and Delpech 1998; Faith 2008; Lyman 2008; Broughton *et al.* 2011; Dusseldorp 2012; 2016; Lyman 2015). We first discuss the methodological background before presenting our dataset and methodology.

3.1 Methodological background

We examine taxonomic richness (*i.e.* the number of represented taxa; NTAXA) of faunal assemblages to evaluate whether an "extended broad-spectrum" economy was in place throughout the Neolithic period. This analysis complements proportional analyses focusing on wild versus domestic resources (cf. Raemaekers *et al.* 1997; Raemaekers 2003), yet circumvents some of the problems associated with such analyses, especially the underrepresentation of specific resources due to behavioural and taphonomic factors.

We assume all subsistence activities are interrelated, and that increases in the importance of one aspect of the subsistence economy (*e.g.* animal husbandry) are reflected in other aspects (*e.g.* decrease in time spent foraging) (Broughton *et al.* 2010, 409-410; Dusseldorp 2016, 364). Evaluating the faunal richness provides a good way to determine changes in allocation of effort between foraging and agricultural activities. This means that increased time allocation in agricultural subsistence methods will lead to a decrease in foraging effort and hence lower NTAXA values (cf. Dusseldorp 2012; 2016).

NTAXA is influenced by assemblage size. Larger assemblages are more likely to sample additional taxa than smaller assemblages (Lyman 2008; 2015). However, the diet breadth (*i.e.* the number of species habitually exploited) determines the rate of skeletal input in assemblages (Lyman 2008; 2015). Hence, in an extended broad-spectrum economy, more taxa will be represented in a faunal assemblage of the same size than if the assemblage were accumulated in a farming society focusing on livestock exploitation.

We omit birds and fish from our analysis for several reasons. First, due to recovery methods, they are likely underrepresented. Second, having a different anatomical structure from mammals, these categories behave differently in our measure of taxonomic richness (Lyman 2015). However, in a qualitative evaluation of the importance of foraging relative to agriculture they should be incorporated.

By studying NTAXA, we work around a number of analytical problems. First, classification of suid remains to wild boar (*Sus scrofa*) or domestic pig (*Sus domesticus*) is problematic (Gehasse 1995; Raemaekers 2003). Genetic analysis presents similar problems as wild boar admixture is present in domestic pigs from very early on in Northwestern Europe. This is alongside the independent domestication of European wild boar at the time of the introduction of domesticated suids with a Near Eastern origin (Krause-Kyora *et al*. 2013). Based on aDNA, the proportions of wild versus domestic suids are therefore also impossible to determine. Our approach circumvents this: a small number of remains generally can be determined reliably to wild boar and pig. Hence both will be reflected. This means a reliable reflection of NTAXA can be attained when no reliable reflection of the proportions of domestic and wild animals can be ascertained.

Second, behavioural patterns in Meso- and Neolithic societies lead to differential representation of resources. Field processing and selective transport of carcasses lead to the underrepresentation of hunted prey (*e.g.* Faith 2007; Dusseldorp and Langejans 2013; Morin and Ready 2013) over livestock butchered on-site. Smaller species are more likely to be transported as whole carcasses than larger ones (*e.g.* Metcalfe and Barlow 1992; Winterhalder 2001, 22-23; Faith *et al.* 2009). This means the proportion of especially larger wild animals is likely an underestimate. However NTAXA will still reflect their exploitation.

This problem may be exacerbated for marine mammals. Seals and cetaceans are present in small numbers at many sites. Their most nutritious part is the so-called sculp, consisting of blubber and skin. Field processing of sculp may render these animals virtually invisible in the archaeological record (Smith and Kinahan 1984; Dusseldorp and Langejans 2013). Sometimes the only archaeological evidence for cetacean exploitation is the presence of species-specific whale barnacles demonstrating sculp presence (Kandel and Conard 2003; Parkington 2006). All local marine mammal species are large and likely to be field-processed; harbour porpoise (Phocoena phocoena): 40-80 kg.; harbour seal (*Phoca vitulina*): 50-170 kg.; grey seal (*Halichoerus grypus*): 100-300 kg (MacDonald 2006). Much larger species such as sperm whale (*Physeter macrocephalus*) are also occasionally represented (Groenman-Van Waateringe *et al.* 1968). Cetacean scavenging opportunities were also probably much more frequent during the Late Mesolithic and Neolithic, as modern population declines due to whaling have been severe (Lotze and Worm 2009, 256, 259).

Other behavioural factors influencing the archaeological visibility of specific species may be cultural discard patterns. Ethnographic evidence suggests rules regarding the discard of specific categories of animal remains influences archaeological visibility (cf. Sadr 2008; Huffman 2010).

3.2 Analysis

To evaluate if the diversity of exploited animal resources (*i.e.* the diet breadth) changes across the Late Mesolithic and Neolithic periods, we compiled a database of published faunal assemblages (n=67) (Appendix at end of paper).

We compare different groups of bone assemblages to determine trends in the taxonomic richness of different subsistence economies, plotting taxonomic richness (NTAXA) as a function of total assemblage size (log∑NISP) (Lyman 2008; Dusseldorp 2016). We plot groups of assemblages to determine if NTAXA increases more quickly relative to assemblage size in earlier than in later groups. This would signify a broader exploited set of resources in the earlier than in the later groups. We also plot freshwater wetland groups and coastal groups from the same period to determine if NTAXA rises more quickly in the former. This would be expected if freshwater sites were special activity locations, whereas coastal locations were residential farming settlements (as suggested by Raemaekers 2003, 744-745).

We subdivided our dataset into three chronological groups, to test whether diversity changes through time. We defined an Early phase, prior to the introduction of livestock, comprising Late Mesolithic and Early Swifterbant sites (5500-4500 cal BCE). A Middle phase consisting of Middle and Late Swifterbant sites (4500-3400 cal BCE), witnessing the introduction of livestock and cultivars, often interpreted as a transitional phase (sensu Zvelebil 1986). And a Late phase with Hazendonk, Vlaardingen and Late Neolithic Beaker Culture sites (3700-2000 cal BCE). Raemaekers (2003, 744) suggested that by the Late phase, the majority of consumed calories would be from domestic resources. Note that our dataset contains no assemblages from the Early phase in the coastal group as this area was subject to large-scale erosion at that time.

We subdivided our dataset into two geographic groups: a coastal group, containing sites from coastal dunes, estuaries and salt marshes, and a freshwater group containing sites from inland wetland contexts including freshwater tidal environments. This represents a trade-off: dividing the dataset into more environmentally specific groups might increase the sensitivity. There would be greater similarities in the resource spectrum available for exploitation, however, these groups would be very small, decreasing the power of the method to determine larger-scale patterns.

