Wet, wealthy worlds: The environment of the Swifterbant river system during the Neolithic occupation (4300–4000 cal BC)

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Abstract

This study presents an updated reconstruction of the vegetation that existed during the Neolithic habitation (4300–4000 cal BC) of the core area of the Swifterbant culture, namely, the small, eponymous river system in the northeastern part of the Flevopolder (province of Flevoland, the Netherlands). Because it is buried by younger sediments, this river system is exceptionally well preserved, both chemically and physically. Four main landscape elements are distinguished, namely, stream channels, river banks, floodplains and sand dunes. The vegetation during the Neolithic period is analyzed by dividing plant macro-remains species lists from three of the Swifterbant sites into groupings of species that are likely to have occurred together. The ecology of the most similar present-day plant communities is then used to infer a landscape position for all vegetation units. Additional data derive from partly unpublished data relating to diatoms, palynology and geology. This leads to an impression of what the vegetation may have looked like, which is then used to interpret the exploitation possibilities for the human inhabitants. It is argued that the marine influence on the vegetation was minimal, that peat formation continued during habitation, that the exploitation of the river banks must have been seasonal and that local cultivation of cereals is likely.

Keywords: vegetation reconstruction; Swifterbant Culture; seasonality; salinity; plant macro-remains; landscape exploitation

1. Introduction

The Swifterbant culture 'constitutes the earliest Neolithic of the Pleistocene sands and wetlands between the rivers Scheldt and Elbe' and covers the time span between ca. 5000 and 3400 BC (Raemaekers 1999, 11). Whereas the oldest phase (prior to 4600 BC) is fully Mesolithic, domesticated plants and animals are present in the later phases. However, wild plants and animals continue to play a major role in subsistence. The people of these Neolithic phases of the Swifterbant culture are therefore described as hunter-gatherer-farmers. Several cultural

overviews have been published over the past fifteen years (Louwe Kooijmans 2005; Peeters *et al.* 2004; Raemaekers 1999; idem 2005). This paper focuses on the Neolithic phase (4300–4000 cal BC) of the Swifterbant culture in its core area: the small, eponymous river system in the northeastern part of the Flevopolder, the Netherlands (fig. 1), hereafter referred to as the (river) system.[1]

Following a series of excavations and publications in the 1970s and 1980s, the Nieuwe Swifterbant Project (new Swifterbant project) set out to deal with a number of remaining questions (Raemaekers *et al.* 2005). An as yet insufficient understanding of past vegetation composition and distribution in the Swifterbant river system seriously hampered several aspects of archaeological interpretation. The goal of this paper is to resolve this issue by applying a new method to both old and new samples of plant macro remains (Schepers *et al.* 2013). Samples from three sites, recovered during excavation, form the basis of this reconstruction (see fig. 1 for their location). Swifterbant S3 and S4 are settlement sites located on the river bank, within 30 metres of each other (Raemaekers in prep.a; Van der Waals 1977). Swifterbant S25 lies approximately 4 kilometres upstream, on the edge of the river dune upon which sites S21–S24 are located. Swifterbant S25 itself, probably not a settlement site, is situated in clay sediments deposited on the edge of the dune (De Roever 1976; Geuverink *et al.* 2009; Raemaekers in prep.b).

The vegetation reconstruction thus achieved will be supplemented by data from other (eco-) archaeological proxies to address a number of issues, some of which have long been a matter of debate. This includes the degree of salinity in the system (e.g. Clason & Brinkhuizen 1978; Van Zeist & Palfenier-Vegter 1981), whether habitation on the river banks was permanent or periodic (e.g. Raemaekers 1999, 41-42; Zeiler 1986), and whether cereal cultivation took place (e.g. Cappers & Raemaekers 2008; Out 2009, 179; Van Zeist & Palfenier-Vegter 1981). Some remarks will also be made with respect to peat formation and the difficulties of detecting changes in the ecology during the period under study.

1.1 Geomorphology

The Swifterbant river system, which is currently covered by 1–2 metres of sediment, was discovered during systematic pedological and geological investigations after land reclamation in the Polder Oost Flevoland (Van der Waals & Waterbolk 1976, 4). The system is situated on the far, landward end of a coastal lagoon (Ente 1976, 18) that opens towards the west (the present-day North Sea), and it is fed from the east by the river IJssel (Ente 1976, 14; see also Vos & Kiden 2005 for a more recent general overview). By integrating data from extensive coring and present-day elevation maps, a detailed reconstruction map of the system was produced by Dresscher & Raemaekers (2010), partly based on the earlier work by Ente (1976).

Basically, four geomorphological units make up the landscape in the region: rivers, river banks, floodplain and sand dunes. Open water, that is, ponds, will have been present in the floodplain as well. The formation process of the river banks at Swifterbant is atypical. The formation of banks along stream channels is caused by the deposition of sediments when the water level in the channel rises and floods out of its normal bed. The flow velocity of water flooding out of the channel drops substantially, causing heavier particles in suspension to settle down. In most cases, these heavier particles will primarily consist of sand. In the case of the Swifterbant river banks, however, these heavier particles do not consist of sand, but of lutum particles bound together. This so-called flocculation typically occurs when fresh and saline water mix, a phenomenon that explains the river bank formation at Swifterbant (Schepers & Woltinge in prep.).

1.2 Research history of the study area

Because of the excellent preservation conditions, several studies have been carried out dealing (in part) with the landscape and the natural vegetation (table 1). The present study focuses on the vegetation in the Neolithic occupation phase of the Swifterbant river system. The study carried out by Van der Linden (2008) and the extensive and thorough palaeoecological chapters in the N23/N307 excavation report (Hamburg *et al.* 2013) provide extensive information on the ecology of the dunes during the Mesolithic occupation.

Author(s)	Plant Macro-remains	Pollen	Wood
Casparie et al. 1977	S3	S3	S3
Van Zeist & Palfenier-Vegter 1981	S3		
Van Rooij 2006*	S4		
Van der Veen 2008*		S4	
De Moor *et al.* 2009	HZL	HZL	
Prummel *et al.* 2009	S2		
Maurer 2011*	S25	S25	
Van der Laan 2011*			S25
Schepers *et al.* 2013	S4		
Schepers & Bottema-Mac Gillavry in prep.	S4	S4	S4

Table 1. Overview of archaeobotanical research relating to the Swifterbant river system. Unpublished student reports are indicated by '*'. The prefix S stands for Swifterbant. HZL refers to Hanzelijn. For locations, see fig.1.

A reconstruction of available vegetation types in the vicinity of the Swifterbant S3 site is presented by Van Zeist and Palfenier-Vegter (1981). Their vegetation reconstruction is further refined by Out (2009, 177-178).

2. Methods

2.1 Sampling and processing

Different sampling strategies were used at the three sites dealt with here. Two main sample categories are present at all three sites. Wet samples were secured in the field and sieved in the laboratory using a stack of sieves with mesh apertures ranging from 5 mm to 200 μm. 'Sieve residues' are the result of sieving on-site with a mesh aperture of 2 mm. Although many wild plant seeds will not be recovered on-site by this method, these residues do contain numerous remains of plants that may have been of economic significance instead. Many economic plants have relatively large remains (e.g. *Corylus avellana* [hazel] and *Crataegus monogyna* [hawthorn]). Three drift line samples were taken near S4. These samples are not from the settlement proper. The volume of each of these samples is large, more than 10 litres (Schepers *et al.* 2013). All of the samples were analyzed. Sieve residues from the S4 settlement layers were analyzed (Schepers & Bottema-Mac Gillavry in prep). At S3, 46 samples of 1 litre from settlement layers and all the sieve residues from the settlement layers were analyzed by Van Zeist & Palfenier-Vegter (1981). Finally, eight samples from the Swifterbant S25 river dune site were analyzed (Maurer 2011). The S25 site is located on the edge of the river dune. The samples mentioned here originate from clay and peat layers dating to the Neolithic period, so technically not from the dune itself. Sieve residues from the find layers at S25 (not necessarily settlement layers) were analyzed by Schepers & Palfenier-Vegter (Raemaekers in prep.b). For the complete species lists and a description of sampling methods for the individual sites, the

reader is referred to the site reports (Maurer 2011; Schepers & Bottema in prep.; Van Zeist & Palfenier-Vegter 1981).

Some additional sampling was done in the buried back swamps near the present-day village of Swifterbant, based on a coring campaign near the Rivierduinweg by Nales (2010). At five locations, the top of the peat layers was sampled to determine the local vegetation at the time of peat formation (using Mauquoi & Van Geel 2007). These results will only be dealt with briefly, as this area is not representative of all Swifterbant back swamps and the peat layers cannot be directly correlated to the habitation period of S3, S4 and S25. The analysis only serves to increase our insight into the vegetation diversity of the back swamp area.

Taxon names follow Van der Meijden (2005), syntaxon codes and names follow Schaminée *et al.* (1995a; 1995b; 1996; 1998) and Stortelder *et al.* (1999). All macro remains are referred to as seeds and all microfossils as pollen, even when this is biologically incorrect. Furthermore, taxa are referred to as species unless a more precise taxonomic level is inevitable.
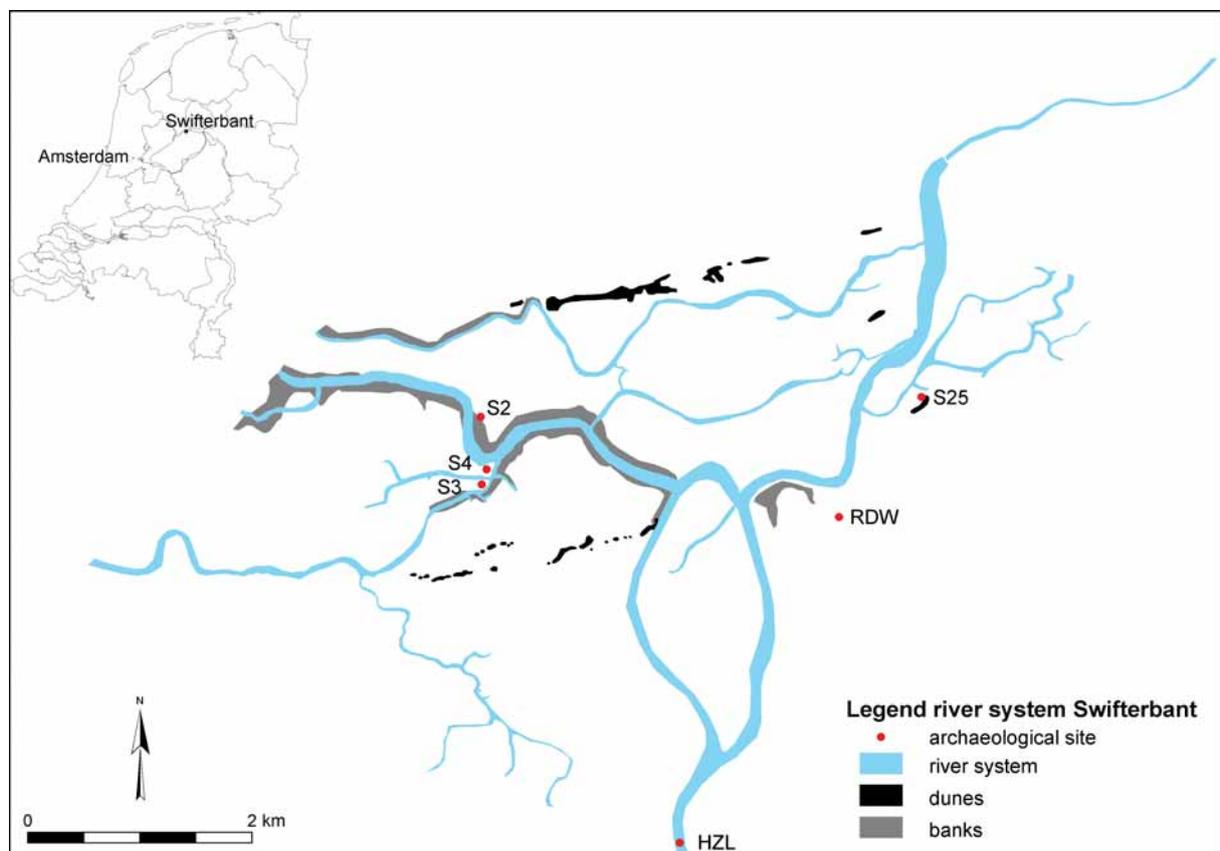
Figure 1. Map of the Swifterbant river system showing the location of the sites used for the interpretation of the vegetation. See table 1 for sources. Samples from S3, S4 and S25 form the basis for the vegetation reconstruction. Data from S2 and HZL are used for a more complete interpretation in the discussion section. Some additional cores were taken at RDW (Rivierduinweg) for the present study, based on the report by Nales (2010). Map after Dresscher & Raemaekers (2010).

2.2 Palaeoassocia

The Palaeoassocia package is a new method for identifying plant communities, already tested for the drift line samples from S4 (Schepers *et al.* 2013). In this paper, the method is used to analyze samples from S3 and S25. The nature of the samples from S2, HZL and Rivierduinweg makes them unsuitable for this type of analysis. Because this paper targets both specialist

and non-specialist audiences, some of the terminology involved in plant sociology, as well as Palaeoassocia itself, requires a short introduction.

Plant communities are specific assemblages of plant species that occur under a certain combination of abiotic conditions, such as light, moisture and nutrient availability (for an introduction, see Braun-Blanquet 1964). A recognized combination of species, a plant community, is called a 'syntaxon' (plural syntaxa). Syntaxa, like taxa, are structured in a hierarchical system, each with its own suffix, ranked from class (-etea), via order (-alia) and alliance (-ion), to the most detailed level of the association (-etum). Because of the rank of syntaxa is implied by their suffix, the rank will not be mentioned for the remainder of this paper. Furthermore, for the sake of brevity, syntaxon names will be referred to by their short name after first mention (e.g. *Bidention tripartitae* is thereafter referred to as *Bidention*). The most commonly used rank in field ecology, the 'species level' in plant communities, is the association. Just like a plant species, this rank of a community has the advantage that it can actually be witnessed as such.

The vast majority of archaeobotanical samples consist of a mixture of species from different plant communities. There are several ways to disentangle this mixture, of which a division in groups such as 'field weeds', 'water plants' and 'trees and shrubs' is the most common one. Palaeoassocia, however, calculates the probability that species in a sample may have grown at the same location, based on a comparison with a large data bank of present-day vegetation studies. If the sample is indeed a mixture, this will result in a number of overlapping groups. Therefore, where the term 'groups' is mentioned in this paper, this relates to a subset of a sample, consisting of species that can occur together in vegetation. These groups are compared with currently well-described plant communities. In many cases no single community provides a perfect match; in that case the package provides a number of suggested syntaxa (fig. 2).
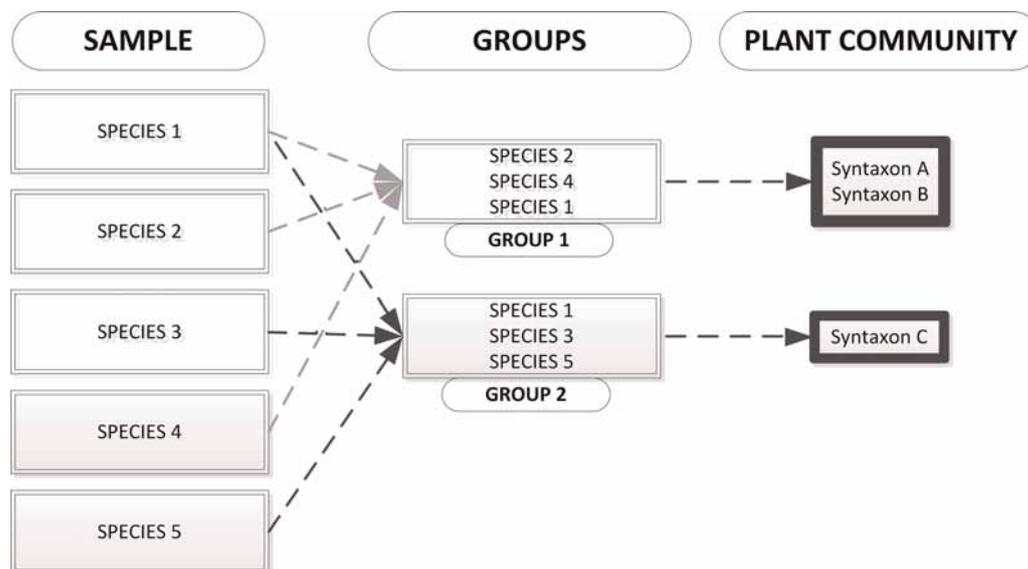
Figure 2. Simplified visualization of the Palaeoassocia method, showing the three main steps. An archaeobotanical sample consisting of a mixture of species from several vegetation types (left) is divided into groups of species that can occur together (middle). The method then identifies that group as one or more possible most similar present-day plant communities (right).