Figure 2 presents an example: A plot of log∑NISP and NTAXA from two groups of South African Later

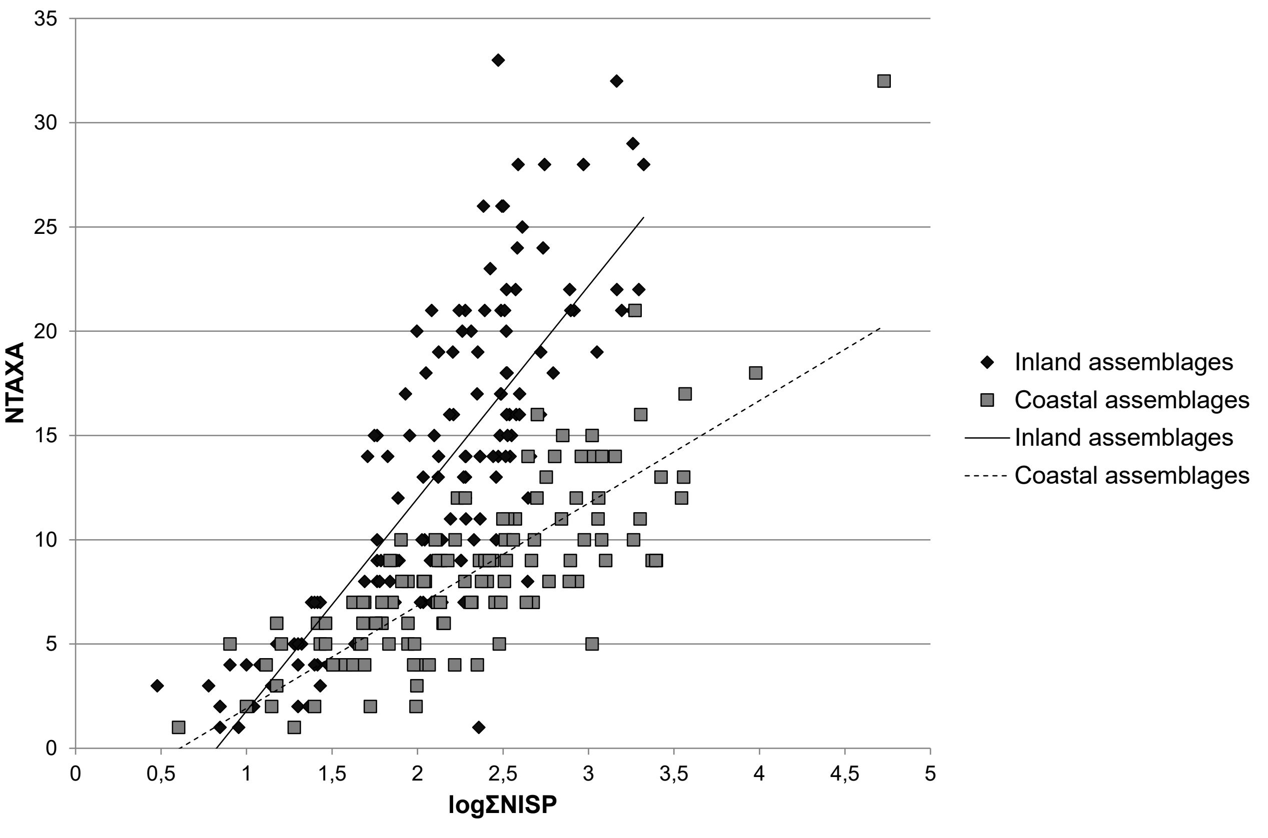

Figure 2: Example of a plot of two groups of assemblages showing clear difference in taxonomic diversity (Dusseldorp 2016, fig. 3).

Stone Age sites, demonstrating that in the rich coastal environment, faunal assemblages are less diverse than at inland sites (from Dusseldorp 2016). If farming provided an important, reliable source of calories, we expect assemblages accumulated by farmers to be similarly less diverse than those of extended broad-spectrum foragers.

Unfortunately, most recent excavation reports do not include data by minimum number of individuals (MNI). Hence we could not plot NTAXA and log∑MNI. This is a limitation, as a high degree of fragmentation is often mentioned (Zeiler 1997; Laarman 2001; Zeiler 2006). MNI provides a way to control for differential fragmentation (Lyman 1994; 2008). It is also the most reliable index to study the relative abundance of different taxa in faunal assemblages (Domínguez-Rodrigo 2012).

Another limitation is our focus on mammal bone assemblages. Based on ethnographic parallels, terrestrial hunter-gatherers in the Low Countries are expected to get >50% of their caloric intake from plant foods. In wetland environments, aquatic resources are expected to be most important (Binford 2001; 2007; Johnson 2014).

Data on specimens only identified to mammal size class are not available for all sites, due to intensive calcination and fragmentation in some assemblages (*e.g.* Laarman 2001; Zeiler 2006). Therefore we have plotted ∑NISP of specimens identified to taxon or specific category (*i.e.* carnivore sp., cervidae sp., etc. where included). We have included all non-human macromammals, also dog (*Canis familiaris*). As tables excluding antler specimens are not given for some assemblages, we have used counts including antler for all assemblages for the sake of consistency. At some sites, micromammals (*e.g.* "rodent sp.", *Arvicola* sp.) were listed. We regard these as background fauna and excluded them.

For assemblages where bones were listed as "pig/wild boar", but the accompanying text states that some specimens from that category were identified with certainty to pig and others to wild boar (*e.g.* Gehasse 1995), we have counted both. We counted general categories as one represented taxon when no specimens