Archaeobotanical species lists frequently include unspecific identifications that could imply two or more species. All examples of this phenomenon contained in the present dataset commonly occur in Dutch archaeobotanical datasets – for example, *Chenopodium glaucum/rubrum* (e.g. De Moor *et al.* 2009; Gehasse 1995) and *Atriplex patula/prostrata* (e.g. Brinkkemper 1993; Buurman 1996). Palaeoassocia does not accommodate groups of taxa as such. In the case of

multi-taxa entries, all species involved are used in the analysis individually, for two reasons. First, species with narrow ecological amplitudes differing from the other species encountered in the sample will be easily identified in either the association matrix or the plant community identification stage. Second, species with broad ecological amplitudes may indeed have co-existed within the region.

The list of suggested syntaxa is reduced following the methodology presented in Schepers *et al.* (2013), but some cautionary comments need to be made. This reduction is partly based on the likeliness of an individual identification being right or wrong. A number of genera (the plural of genus, being the taxonomic level above species) are, or can be, represented by several species for which the possibility of a misidentification cannot be ruled out. To assess the possibility of misidentification, the Dutch archaeobotanical database RADAR was used to evaluate which taxa are often grouped together in identification or are identified to the genus level only (Van Haaster & Brinkkemper 1995, version 2006). The genera for which this is considered a possibility are *Arctium*, *Bolboschoenus/Schoenoplectus*, *Carex* and *Persicaria*. All species resulting from a splitting up of unspecific identifications are also not taken into account at this stage (e.g. either of the two species resulting from the splitting up of *Atriplex patula/prostrata*), unless both species are present in a group and both are obscuring the syntaxon (see for detailed explanation Schepers *et al.* 2013).

Species that are 100% weird to all suggested syntaxa are ignored, since they are apparently unrelated to the whole set, despite initially ending up in the same association matrix group. Crab apple (*Malus sylvestris*) is rarely identified in modern relevées because it is virtually impossible to distinguish it with certainty from any of the modern apple cultivars (Van der Meijden 2005, 391). Furthermore, this species may have been tended or even planted because of its economic significance in prehistory. The only crop plant in the taxon list, barley (*Hordeum vulgare*), is also ignored here. The final exception is *Cladium mariscus*. In this case, the high weirdness values are not considered a valid reason to exclude a syntaxon, because an as-yet-unsolved bug in the software causes this species to have higher association values with a lot of taxa than can realistically be expected based on its ecological characteristics. However, this software glitch does not prevent us from identifying the *Cladietum marisci* altogether, because in this plant community, the eponymous *C. mariscus* will obviously not be an uncommon species.

The samples from S3 and S25 were analyzed with Palaeoassocia to identify the most likely plant community or communities represented by these groups. The data thus produced were added to the results from the S4 drift line samples.

With respect to the syntaxa identified from the drift line samples, two minor alterations were made. First, syntaxon 30Bb1b (*Spergulo arvensis-Chrysanthemetum euphorbietosum*) is discarded because of the absence of *Fallopia convolvulus* in the samples. This species is present in over 95% of the present-day relevées of that type. Secondly, syntaxon 29Aa3c (*Chenopodietum rubri rorippetosum*) is allowed as a possible plant community because the species initially preventing it from ending up as a possible suggestion, *Bolboschoenus maritimus*, is no longer accepted here as a valid species for discarding a syntaxon.

All samples analyzed are categorized into four main categories of vegetation structure, following Schaminée *et al.* (1995a; 1995b; 1996; 1998) and Stortelder *et al.* (1999), namely, (1) open water and marshes; (2) grasslands and heathlands; (3) coastal and inland pioneer communities; and (4) rough, thickets and woodlands. For reasons of brevity, these will be referred to as (1) wet communities, (2) grassland communities, (3) pioneer communities and (4) woodland communities.

Syntaxa suggested more frequently are considered to reflect correct identifications with a higher reliability. Because the number of samples studied per site differs, a comparison based on absolute numbers is of little value. Instead, the syntaxa are categorized into five main categories, by percentage of the most frequently identified syntaxon per site and vegetation struc-

ture. These categories are 4 (100–75%), 3 (75–50%), 2 (50–25%) and 1 (25–>0%). Syntaxa only suggested once are indicated by a '+'. For example, the most frequently identified syntaxon in the pioneer communities for the S3 site was suggested 50 times. All syntaxa suggested more than 38 times (>75%) are in category 4, syntaxa suggested between 25 and 38 times are in category 3, and so forth. Syntaxa only suggested once for all three sites are omitted from the list.

3. Results

3.1 Plant communities

The 46 samples from S3 were split into a total of 266 groups. The eight samples from S25 resulted in a total of 32 groups, leading to a total of 298 groups to be analyzed using Palaeoassocia. Eleven syntaxa were considered a misidentification because a species vital to that vegetation type was missing in the samples, while the species is normally easily recognized and frequently found in archaeobotanical research.[2] Thus the total number of plant communities identified is 43 (table 2). Unless otherwise specified by means of a citation, information on syntaxa in this section is derived from Schaminée *et al.* (1995a; 1995b; 1996; 1998), Stortelder *et al.* (1999) and the vegetation expert system SynBioSys (Hennekens *et al.* 2010). The identified syntaxa are described here individually and including their intersyntaxonomic relationships. The codes between brackets serve for an easy comparison with table 2.

3.1.1 Wet communities

Wet communities are represented by the *Phragmitetea* (08), including reed swamp communities and tall sedges and two syntaxa from the *Parvocaricetea* (09, small sedges). Within the *Phragmitetea,* one association in the *Nasturtio-Glycerietalia* (08A) is present. This comprises communities of shallow, moving water. This movement can be both vertical and horizontal and can therefore not be seen as synonymous to running. The *Polygono-Veronicetum anagadillis-aquaticae* (08Aa2) is closely related to communities within the *Bidentetea tripartitae* (29, see 'Pioneer communities') and is characteristic of tidal movement in fresh water environments. The association indicates moving water, which fits the fact that it has not been recognized in the settlement samples from S3, but is dominant in the drift line samples from S4.

All other plant communities in this class are within the *Phragmitetalia* (08B), which consists of communities indicative of standing or slightly moving water. For the Swifterbant area, different associations within this order are identified. They comprise closely related plant communities, which will all have co-existed in the area at some moments in time, yet were spatially distributed according to their particular tolerances. The *Cicuto-Caricetum menyanthetosum* (08Ba2b) is a subassociation of the *Cicuto-Caricetum pseudocyperi.* Nowadays, this association thrives in dug-out peat pits, which were absent in prehistory. But it also occurs on floating islands and old terrestrialized stream channels, landscape elements that must have been abundantly present in the Swifterbant area. Open water with slightly brackish conditions is indicated by the *Scirpetum tabernaemontani* (08Bb2), which is often found in association with the more fresh water, but also slightly brackish *Typho-Phragmitetum* (08Bb4). Within this association, the 'salt marsh' species *Aster tripolium* may have occurred as well (see section 5, 'Salinity'). The predominance of the *Typho-Phragmitetum* indicates that, although some brackish influence in the river branches occasionally occurred, fresh water conditions were dominant. The *Caricetum gracilis comaretosum* (08Bc2b) appears to occur where silt or organic material is deposited.