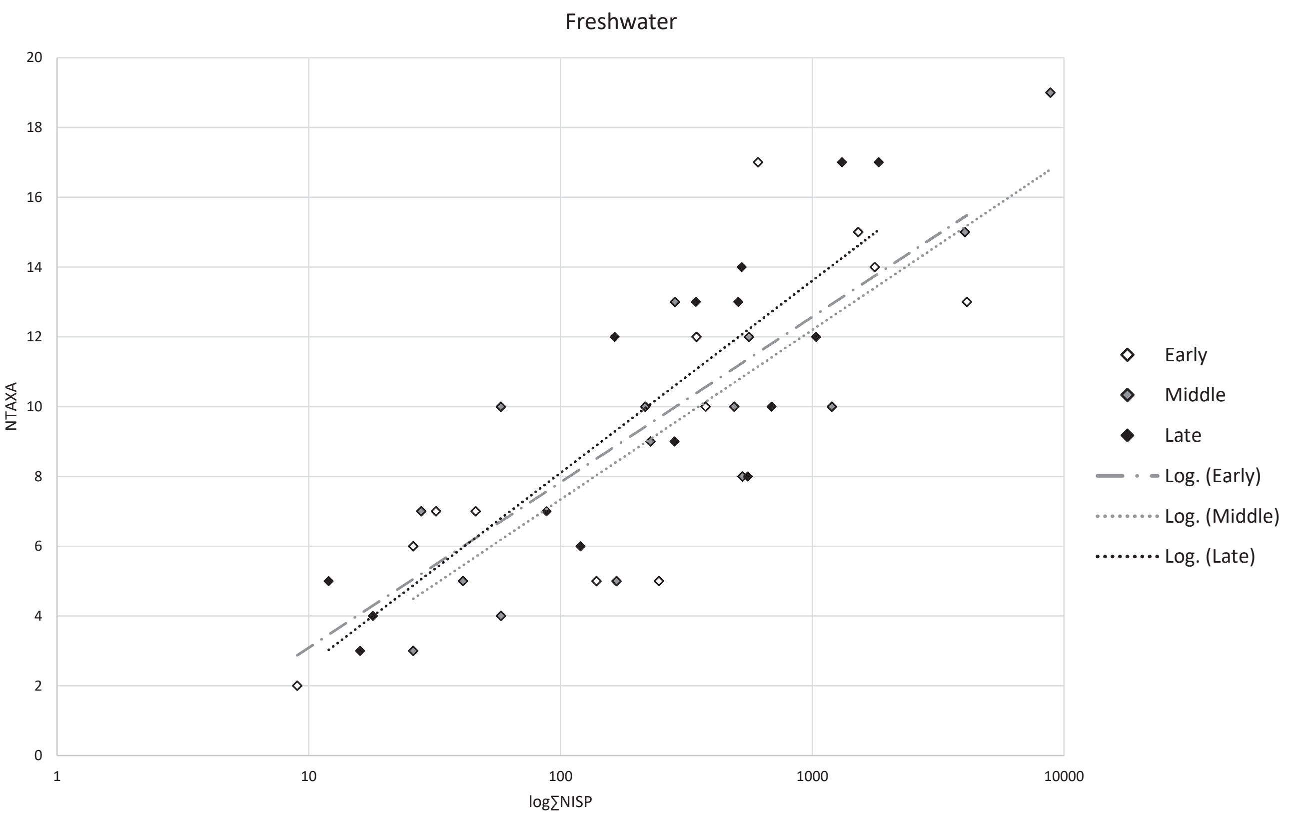

Figure 3: Plot of log∑NISP and NTAXA for freshwater assemblages divided into three chronological groups.

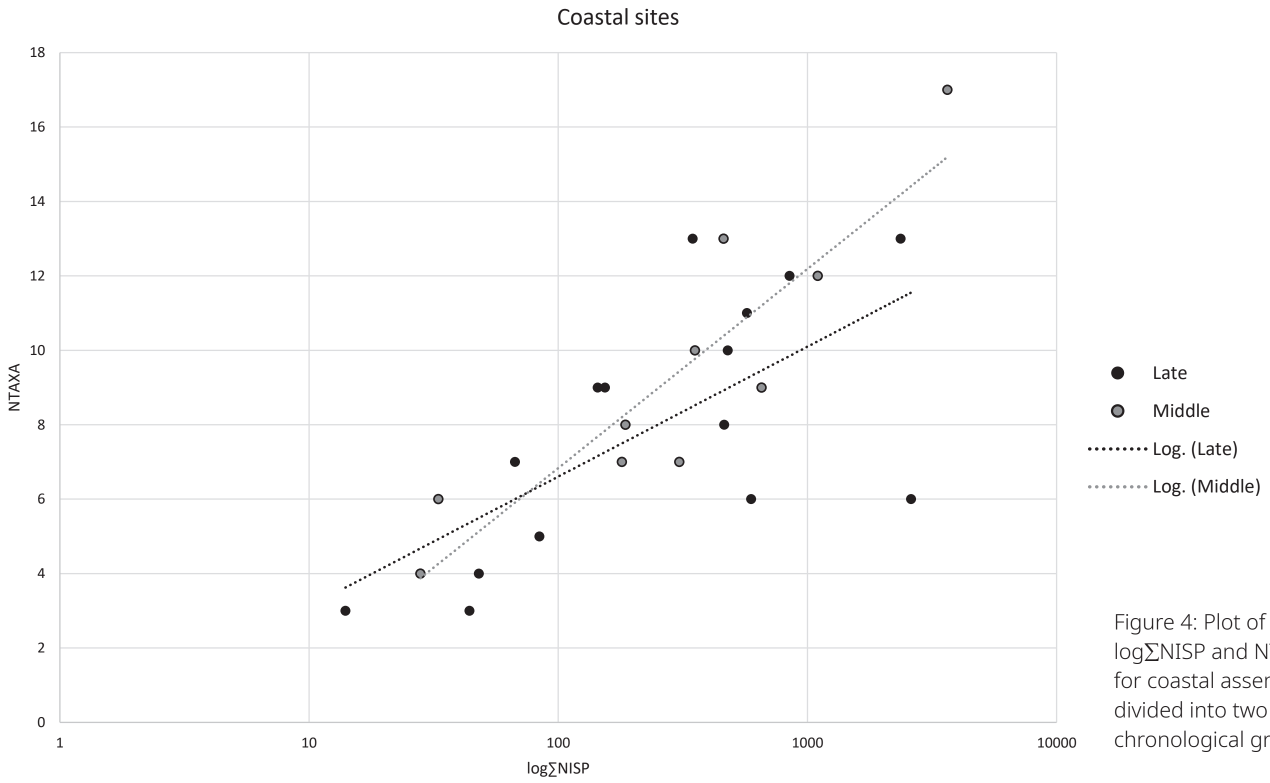

Figure 4: Plot of log∑NISP and NTAXA for coastal assemblages divided into two chronological groups.

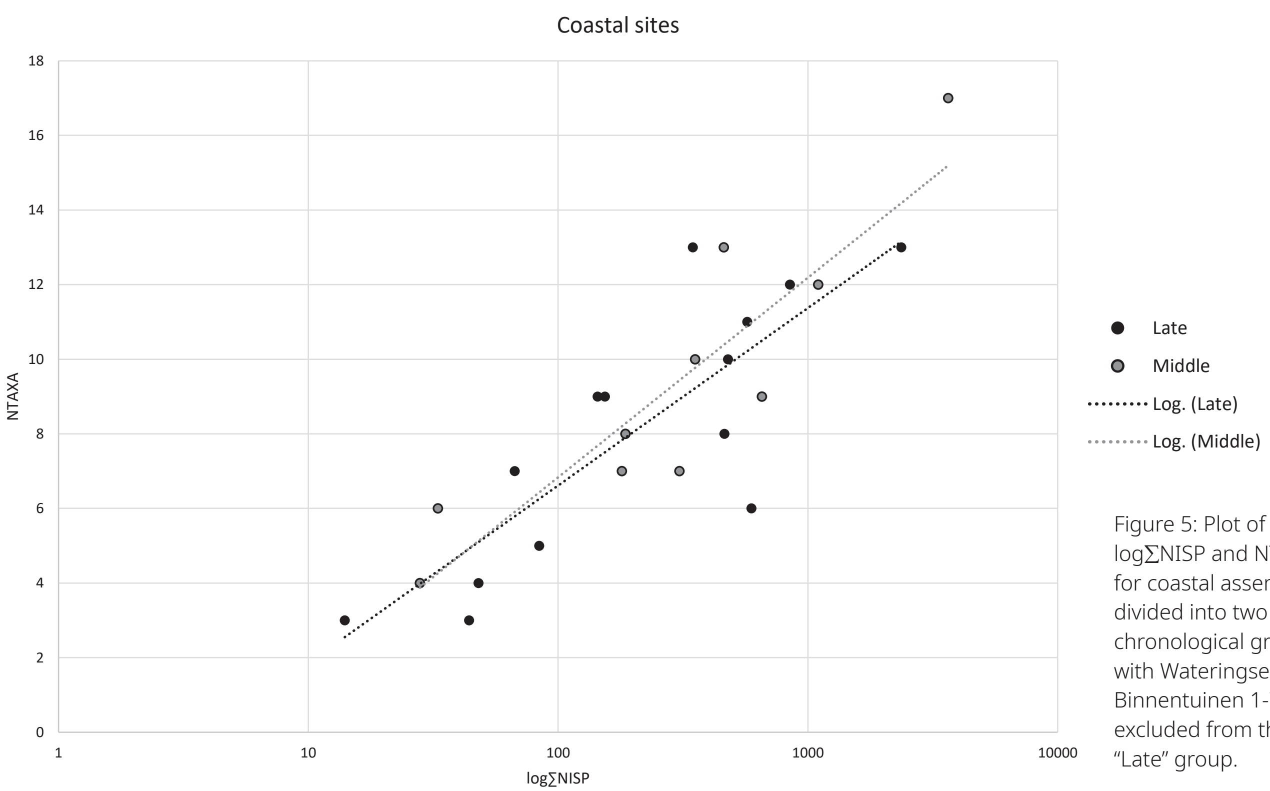

Figure 5: Plot of log∑NISP and NTAXA for coastal assemblages divided into two chronological groups with Wateringse Binnentuinen 1-7 excluded from the "Late" group.

were determined to any species from that category (*i.e.* "cetacean" would be counted as a represented taxon when no bones belonging to a specific whale species were reported in that assemblage).

4. Results

We plot the different groups of assemblages in a series of graphs to illustrate trends in NTAXA across groups of sites.

In the freshwater category, there are three groups of assemblages: Early (n=12), Middle (n=15) and Late (n=15). All groups have high r^2 values, demonstrating the categorisation explains an important part of the variability in the dataset (Early r^2: 0.68; Middle r^2: 0.72; Late r^2: 0.75; $P<0.05$). The slope of the regression lines through the groups (figure 3) is almost identical. This suggests that the diversity of the faunal assemblages in freshwater wetland contexts remains constant through time. This contrasts with expectations as in the Late group the increased role of agriculture is expected to result in a reduced diversity of faunal assemblages.

In the coastal area, the slope of the regression lines through the Middle (n=10) and Late (n=15) phases differ (figure 4). NTAXA values are lower relative to assemblage size in the Late period. This means a less diverse set of resources was exploited. This is the predicted pattern for an increased role of livestock in the subsistence economy. The r^2 value of the regression line through the "Late" group is relatively low, but statistically significant (r^2: 0.44; $P<0.05$). The "Middle" group has a high r^2 value (r^2: 0.80; $P<0.05$). We performed a t-test, which demonstrates the difference between the slopes of the regression lines is not statistically significant (t-value: 1.3; t-critical: 2.08; p: 0.21).

The low r^2 value of the "Late" group is due largely to the inclusion of one single assemblage: Wateringse Binnentuinen zone 1-7, which is dominated by cattle (*Bos taurus*). Its exclusion leads to a higher r^2 value (r^2: 0.68; $P<0.05$), but also to a changed slope of the regression line, which becomes virtually indistinguishable from that of the Middle group (fig. 5). The lower faunal diversity of the Late group is thus not a very robust pattern.

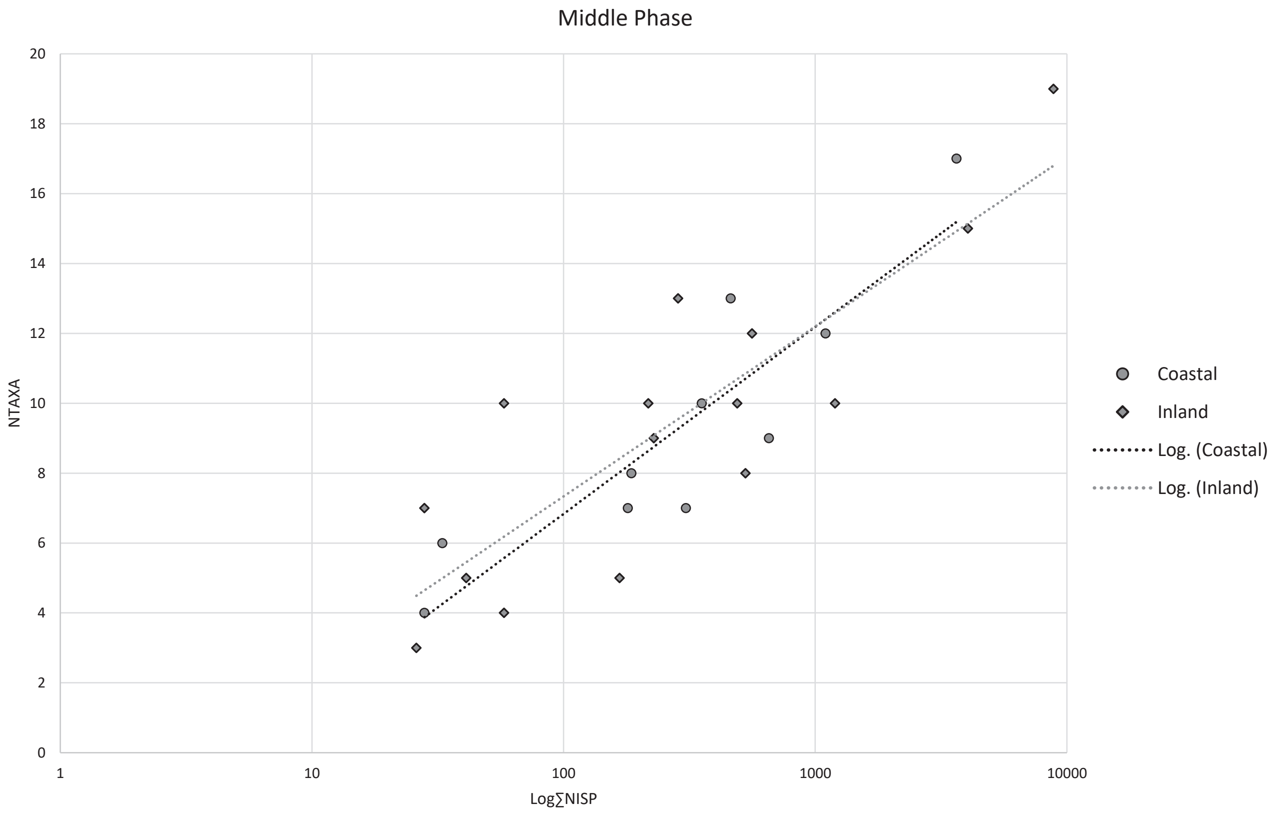

Figure 6: Plot of log∑NISP and NTAXA of assemblages from the "Middle" phase.