Code	Syntaxon name	S3	S4	S25
08Aa2	Polygono-Veronicetum anagallidis-aquaticae (p)		4	+
08Ba2b	Cicuto-Caricetum menyanthetosum (p)	2		4
08Bb2	Scirpetum tabernaemontani (p)	1	+	
08Bb4a	Typho-Phragmitetum typhetosum angustifoliae (p)	3		
08Bb4c	Typho-Phragmitetum typicum (p)	3		4
08Bc2b	Caricetum gracilis comaretosum (p)	+	2	
08Bd1	Cladietum marisci (p)		2	
09Aa3b	Carici curtae-Agrostietum caricetosum diandrae (p)	2		
09Ba1	Scorpidio-Caricetum diandrae (p)	4		
12Ba2b	Triglochino-Agrostietum nasturtietosum	4		+
12Ba2c	Triglochino-Agrostietum juncetosum gerardi	2		
27Aa2c	Centaurio-Saginetum epilobietosum	1		
29Aa1	Polygono-Bidentetum	+		4
29Aa2b	Rumicetum maritimi chenopodietosum	3	4	+
29Aa3a	Chenopodietum rubri spergularietosum	1	1	
29Aa3b	Chenopodietum rubri inops	3	1	+
29Aa3c	Chenopodietum rubri rorippetosum	4	2	+
29Aa4	Eleocharito acicularis-Limoselletum	+	2	
30Ab1a	Veronica-Lamietum typicum	1		
30Ab1b	Veronica-Lamietum alopecuretosum	3		
30Ab3	Chenopodio-Oxalidetum fontanae	2	+	
30Bb1a	Spergulo arvensis-Chrysanthemetum typicum	1		
31Aa2b	Erigeronto-Lactucetum erysimetosum	3	+	
31Ab1a	Urtica-Malvetum atriplicetosum	1		
31Ab2c	Hordeetum murini arctietosum	1	1	
31Ab3a	Balloto-Arctietum typicum	2	1	
31Ab3b	Balloto-Arctietum diplotaxietosum	1		
31Ab3c	Balloto-Arctietum verbascetosum	4	2	
31Ca1b	Echio-Melilotetum	1	1	
32Ba2a	Soncho-Epilobietum typicum	1		3
32Ba2b	Soncho-Epilobietum althaeetosum	1		
37Ab1a	Pruno-Crataegetum typicum	+	4	
37Ac4	Pruno spinosae-Ligustretum	1		
38Aa1b	Artemisio-Salicetum agrostietosum stoloniferae	4		
38Aa2a	Irido-Salicetum menthetosum	3		4
38Aa2b	Irido-Salicetum alopecuretosum pratensis	2		4
38Aa3a	Cardamino amarae-Salicetum anthiscetosum	1		
39Aa2b	Carici-elongatae-Alnetum cardaminetosum amarae (p)	2		
39Aa2c	Carici-elongatae-Alnetum ribetosum nigrae (p)	+		4
43Aa1a	Violo odoratae-Ulmetum allietosum		3	
43Aa1b	Violo odoratae-Ulmetum inops	1		
43Aa3b	Crataego-Betuletum menthetosum			3
43Aa4	Carici remotae-Fraxinetum		+	3
43Aa5	Pruno-Fraxinetum	+	4	3

Table 2. Suggested syntaxa by site for three of the Swifterbant sites. Syntaxa are arranged according to their syntaxon number. This facilitates an easy comparison with the results (section 3). The colour scheme follows the field guide of Dutch plant communities (Schaminée et al. 2010). Blue: wetlands. Light green: grasslands. Orange: pioneer. Dark green: woodlands. Within these categories, numbers indicate the frequency with which syntaxa have been identified, expressed as a percentage of the most frequently identified syntaxon for that site: 4 (75– 100%), 3 (50–75%), 2 (25–50%) and 1 (>0–25%). Syntaxa only suggested once are indicated with a '+'. The crossed out syntaxon is discarded on ecological grounds. A '(p)' indicates that this plant community is part of a hydrosere related to peat formation.

The two associations within the *Parvocaricetea* (09) are only identified in the S3 settlement samples, and share a great number of species. They point in the direction of terrestrialization of sandy soils in a peat fen. The fact that these are only indicated or documented for the settlement site S3 probably indicates that they represent a signal from the back swamp areas

behind the levees proper, unaffected by the occasional brackish influence present in the Swifterbant river system.

3.1.2 Grassland communities

The only grassland association identified is the *Triglochino-Agrostietum stoloniferae* (12Ba2). All grassland types within its class are indicative of trampled places and can cope with very dynamic conditions. From the two sub-associations identified, the *Triglochino-Agrostietum juncetosum gerardi* (12Ba2c) gives a slight indication for brackish conditions. This is primarily caused by the presence of its eponymous species, *Juncus gerardii*. The other subassociation (*Triglochino-Agrostietum nasturtietosum*, 12Ba2b) is located along stream channels and pools in wet marshes previously in direct connection with the sea. The genus *Triglochin* in the syntaxon name refers to the fresh water species *T. palustris* and not the salt marsh species *T. maritima*. This subassociation shares a number of species with related associations within the *Bidentetea* (29, see 'Pioneer communities') and can appear after succession from associations within the *Caricion nigrae* (09Aa), the *Phragmition australis* (8Bb) and the *Sparganio-Glycerion* (08Aa), all present among the wet communities identified in this analysis.

3.1.3 Pioneer communities

Twenty pioneer plant communities are suggested. Since fourteen of these communities fall within three alliances, the description of the pioneer communities below will focus on these three alliances.

All associations within the *Bidention tripartitae* (29Aa) have been identified for the Swifterbant region. The *Bidention* is the only alliance represented strongly at all three sites. Its dominance is confirmed by the large number of diagnostic species present in the datasets, including *Bidens tripartita*, *Persicaria hydropiper* and *Ranunculus sceleratus*. The communities occur on nitrogen-rich soils that are inundated in winter and may fall dry in summer, but will hardly ever dry out. The plant communities occur naturally along waterways, but may benefit from anthropogenic influence in avoiding their place being taken over by vegetation types classified within the *Phragmition* (08Bb, see 'Wet communities'). The best represented community overall is the *Rumicetum maritimi chenopodietosum* (29Aa2b), which can gradually transfer into the very well-represented *Chenopodietum rubri* (29Aa3) under a moderate grazing regime and low ground water level. Whereas the analysis from the S3 and S4 sites shows great similarity (although the *Chenopodietum* is better represented at S3), the situation at S25 is different and deserves some extra attention. The best represented association at S25 is the *Polygono-Bidentetum* (29Aa1), which differs the most from other associations in this class because it can cope with slightly more shade.

Both the *Stellarietea mediae* (30) and the *Artemisietea vulgaris* (31) are classes of anthropogenic vegetation types, being the 'arable weed' communities and the 'ruderal places' communities, respectively. They are evidently better represented in the S3 settlement samples than in the S4 drift line samples, and are fully absent from the river dune site S25.

Plant communities within the *Artemisetea* (31) are indicative of an environment where constant light grazing and other disturbances, such as trampling, occurred. They also benefit from waste depositions and become less common with an increase in human hygiene. It should be mentioned here that a number of species characteristic of the identified syntaxa, such as *Ballota nigra*, are rarely found in archaeobotanical samples predating the Roman era. The best supported alliance within the class, the *Arction* (31ab) occurs on ammonia-rich soil. The *Chenopodietum* (29Aa3) is a community often found nearby, as is the *Pruno-Crataegetum* (37Ab1, see 'Woodland communities') when disturbance ceases.