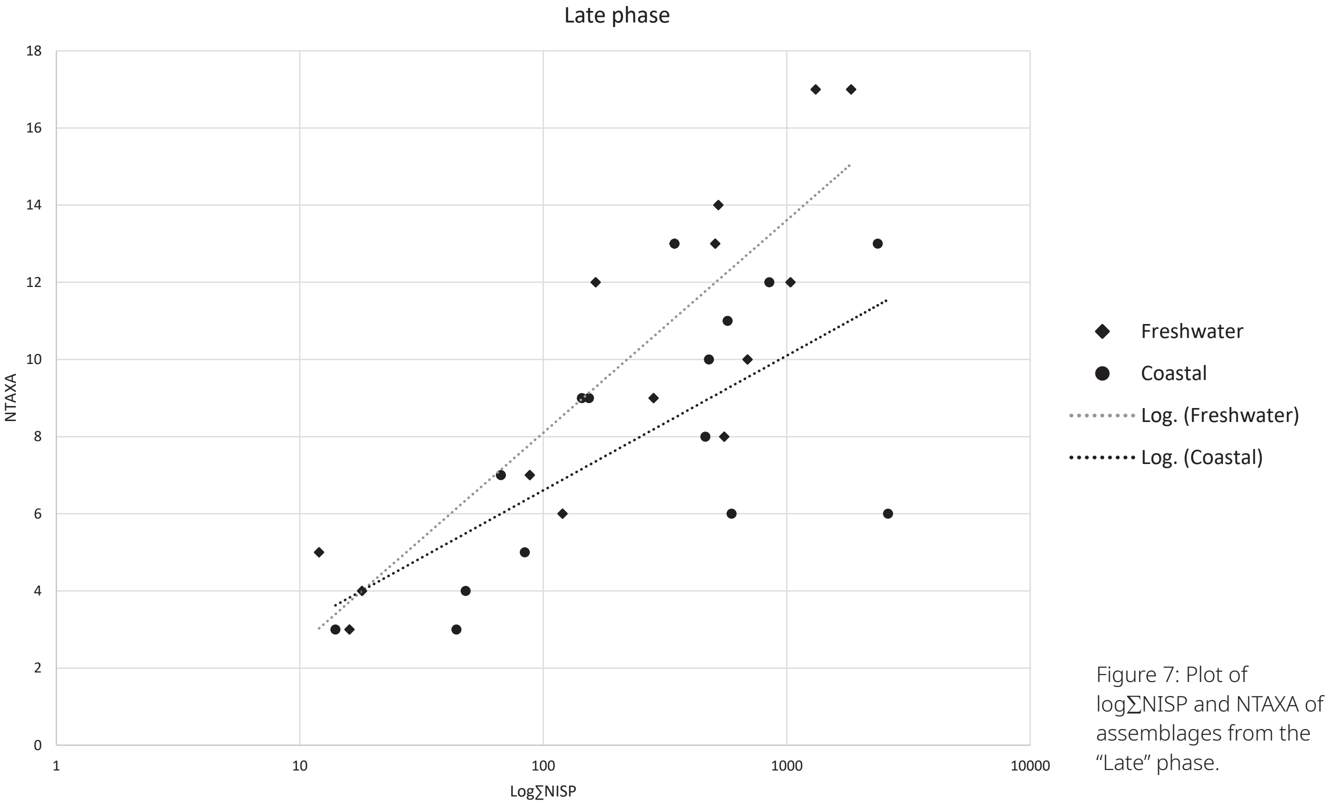

Figure 7: Plot of log∑NISP and NTAXA of assemblages from the "Late" phase.

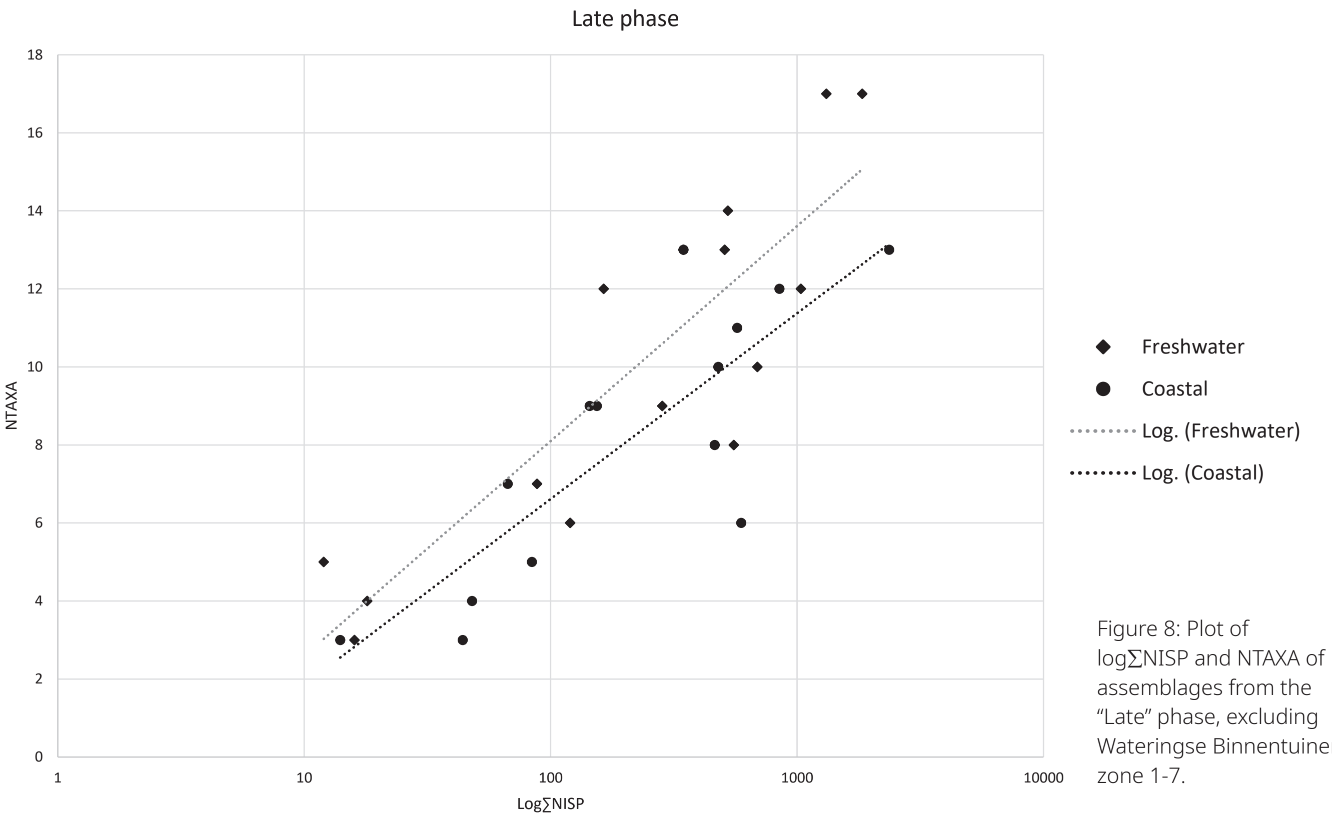

Figure 8: Plot of log∑NISP and NTAXA of assemblages from the "Late" phase, excluding Wateringse Binnentuinen zone 1-7.