3.1.4 Woodland communities

Thirteen (sub)associations were identified in the woodland vegetation group, representing five alliances. Two associations were identified within the *Rhamno-Prunetea*. The *Pruno spinosae-Ligustretum* (37ac4) is indicative of rocky outcrops and is currently only found in the south of the Netherlands. Due to the absence of rocky sediments near Swifterbant, its presence in the region is very unlikely. The *Pruno-Crataegetum typicum* (37Ab1a), on the other hand, is found on annually inundated (sandy) clay in large river deltas or channels. Although the Swifterbant river system was not a 'large' river, the incidental occurrence of this plant community cannot be excluded.

Several communities within the *Salicion albae* (38Aa) are represented. The *Artemisio-Salicetum agrostietum stoloniferae* (38Aa1b) can occur as pioneer vegetation on newly-formed soils along rivers (e.g. point-bars, wash-over deposits and crevasses splays). Depending on sedimentological and hydrological conditions, it can be succeeded by associations within the alliance, such as the *Irido-Salicetum albae* (38aa2), also identified in the Swifterbant data. When the bank is eroded it can be succeeded by, among others, associations within the *Bidention* (29Aa, see 'Pioneer communities'). The alder carr is represented by two varieties of the *Carici elongatae-Alnetum* (39Aa2), one of the two associations within the class. This syntaxon differs from the other association, the *Thelypterido-Alnetum,* by its closer relation to the *Alno-Padion* (43Aa) communities and a relatively high presence of nitrophilous species, including *Galium aparine* and *Urtica dioica*. Within the *Alno-Padion*, we see a strong representation of the *Pruno-Fraxinetum* (43Aa5), which is characterized by the presence of nitrophilous species as well.

3.2 Sieve residues

The analysis of the sieve residues in particular contributes to the understanding of the prehistoric food economy, because this provides a better insight into the economic plant composition. Table 3 shows the results of the study of sieve residues from S3, S4 and S25. The data published by Van Zeist and Palfenier-Vegters (1981, 118, table 3) cannot be presented in the same way as those from S3 and S4, since the authors present the total number of remains instead of the number of samples. The strong presence of *Ficaria verna* tubers at S4 suggests they were somehow not recognized at S3. The inverse probably applies for the stem fragments of *Phragmites australis*, which have not been identified at S4. *Galium aparine* is not mentioned in their table 3, but was found in their sieve residues according to the text (Van Zeist & Palfenier-Vegter 1981, 131). Species only found once at a single site have been omitted for this study.

The most striking difference between river bank sites S3 and S4, on the one hand, and river dune site S25, on the other, is the absence of cereal remains at S25. The few samples from river bank site S2 are in this respect comparable to those from S3 and S4 (Prummel *et al.* 2009, 24). Furthermore, *Corylus avellana* and *Quercus* (probably *robur*) show opposite patterns. Whereas hazel is very commonly present at S3 and S4 but rare at S25, oak is virtually absent at S3 and S4 and quite common at S25. The high values of *Cenococcum geophilum* at S25 point in the direction of somewhat drier conditions and may relate to the surfacing of the sandy subsoil at that location (Van Geel 1978, 16,102).

Taxon	Plant part	s3	s4	s25
Alnus glutinosa	cone	+	19	**37**
Corylus avellana	fruit	+	**71**	6
Crataegus monogyna	endocarp	+	12	**34**
Galium aparine	fruit	+	**36**	1
Malus sylvestris	exocarp	+	1	1
Ceratophyllum	fruit	1	1	
Hordeum vulgare	fruit	++	**86**	
Triticum turgidum subsp. *dicoccon*	fruit	+	23	
Ficaria verna	tuber		28	1
Quercus	fruit / cupule		1	32
Nymphaea alba	seed	+		
Phragmites australis	fruit	+		
Hordeum vulgare	rachis		2	
Cenococcum geophilum	sclerotium			**39**
n			119	101

Table 3. Number of sieve residue samples in which taxa occur at three of the Swifterbant sites. Bold numbers indicate the top three taxa per site; underlined taxa indicate probable food plants. The prefix S stands for Swifterbant. The taxa are ordered according to the site where they occur, in the following order: all three sites; S3 and S4; S4 and S25; S3; S4; S25. ++ = common, + = present.

4. Interpretation and spatial distribution

4.1 Stream channels and ponds

Although the vegetation in and along the banks of the different river branches will have differed over space and time (see section 5, 'Time depth'), it will have been dominated by the *Phragmition australis* (08Bb). Along the main channel, club-rushes will have formed a major component of the first line of vegetation. The culms of several club-rushes, including *Schoenoplectus lacustris* (both subsp. *lacustris* and subsp. *tabernaemontani*) and *Bolboschoenus maritimus*, are more rigid than *Phragmites australis* (reed) and will therefore be better able to withstand moving water. The club-rushes will be less commonly present along the secondary and tertiary channels, but will appear in deeper parts of standing water, for example, in open areas in the back swamps. On more open parts of the bank, specific vegetation types for small river banks will have become established. This openness can be caused by erosion, sedimentation (creating new substrates) or human clearance of the banks. Plant communities dominated by tall sedges were present at places where ongoing sedimentation within reed vegetation reduced the relative water level (see section 5, 'Floodplain fens and peat formation'). There is some evidence of floating islands as well. They will not have been present in the main channel, but in open water in marsh ponds in the back swamps. Given the low availability of peaty, sandy substrate in the Swifterbant region, the coverage of the *Cladietum marisci* (8Bd1) was probably lower than that of the *Phragmition* communities. A number of plant communities is present that suggest mesotrophic conditions (9Aa3b and 9Ba1, see table 2), but the nutrient availability in the area suggests that their distribution must have been sparse (see section 5, 'Floodplain fens and peat formation').

With respect to plant communities within the *Phragmition* (08Bb), it must be noted that these communities can be very poor in species, and in many instances consist almost entirely of the type-species. Therefore, it is invalid to exclude the presence of the *Scirpetum lacustris* (consisting primarily of *Schoenoplectus lacustris* subsp. *lacustris*) in the area, given the very modest and incidental brackish signal (see section 5, 'Salinity'). Following the same line of reasoning, species-poor plant communities of deeper water will also have been present, but

are undetectable for methodological reasons. For example, the presence of plant communities belonging to the *Potametea* is very likely, but now hidden within associations of the *Phragmitetalia* (08, fig. 3). Relatively pure patches of (yellow) water lily (*Nymphaea alba/Nuphar lutea*) may well have been present in the deeper parts of cut-off stream channels and ponds.[3]

*Figure 3. Zonation of species-poor plant communities of reed (*Phragmites australis = Typho-Phragmitetum, *left: bright green) and club rush (*Schoenoplectus lacustris subsp*. lacustris = Scirpetum lacustris, *right: dark green). White water lilies (*Nymphaea alba*) float between the culms of both species (and hence occur in both communities), but they also occur in their 'own' community (*Myriophyllo-Nupharetum*) in the background (Buchholz, Germany, august 2012).*

4.2 Exploitation of stream channels and ponds

The settlement layers of the Swifterbant river bank sites S4 and S3 may have been artificially raised with reed bundles (Van der Waals 1977, 18). In addition, last year's reed vegetation may have been burnt down to clear the shores, which would explain not only the high number of charred reed stem fragments, as recognized by Van Zeist & Palfenier-Vegter (1981), but also the high number of *Galium aparine* (cleavers) fruits encountered at the site. Although *G. aparine* is not typically for a *Phragmition*, field observations by the author show that reed vegetation bordering 'disturbed soils' provide an excellent climbing opportunity for this species (but for other explanations, see Out 2009, 344-345). Recent Palaeolithic research in Belgium tried to interpret the burning of reed as reflecting attempts by prehistoric people to attract large herbivores (Bos *et al.* 2013), but in the Swifterbant wetland this explanation seems unlikely. The channels will also have been the areas where fish were caught. The analysis of fish remains indicates a strong presence of fish characteristic of the so-called bream zone (Brinkhuizen 1976; Hullegie 2009). In this zone, the current flow velocity was low and banks were partly covered in dense vegetation. The open water in the ponds in the floodplain will also have contained fish, as is confirmed by the find of a small fish tooth in the floodplain samples, and may also have provided open water for waterfowl.[4]

4.3 River banks and sand dunes

The dense vegetation of stream channels and ponds described above will partly have consisted of communities within the *Phragmition*. Especially along the main channel, however, riparian forest types will have been abundant, with several willow species dominating the tree layer.