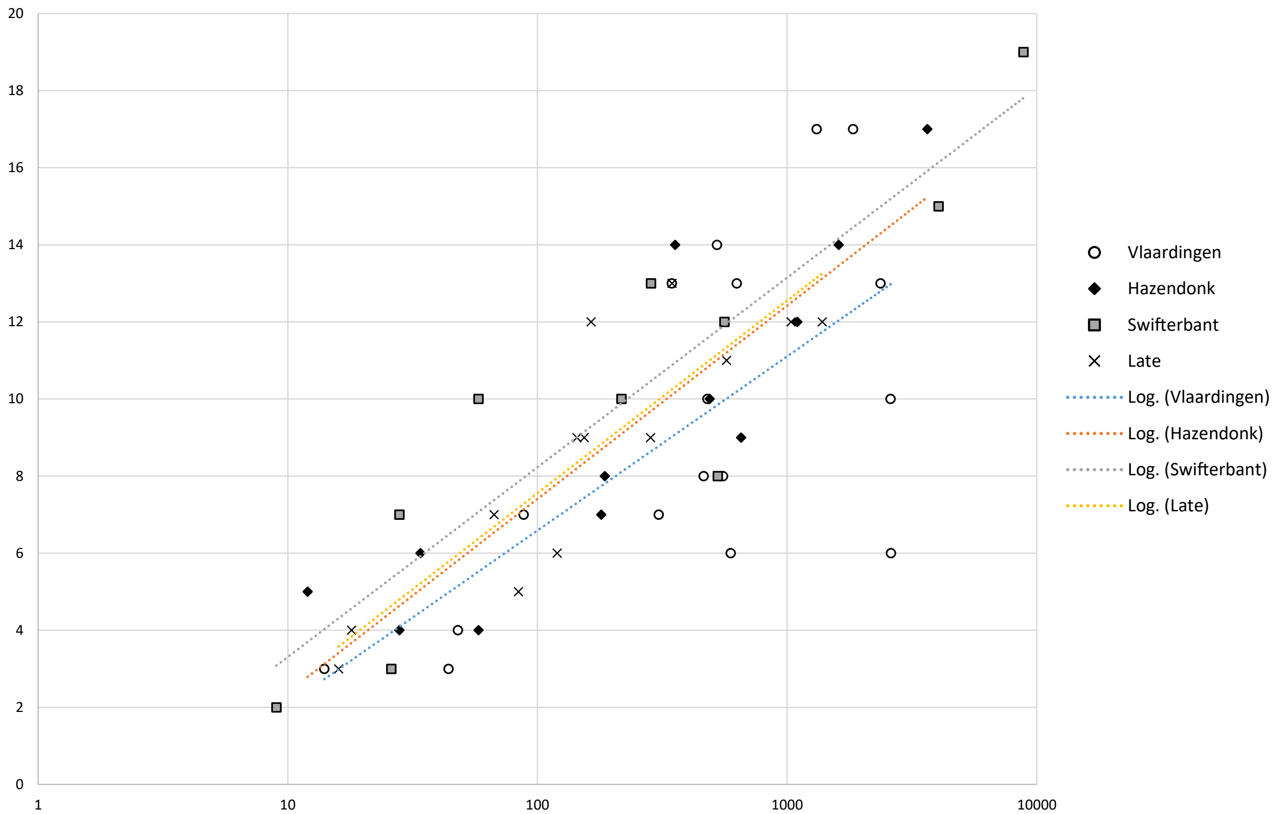

Figure 9: Plot of log∑NISP and NTAXA of assemblages from different cultural groups.

We also compare different geographical zones. Figure 6 shows that in the Middle phase, the freshwater and coastal groups exhibit very similar NTAXA values. Figure 7 shows that the "Late" assemblages from the freshwater area are more diverse than the coastal assemblages. However, the difference between the slopes of the regression lines is not significant (t-value: 1.45; t-critical: 2.06; p: 0.16). Excluding Wateringse Binnentuinen zone 1-7 from the coastal group leads to more similar taxonomic richness in the freshwater and coastal datasets. Still, coastal assemblages exhibit slightly lower NTAXA values (figure 8).

Finally, we have plotted the assemblages by cultural group (figure 9) to examine if different cultural groups produce different types of faunal assemblages cross-cutting our geographic division. We have plotted Middle and Late Swifterbant (n=10; r^2: 0.83; P<0.05), Hazendonk (n=12; r^2: 0.80; P<0.05), Vlaardingen (n=16; r^2: 0.44; P<0.05), and a Late Neolithic group with assorted beaker phenomena (n=13; r^2: 0.77; P<0.05). No clear difference in the diversity of the faunal assemblages is apparent. The variety of the Vlaardingen group is caused in part by the assemblage from Wateringse Binnentuinen zone 1-7, omitting it yields an r^2 value of 0.6 (P<0.05).

5. Discussion

Our analysis shows that the diversity of faunal assemblages is remarkably constant throughout the Late Mesolithic and Neolithic in Dutch wetland contexts. This suggests a persistence of the extended broad-spectrum economy throughout the Late Neolithic. Our results are surprising in view of existing models (*e.g.* Raemaekers 2003; Amkreutz 2013). One possible explanation is that our analysis is not sensitive enough to pick up important changes in taxonomic diversity. We consider this unlikely as the method has been shown to be sensitive to differences across landscape context and differences in hunter-gatherer subsistence strategies (*e.g.* Grayson 1991; Faith 2008; Dusseldorp 2016). If current patterns are confirmed at more sites, the slight differences between some groups may attain statistical significance. For instance, the slightly lower diversity in the coastal zone during the Late Neolithic could be shown to reflect a greater importance of farming in this area.

Another factor is the composition of the dataset. The distribution of known assemblages is uneven across periods and landscape settings. This is illustrated by the Early phase, with no known coastal sites. Similarly, assemblages from estuary contexts are almost exclusively late and from one specific area. Hypothetical future discoveries of *e.g.* Swifterbant sites in a coastal dune setting would complement our analysis and might reveal an increased reliance on agricultural subsistence methods in more suitable landscape areas (cf. Wateringse Binnentuinen for the Vlaardingen period).

The influence of the biased distribution of faunal assemblages should not be underestimated. For the Vlaardingen phase, Raemaekers (2003, 744-745) proposes a division of three types of sites: permanent settlements in the dunes, and seasonally inhabited special activity camps in wetland contexts. The former are characterised by the presence of house sites, cereal remains, a wide activity spectrum and faunal assemblages dominated by domestic animals. However, bone remains at these locations are often poorly preserved and hence we could not include all of these sites in our dataset (*e.g.* Haamstede-Brabers, yielded only a single identifiable specimen (Amkreutz 2013)). Recently discovered sites such as Wateringse Binnentuinen (Bulten and Stokkel 2017) may confirm this classification. However, if the "consolidation phase" (sensu Zvelebil 1986) had started, we would expect the "Wateringse Binnentuinen-pattern" to be commonplace, while it appears to represent an exception. The influence of taphonomic bias here is difficult to evaluate.

An interpretation in terms of foraging behaviour suggests that although many late assemblages are dominated by cattle bones, the persistent representation of varied wild resources shows that this numerical dominance need not imply caloric dominance. The apparent contradiction between our results and those of proportional analyses can be explained at least in part by field processing and transport, leading to the underrepresentation of wild resources. This is likely most severe for marine mammals in the coastal zone.

Continued investment in foraging is demonstrated by the identical taxonomic diversity through time. Some of the most diverse assemblages from our Middle and Late phases are numerically as large as the Wateringse Binnentuinen zone 1-7 assemblage (Appendix). Hence the activities responsible for the accumulation of diverse assemblages were not occasional, but represented a crucial element of subsistence economies.

One potential distorting factor is if the introduction of agriculture led to changed foraging strategies masking the expected narrowing of the resource base. With less time available for foraging, hunting may have been less selective, targeting "anything that moved". This would increase faunal assemblage diversity, for an activity of minor importance. We think this is unlikely as investments in foraging for *e.g.* fish and birds remains high and hence considerable effort in hunting was coupled with deliberate prey selection.

Birds are of prominent importance especially in the coastal zone (Bakels and Zeiler 2005; Zeiler *et al.* 2011). Fish are present in moderate numbers in many assemblages and are likely underrepresented especially in older excavations due to absence of sieving. Ironically, in the most recent excavations, only selective sieving in samples taken for botanical analysis is practised (see site comparison in Van Dijk *et al.* 2017). The importance of aquatic resources thus continues to be overlooked.

The importance of wild resources in the subsistence economy is further confirmed by stable isotope analysis at the site of Schipluiden. Here $\delta^{15}N$ values suggest that many people here consumed a largely aquatic diet (Smits and Van der Plicht 2009, 80-81). Discrepancies between bone assemblages and stable isotope analysis are sometimes difficult to resolve and elevated $\delta^{15}N$ values may be caused by other factors than fish consumption (*e.g.* Dusseldorp 2011). However, there is ample evidence of continued extreme investment expended on the exploitation of fish, for instance from the recovery of fishing weirs at Emmeloord and Almere (Bulten *et al.* 2002; Ter Voorde 2017). These were extensive, permanent installations (sensu Torrence 1983), in the case of the Middle to Late Neolithic Almere weir, over 190 meters (Ter Voorde 2017).

Much variation is hidden within the groups. Especially in the Vlaardingen phase (Zeiler *et al.* 2011). This points to the potential of examining more fine-grained environmental groupings (Raemaekers 2003; Amkreutz 2013). It also suggests that people, or groups of people behaved variably during the period under consideration. The dynamic nature of the landscape and the myriad possibilities afforded by the available resource spectrum may have given rise to this. There were fewer factors constraining individual agency than in later periods with more depleted environments and more interconnected relationships with fully-fledged farming communities on the Pleistocene soils, or in earlier periods when agricultural options were not yet available.

From an economic perspective, practicing an extended broad-spectrum foraging economy may have become increasingly lucrative during the Neolithic. The small-scale agriculture in evidence at *e.g.* the Swifterbant sites (Huisman *et al.* 2009; Huisman and Raemaekers 2014) can be seen as landscape engineering similar to fire use (Scherjon *et al.* 2015). Such small-scale clearings in the landscape likely increased the productivity for game species. At the Hazendonk, this appears to lead to an increase in cervid exploitation (Zeiler 1999). This landscape engineering contributed to the limited relative advantage of farming over foraging (cf. Rogers 1995). However, it suggests a situation in which some Neolithic groups could eat their cake and have it too: with increased foraging productivity, more time may have been available for other activities, such as experimenting with agriculture. We think such niche construction may play an important part in explaining the long persistence of the extended broad-spectrum economy.

6. Conclusion

We contend that the transition from foraging to agriculture in the Dutch wetlands lasted throughout the Neolithic period into the Early Bronze Age. Due to varied biases, we argue that focussing on taxonomic diversity of faunal assemblages may be more informative to determine whether extended broad-spectrum foraging was practiced. The similar diversity of faunal assemblages suggests that many individuals and groups subsisted on an extended broad-spectrum menu throughout the Neolithic. Our results support the suggestion that the adoption of small-scale agriculture may actually have reinforced foraging economies and worldviews. The extended broad-spectrum economy is not simply a transitional system, but a successful solution to living in the wetlands in its own right. Studying this period from the perspective of Neolithisation suggests a teleological bias.

No single proxy can determine the nature of past livelihoods, and complementary analyses of other proxies will increase our understanding of diachronic changes in wetland societies' subsistence methods amd the role of food production in the region. This extended broad perspective is a lesson learned from Corry Bakels who always ventured widely, both in science and in the world. By her extended sojourn in her Leiden home range she continues to bring along new ideas and angles to our research of past communities. By doing so she inspired many to also broaden their horizon and even managed to demonstrate the beauty hidden in a pollen diagram.

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Appendix: Inventory of assemblages included in the analysis

Assemblage	Cultural attribution	Date	∑NISP	NTAXA	Category	Reference
Barendrecht- Carnisselande 1	Vlaardingen	2500-2200 BCE	88	7	Freshwater	(Moree *et al.* 2011)
Barendrecht- Carnisselande 2	Bell Beaker	~2200 BCE	18	4	Freshwater	(Moree *et al.* 2011)
Barendrecht- Carnisselande 3	Bell Beaker – Early Bronze Age	2275-1886 BCE	1036	12	Freshwater	(Moree *et al.* 2011)
Barendrecht- Vrijenburg	Hazendonk 3	4789 ± 45 BP	12	5	Freshwater	(Zeiler and Brinkhuizen 2005)
Bazel-Sluis	Mesolithic – Swifterbant		211	10	Freshwater	(Meylemans *et al.* 2016)
Hardinxveld-Giessendam De Bruin Fase 1	Late Mesolithic	5475-5100 BCE	347	12	Freshwater	(Mol and Louwe Kooijmans 2001; Oversteegen *et al.* 2001)
Hardinxveld-Giessendam De Bruin Fase 2	Swifterbant	5100-4800 BCE	1772	14	Freshwater	(Mol and Louwe Kooijmans 2001; Oversteegen *et al.* 2001)
Hardinxveld-Giessendam De Bruin Fase 3	Swifterbant	4685-4459 BCE	5262	17	Freshwater	(Mol and Louwe Kooijmans 2001; Oversteegen *et al.* 2001)
Doel – Deurganckdok	Swifterbant	4550-3960 BCE	26	3	Freshwater	(Van Neer 2005)
E170	Swifterbant	3900 BCE	28	7	Freshwater	(Gehasse 1995)
Ewijk – Ewijkse Velden	Vlaardingen	3000 BCE	554	8	Freshwater	(Bakels and Zeiler 2005; Amkreutz 2013a)
Groenenhagen-Tuinendonk De Zwanen-Rietpark	Swifterbant, vroeg	5000-3900 BCE	9	2	Freshwater	(Schiltmans 2013; Zeiler 2013)
Hazendonk 1&2	Swifterbant	4020-3790 BCE	167	5	Freshwater	(Zeiler 1997; Amkreutz 2013)
Hazendonk 3	Hazendonk groep	3670-3610 BCE	490	10		(Zeiler 1997; Amkreutz 2013)
Hazendonk Vl1b	Vlaardingen	3270-3090	524	14	Freshwater	(Zeiler 1997; Amkreutz 2013)
Hazendonk Vl2b	Vlaardingen	2580-2480 BCE	2597	10	Freshwater	(Zeiler 1997; Amkreutz 2013)
Hazerswoude Rijndijk	Vlaardingen-EGK		345	13	Freshwater	(Grimm 2010)
Hekelingen I	Vlaardingen		628	13	Freshwater	(Clason 1967)
Hekelingen III	Vlaardingen	3200-2800 BCE	1314	17	Freshwater	(Prummel 1987: Amkreutz 2013)
Hellevoetsluis-Ossenhoek	Vlaardingen	3330-2700 BCE	2366	13	Coastal	(Goossens 2009; Van Dijk 2009)
Hoge Vaart	Mesolithic/Swifterbant	5500-4500 BCE	1523	15	Freshwater	(Laarman 2001)
Houten Vleugel	Late-Neolithic/Early Bronze Age		120	6	Freshwater	(Besselsen and Van der Heiden 2008; Slopsma 2008)