Figure 4. Vegetation types present in the Swifterbant area during the prehistoric habitation period. Clockwise from top left: (1) river bank vegetation showing zonation from reed (Phragmites australis) *to nettle (*Urtica dioica) *(Vennebroek, The Netherlands, August 2012); (2) alder carr (Nietap, The Netherlands, June 2012); (3) willow carr (Millingerwaard , The Netherlands, July 2013; (4) shallow water vegetation with water plantain (*Alisma plantago-aquatica) *and spike-rush (*Eleocharis)*(Appelscha, The Netherlands, May 2012).*

It is, nonetheless, partly due to the identification of species from *other* communities that the willow carr can be identified, as no macro remains of this tree were found. This can be explained by the fact that the undergrowth contains species from a number of other classes identified in the analysis, including the *Bidentetea, Stellarietea*, *Artemisietea, Phragmitetea, Convolvulo-Filipenduletea* and *Plantaginetea majoris* (Stortelder *et al.* 1999, 167). Willow wood and/or charcoal was identified by Casparie *et al.* (1977) and Van der Laan (2011), and willow pollen is present in all samples studied in the region (Casparie *et al.* 1977; Van der Veen 2008; Maurer 2011). Long-distance import or transport of willow wood is unlikely due to the poor quality of the wood, and its local origin is further confirmed by beaver tooth marks on a number of willow sticks (Casparie *et al.* 1977, 45).

Willow carr vegetation was present along the primary and secondary stream channels (fig. 4). Wet willow forests will also have made up part of the floodplain vegetation (see below). Other tree species, such as alder and birch, will have occurred only occasionally in this vegetation (Rodwell 1998, 65).

Where willow carr and reed communities (*Phragmition*) were absent (either through erosion or clearance by humans) and nutrient-rich litter and fresh sediment was deposited, pioneer vegetation dominated by such species as *Persicaria hydropiper* (water pepper) and *Bidens* (beggarticks) appeared. Along the sand dunes, a more shade-tolerant association within the *Bidention* was present. The shade was probably primarily caused by the presence of oak trees (*Quercus*), as shown by the acorns frequently encountered in the S25 sieve residues and other finds of acorns and leaves of oaks surrounding the dunes (Casparie *et al.* 1977, 42). The exact composition of the 'oak forest' on the dunes cannot be identified, but oaks frequently occur in plant communities within the *Alno-Padion*. These forest types grow on drier soils than a willow carr. Although Van Zeist & Palfenier-Vegter are probably right that *Alno-Padion* forests will have occurred on higher parts of the river banks (1981, 135), similar woodland with higher percentages of oak may have been present on the sand dunes. Vissinga's (2007, 23) corings at the river dune in the vicinity of sites S21–S25 yielded large pieces of wood, not unlike those documented for S25 by Geuverink *et al.* (2009, 11). De Moor *et al.* (2009, 69) suggest a regional picture of a mixed oak forest. The suffix -etum in this so-called *Quercetum mixtum* suggests an association, but it is actually a palynological umbrella term for Atlantic forests in low-altitude areas dominated by *Quercus* and accompanied by *Tilia*, *Ulmus* and *Betula* trees. Within modern syntaxonomy, these can be assigned in the Netherlands to the *Quercetea robori-petraea* and the *Querco-Fagetea*, which includes the *Alno-Padion*. As such, we can assign part of what De Moor *et al.* (2009) describe as mixed oak forest to the sand dunes, which fits their interpretation as regional vegetation. The comparison with the study by De Moor *et al.* (2009) is restricted to their section VII, which deals with the infilling of a 'gully' probably connected to the Swifterbant system. Wet grassland communities will have been present on the river banks in the vicinity of the settlement sites.

4.4. Exploitation of river banks and sand dunes

The analysis of wood from S3, S4 and S25 shows a strong dominance of alder, irrespective of its use (Casparie *et al.* 1977; Schepers & Bottema in prep.; Van der Laan 2011). Casparie *et al.* are probably right in their claim that this points to an abundant availability of alder, rather than a preference for this species. Although oaks were present on the dunes, they were apparently not common enough to merit or reflect intensive exploitation. Some further remarks regarding the woodland vegetation are made below, but for the more general or cultural overview of wood collecting strategies the reader is referred to Out (2009; 2010). Along the primary stream channel, willow carr must have dominated the river banks. De Roever (2004, 10) suggests the higher river bank of S2 as a one of the possible locations for the *Alno-Padion* forest. This forest provided food plants such as brambles and wild apple, partly also present in the alder carr in the back swamps.

The identified grassland communities will only persist under a grazing regime. Great parts of the river banks must have been used for this purpose, as is also supported by coprophilous fungi from the settlement layer at S4 (Van der Veen 2008).[5] Grassland vegetation, and more specifically *grass* in grassland vegetation, is characterized by the ability to adapt to grazing by spreading vegetatively and by the presence of meristeme tissue close to the soil. Grasslands can therefore be underrepresented in the archaeobotanical record (Woldring & Kleine 2008, 266). The river banks were also used for cereal cultivation (see cereal cultivation below).

The high number of burnt cereal remains and hazelnut shells recovered also confirm that the river banks were used intensively. The absence of acorns at S3 and S4 suggests that, despite the fact that this is theoretically possible, acorns were not used for human consumption – which tallies with Out's (2009, 347) view on the subject.

Pioneer communities are indicative of disturbance. The identification and interpretation of arable weed communities and other synanthropic vegetation types have long been a matter of debate in archaeobotany (e.g. Bogaard *et al.* 2010; Eggers 1979; Hillman 1991; Knörzer 1971; Kreuz & Schäfer 2011). The decision to only exclude vegetation types if species are missing that would normally be present in over 95% of the present-day relevées of that type causes a number of associations within the arable weed class to be accepted. The absence of typical field weed species, such as *Thlaspi arvense* and *Fallopia convolvulus,* would have led to an exclusion of more syntaxa if this arbitrary percentage had been set lower. A number of the S3 samples evidently reflect a species combination that fits within the *Stellarietea*, but lack some of the species quite common in the *Bidention*. Since the S3 material shows excellent preservation, this can only be regarded as reflecting past realities. Many species within the *Bidention* show a strong overlap with more anthropogenically influenced plant communities within the *Stellarietea* and *Artemisietea*. Therefore, species of the *Bidention* are sometimes mistaken as indicators of human disturbance (Van Beurden 2008, 22). The present analysis shows, however, that plant communities within the latter classes are most strongly represented where they are expected: at settlement sites. The 'natural' pioneer communities within the *Bidention* were abundant along the banks under the willow carr vegetation.

It should be emphasized that there is very little evidence for intensive use of the dunes. Evidence for both oak wood and acorns is scarce, and the undergrowth of the more closed canopy at these dunes, as confirmed by the shade-tolerant *Bidention* vegetation, will not have provided the abundant biomass of the more open areas in other parts. The sandy subsoil will also have made the dunes less attractive for cereal cultivation in comparison with the nutrient-rich river banks, despite the certainty that flooding would not occur.

4.5 Back swamps

The back swamps are the relatively low-lying parts of the floodplain behind the river banks, which will flood when the water level in the gully exceeds bank height, or when the banks are breached during crevasse splay formation. While no excavations took place in back swamp areas, it is important to try to reconstruct the vegetation in these areas as well, because its distribution affects exploitation possibilities.

Extensive coring projects for the adjacent floodplain were published by Nales (2010) and at a greater distance from the river system by Coppens (2009). Nales's research shows that the floodplain levels contemporaneous with the Swifterbant habitation have suffered from substantial erosion. Some remarks can, however, still be made. The back swamps consisted of both clay and peat. When the back swamps flooded, new clay was deposited in the area, which will subsequently have been colonized by reed. At some places, this reed vegetation was able to develop into peat layers; at other localities ongoing clay sedimentation resulted in what Ente (1976, 19) describes as 'soft back swamp deposits', which are relatively rich in organic matter. Whereas Coppens found exlusively reed- or sedge-peat, Nales presents a more diverse picture, with some corings yielding wood remains, and others containing almost exclusively reed or unidentified root fragments. This is a direct result of the fact that the research done by Nales is much closer to the river system. Sampling of the top of the peat where it was not eroded confirmed the existence of open water in the floodplain, in the form of high numbers of *Cladium mariscus* as well as *Daphnia* and *Chara* species (see appendix). One find of a foraminifera shell indicates incidental flooding with brackish water. The presence of open water is also indicated by soft back swamp clay deposits containing only a few plant remains.