Assemblage	Cultural attribution	Date	∑NISP	NTAXA	Category	Reference
Hüde	Swifterbant	4700-3500 BCE	8843	19	Freshwater	(Hübner *et al.* 1988)
J78	Single Grave Culture		41	5	Freshwater	(Gehasse 1995)
Keinsmerbrug	Single Grave Culture	2580-2450 BCE	144	9	Coastal	(Smit *et al.* 2012; Zeiler and Brinkhuizen 2012)
Kolhorn Northern site	Single Grave Culture	4100-3900 BP	346	13	Coastal	(Zeiler 1997; Van Heeringen and Theunissen 2001)
Kolhorn Southern site	Single Grave Culture	4100-3900 BP	154	9	Coastal	(Zeiler 1997; Van Heeringen and Theunissen 2001)
Leidschendam	Vlaardingen		463	8	Freshwater	(Groenman – Van Waateringe *et al.* 1968)
Leidschendam-Prinsenhof	Vlaardingen	3400-2600 BCE	14	3	Freshwater	(Hamburg 2005)
Mienakker	Single Grave Culture	2880-2581 BCE	572	11	Coastal	(Kleijne 2013; Zeiler and Brinkhuizen 2013)
Molenaarsgraaf	Bell Beaker	3630 40 3780 50 3635 60 3640 30 3635 40	284	9	Freshwater	(Louwe Kooijmans 1974; Bakels and Zeiler 2005)
Nijmegen 't Klumke	Hazendonk 3	3770-3630 BCE	58	4	Freshwater	(Van den Broeke 2007; Zeiler 2007)
P14 A	Swifterbant	4400-4100 BCE	217	10	Freshwater	(Gehasse 1995)
P14 B	Swifterbant	4100-3800 BCE	561	12	Freshwater	(Gehasse 1995)
P14 C	Swifterbant	3800-3600 BCE	285	13	Freshwater	(Gehasse 1995)
P14 E	Swifterbant	3600-3300 BCE	58	10	Freshwater	(Gehasse 1995)
P14 EKW	Single Grave Culture	2600 BCE	164	12	Freshwater	(Gehasse 1995; Amkreutz 2013a)
Hardinxveld-Giessendam Polderweg fase 0	Mesolithic	Pre 5500 BCE	46	7	Freshwater	(Louwe Kooijmans and Mol 2001; Van Wijngaarden-Bakker *et al.* 2001)
Hardinxveld-Giessendam Polderweg fase 1	Mesolithic	5500-5300 BCE	4119	13	Freshwater	(Louwe Kooijmans and Mol 2001; Van Wijngaarden-Bakker *et al.* 2001)
Hardinxveld-Giessendam Polderweg fase 1/2	Swifterbant	5100 +/- 100 BCE	377	10	Freshwater	(Louwe Kooijmans and Mol 2001; Van Wijngaarden-Bakker *et al.* 2001)
Hardinxveld-Giessendam Polderweg fase 2	Swifterbant	5100-4900	246	5	Freshwater	(Louwe Kooijmans and Mol 2001; Van Wijngaarden-Bakker *et al.* 2001)
Rijswijk A4 locatie 1	Hazendonk group	3940-3200 BCE	186	8	Coastal	(Laarman 2004; Amkreutz 2013)

Assemblage	Cultural attribution	Date	∑NISP	NTAXA	Category	Reference
Rijswijk A4 locatie 4	Hazendonk group	4350 – 3380 BCE	28	4	Coastal	(Laarman 2004; Amkreutz 2013)
Rijswijk Ypenburg laag 1	Hazendonk group	3860 – 3200 BCE	33	6	Coastal	(De Vries 2004)
Rijswijk Ypenburg laag 2	Hazendonk group	3860 – 3200 BCE	461	13	Coastal	(De Vries 2004)
Rijswijk de Schilp	Vlaardingen		594	6	Coastal	(Zeiler *et al.* 2011)
Schipluiden phase 1	Hazendonk group	3630-3550 BCE	180	7	Coastal	(Mol *et al.* 2006; Zeiler 2006)
Schipluiden phase 2a	Hazendonk group	3550-3490 BCE	3642	17	Coastal	(Mol *et al.* 2006; Zeiler 2006)
Schipluiden phase 2b	Hazendonk group	3550-3490 BCE	1610	14	Coastal	(Mol *et al.* 2006; Zeiler 2006)
Schipluiden phase 3	Hazendonk group	3490-3380 BCE	1099	12	Coastal	(Mol *et al.* 2006; Zeiler 2006)
Slootdorp Bouwlust	TRB	c. 3500-3100 BCE	1383	12	Coastal	(Hogestijn and Drenth 2000/2001)
Swifterbant S2	Swifterbant	4300-4000 BCE	528	8	Freshwater	(Prummel *et al.* 2009)
Swifterbant S3	Swifterbant	4300-4000 BCE	4043	15	Freshwater	(Zeiler 1997)
Tiel-Medel	Swifterbant-Hazendonk		1198	10	Freshwater	(Ten Anscher 2018)
Urk-E4	Swifterbant	4200-3400 BCE	228	9	Freshwater	(Oversteegen 2001; Peters and Peeters 2001)
Vlaardingen	Vlaardingen	3200-2600 BCE	1837	17	Freshwater	(Clason 1967; Amkreutz 2013a)
Voorschoten Boschgeest	Vlaardingen	2870-2500 BCE	479	10	Freshwater	(Groenman – Van Waateringe *et al.* 1968; Amkreutz 2013a)
Wateringen 4	Hazendonk	3625-3400 BCE	654	9	Coastal	(Raemaekers *et al.* 1997)
Wateringse binnentuinen zone 8	Vlaardingen		44	3	Coastal	(Stokkel and Bulten 2017)
Wateringse binnentuinen zone 1-7	Vlaardingen		2606	6	Coastal	(Stokkel and Bulten 2017)
Wateringse veld	Vlaardingen-EGK	2650-2300 BCE	306	7	Coastal	(Van Dijk and Beerenhout 2014)
Wetsingermaar	TRB	3500 BCE	16	3	Freshwater	(Raemaekers *et al.* 2011/2012)
Yangtzehaven trench 2	Mesolithic	8555-8300 BCE	32	7	Freshwater	(Zeiler *et al.* 2015)
Yangtzehaven trench 1	Mesolithic	8555-8300 BCE	139	5	Freshwater	(Zeiler *et al.* 2015)
Zandwerven	Vlaardingen	2900-2300 BCE	50	4	Coastal	(Clason 1967; Amkreutz 2013a)
Zeewijk context A	EGK	2600-2450 BCE	67	7	Coastal	(Van Heeringen and Theunissen 2001)
Zeewijk context B	EGK	2600-2450 BCE	84	5	Coastal	(Van Heeringen and Theunissen 2001)
Zutphen Ooijerhoek	Mesolithic	9400-8700	26	6	Freshwater	(Groenewoudt *et al.* 2001)