Combining these observations, it appears that the floodplain in the Swifterbant area consisted of a mosaic of open water and reed/sedge swamps. Several wet woodland types will have been present here and there, mainly along the river banks and river dunes. De Moor *et al.*

(2009, 69-71) studied sediments from a 'creek' fill probably connected to the Swifterbant system. Based on the study of both pollen and macro remains, they identified the local vegetation as alder carr, reed swamps and Great fen-sedge swamp. Their reconstructed local vegetation fits well within the overall ecological characterization of the region, but undervalues the woodland diversity. The presence of alder carr (fig. 4) on the transition between river banks and back swamps, as suggested by Van Zeist & Palfenier-Vegter (1981, 139), holds true for the more inland parts of the system, but near the main channel and more towards the west, willow carr will have dominated. The ongoing deposition of nutrient-rich sediment (Grootjans *et al.* 2012, 206) along most of the river banks will have been better suited to the development of willow carr, resulting in a riparian forest. Alder carr will have been absent along the main channel, and should instead be located in the less dynamic parts of the floodplain and cut-off river channels. This will still have covered substantial areas.

4.6 Exploitation of back swamps

The exploitation of the back swamps has partly been dealt with in the section titled 'Stream channels and ponds'. The open water will have been suitable for fishing and fowling, whereas the edge of the alder carr provided a rich variety of possible plant food sources, such as *Humulus lupulus* (hop), *Rubus fruticosus* (bramble) and *Crataegus monogyna* (hawthorn).

5. Discussion

5.1 Actualism

In the paper that introduces the Palaeoassocia method (Schepers *et al.* 2013), a whole paragraph is devoted to the validity of using present-day plant communities to reconstruct past vegetation. In the introduction to that paper, the alternative approaches to vegetation reconstruction are also dealt with at length. As Bakels & Zeiler point out, 'the wet part of the Netherlands was […] a mosaic of different kinds of vegetation' (2005, 311). By using the most detailed approach possible, the present analysis aims to sharpen the resolution of our view on this mosaic, leading to much more detail than can be achieved by using ecological groups, such as 'ruderal species' or 'marsh plants'. It would be 'safer' to restrict the syntaxonomic depth to the class or alliance level, but these levels do not facilitate detailed visualization and hamper a thorough insight into the possible exploitation by man. Moreover, the analysis suggests multiple possible plant communities for most groups, which are all taken into consideration in the interpretation.

5.2 Salinity

A number of proxies indicate an open coast and an incidental influx of brackish or saline water. First, the formation of the river banks themselves at Swifterbant is a direct result of the mixture of fresh and brackish water (see section 1, 'Geomorphology'). According to analyses conducted by De Wolf & Cleveringa (2005; idem 2006; idem 2009a&b), the frequent presence of coastal diatoms testifies to a clear but incidental coastal influence. Their analysis of the diatoms took into account not only the ecological specifics of the diatom species recovered, but also the fragmentation of the diatoms (cf. methodology of Vos & De Wolf [1988]). The large number of broken shells from marine species enabled De Wolf & Cleveringa to differ-

entiate between autochthonous and allochthonous species, labelling the marine diatoms as 'coastal allochtones'. Related to this, the foraminifera found in several palynological spectra confirm an incidental marine influence (Van der Veen 2008, 5).

Second, Van Zeist & Palfenier-Vegter (1981, 140) have already pointed out that the presence of *Aster tripolium*, *Juncus gerardii* and *Salicornia europaea* in the samples suggests a marine influence, but that the overall plant evidence does not suggest that the area was more or less regularly flooded with brackish water. The salinity ratio, calculated from a selection of halophytes and glycophytes as proposed by Behre, would result in a 33.3 ratio, which cannot be right given the overall picture (1991, 159-160). As was pointed out by Brinkkemper, the fact that Behre's system is based on presence/absence at the site level may have caused this effect (1993, 102). *Salicornea europaea* (s.l.) is ruled out completely as not fitting the overall Swifterbant ecology by the present analysis, because it is bound to high salinity values, although Meltzer & Westhoff (1942, 238) mention that it occured under brackish conditions in the former Zuiderzee. The poor physical preservation of the *S. europaea* seeds from the Swifterbant samples seems to confirm long-distance transport. The characteristic hairs, formed by elongated cells of the outer integument, have eroded (Shepherd *et al.* 2005, 923). Analogous to the broken diatom scales, these seeds can be labelled coastal allochtones (fig. 5). However, the only two finds of *Salicornea europaea* in the area originate from the deepest levels. These seeds may therefore also be considered a faint signal of a pioneer stage in the river bank vegetation. Their position directly beneath the cereal field at S4 would then indicate a rapid desalinization of the river banks. Although no present-day Dutch vegetation type in direct succession of *Salicornia*-dominated vegetation was identified in the analysis, it is worth mentioning that a basal community dominated by a more salt-tolerant variety of *Bolboschoenus maritimus* (var. *compactus*, Weeda *et al.* 2003, 249) can occur in succession of a *Salicornietum*, as is quite common in the Dutch and Belgium Scheldt estuary (Beeftink 1965, 123-124; Vandenbussche *et al.* 2002, 58-62). The more salt-tolerant variety of *B. maritimus* cannot be distinguished archaeologically from the fresh to brackish form (var. *maritimus*).
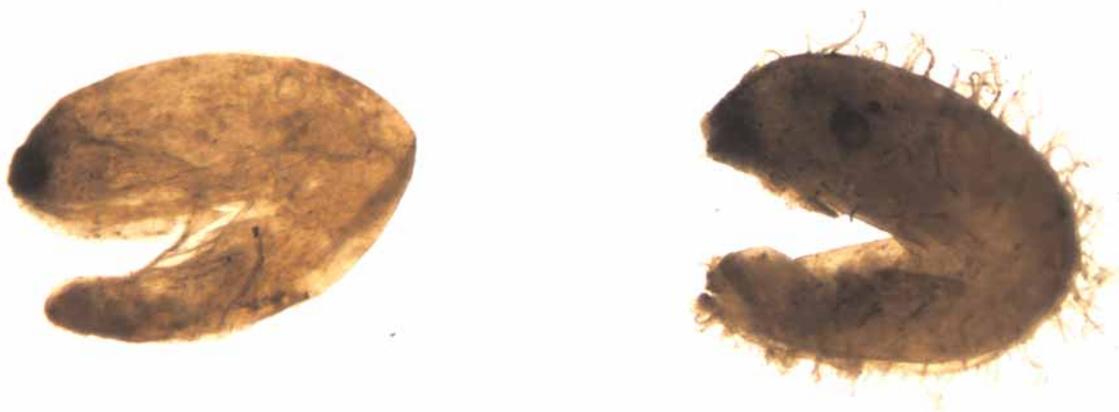
Figure 5. Subfossil seeds of Salicornia europaea *from Swifterbant (left) and Heveskesklooster, province of Groningen, the Netherlands, iron age terp (right). The hairs that are present on the Heveskesklooster specimen have eroded on that from Swifterbant.*

Juncus gerardii and *Aster tripolium* are predominantly coastal species today and will have been so in the past. They can also occur in fresh environments and will have been present in the Swifterbant river system (Van der Meijden 2005, 137-138, 593; see also Hogestijn 1989, 121).

The third and final proxy for landscape conditions are the stable isotope investigations on human bones from the area. These show δ^{13}C and δ^{15}N values consistent with a strong aquatic component, but lacking a strong marine signal when compared with some other Dutch wetland sites (Smits & Van der Plicht 2009, 79). In accordance with the interpretation by Van Zeist & Palfenier-Vegter (1981), a brackish influence must have been present only incidentally, for example, during seasonal storms, and saline influx would have affected the main channel in particular. The overall nature of the Swifterbant river system ecology is therefore best described as a freshwater riparian system. In contrast, the historic Zuiderzee, whose tidal inlet lay along its northern edge (the present-day Wadden Sea), was brackish and locally even saline (Hogestijn 1989; Jansen & Wachter 1930; Van Goor 1922).

5.3 Floodplain fens and peat formation

At Swifterbant, several plant communities have been identified that can be related to peat formation (indicated with a '(p)' in table 2). Although there has been some debate on proper terminology relating to peat ecology (e.g. Wheeler & Proctor 2000; Joosten & Clarke 2002), some consensus has been reached. A peatland where peat is currently being formed is labelled a mire. Mires can be divided into ombotrophic acidic bogs (rainwater-fed) and rheotrophic neutral to base-rich fens (ground- or surface water–fed; Grootjans *et al.* 2012, 204; Wetzel 2001, 820). In Dutch geology and archaeology, peat development is commonly illustrated by referring to Visscher (1949, 44, fig. 6), schematically showing the relationship between vegetation types involved in peat formation and the peat types produced by these types (e.g. Berendsen 2004, 228; Van Asselen & Bos 2009, 59). This simplified scheme applies specifically to the terrestrialization of depressions containing open water, such as pingo scars. This terrestrialization process has long been known to progress via a more or less standard vegetation succession, the hydrosere (Wheeler & Proctor 2000, 190), as is also shown by Visscher (1949). In the current vegetation succession analysis, starting from open water, all successive communities related to rheotrophic peat formation have been identified (table 2), including reed swamps, sedge swamps and alder carr communities. Whether or not a plant community is related to peat formation is based upon a comparison of the identified plant communities with the publications mentioned above. In other words, although the Swifterbant system is not a closed water body, such as a pingo scar or a small lake, all stages of rheotropic peat development existed simultaneously over the area during the habitation period. Because the Swifterbant back swamps are part of a floodplain, the development of large-scale oligotrophic (nutrient-poor) bogs is not very likely. Intensive flooding in winter and spring, depositing fresh silt and clay sediments, will increase the nutrient availability (Grootjans *et al.* 2012, 206). Bogs nonetheless *did* develop at a greater distance from the stream channels (Brinkkemper *et al.* 2009, 56). The thus created picture of the distribution of fens and bogs is confirmed by the distribution of *Sphagnum* peat in the maps presented by Peeters (2007, 64-71, fig. 3.12) and corings in and near the floodplain (Coppens 2009; Nales 2010). Bogs can develop in open coastal systems, as shown by research in the Scheldt estuary (Deforce 2011), but this requires a different geomorphology. Peat moss spores and leaves are commonly found in the Swifterbant region (e.g. Van der Linden 2008; Van Zeist & Palfenier-Vegter 1981; Weijdema *et al.* 2011). These plant remains can therefore be interpreted as the result of long-distance transport or as a signal of incidental meso- or oligotrophic patches that commonly occur in predominantly eutrophic fenland areas (e.g. Rintjema *et al.* 2001, 99-100).

5.4 Periodic occupation

Whether or not the habitation at the Swifterbant river bank sites was periodic has been discussed repeatedly (e.g. Raemaekers 1999, 41-42; Louwe Kooijmans 1993, 90-94; Zeiler 1986; idem 1997, 86-87). Plant communities within the *Bidention* as well as the *Salicion* confirm the hypothesis that large parts of the river banks must have flooded in winter time, because these pioneer plant communities consist for a large part of communities that grow on newly deposited sediment. In the summer season, wet *Bidention* communities can even occur in river beds that have fallen dry. In different spits of the S3 samples, a hint of this process is visible in the data. In the deepest spit, spit 9, aquatic communities are amongst the suggested syntaxa for 4 out of 6 samples. One spit higher this has fallen to 1 out of 9, after which it climbs again, to 4 out of 6 in level 6 (fig. 6). The samples most likely show periodic flooding of the river bank, which resulted in the deposition of seeds from aquatic plants as well. Seed density was used as a criterion for which samples to analyze at S3. The strategy to focus on more 'seed-rich' samples will have caused an overrepresentation of pioneer vegetation. There is a good chance that the process described here would have been identified more convincingly had more – and more random or landscape-determined – samples been analyzed, among which samples with few seeds. The fact that flooding took place between habitation phases is also shown by the diatom analysis of the S4 settlement layers (De Wolf & Cleveringa 2005). Diatoms from a vertical section of settlement layers showed that the relative presence of marine diatoms fluctuates in comparison with the aerophilous species, although marine species are constantly present. The lithology of the Swifterbant river banks is also indicative of an occasional mixture of fresh and brackish water (see 'Salinity'). Had saline marine influx occurred daily, as opposed to seasonally, the overall ecology would have been considerably more brackish.
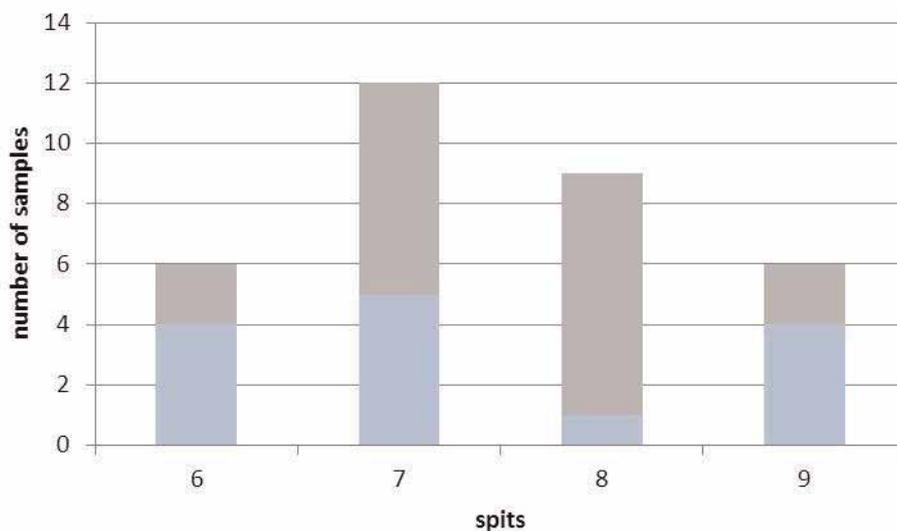
Figure 6. Number of samples for which a wet community is among the suggestions in the Palaeoassocia analysis for spits 6–9 of Swifterbant site S3. Blue represents samples with wet communities, grey represents samples lacking wet communities. Layer 9 is the oldest/deepest. Because the four deepest spits represent 33 out of 46 samples, the top 5 spits have not been shown here. Note that wetter (6, 9), mixed (7) and drier (8) episodes alternate.

In summary, all palaeolandscape proxies indicate periodic flooding of the river banks, in line with the early findings of Ente on this matter (1976, 32). The strong representation of plant communities within the *Bidention* suggests this process must have repeated itself over and

over again over the years (see 'Time-depth'). Whether or not this happened *every* year cannot be reconstructed. All these data add up to the simple field observation that relatively clean clay layers alternate with 'finds layers', thus testifying to ongoing sedimentation during the formation of the cultural layer (De Roever 2004, 21). Peeters' (2007, 206) suggestion that these floods mainly occurred during a first phase of occupation is not supported by eco-archaeological data. Zeiler's suggestion that some years may have been more favourable for year-round occupation cannot be dismissed outright, but it seems improbable. The suitability of river banks for hunting and fowling during wetter times, however, was high (Zeiler 1997, 87). Isotope evidence from human remains seems to point to seasonal utilization of upland territory (Smits & van der Plicht 1999, 79-80).

5.5 Time depth

Like Van Zeist & Palfenier-Vegter's earlier (1981) landscape reconstruction, the present interpretation pays little attention to developments over time, primarily because the radiocarbon calibration curve shows a plateau for the period of Swifterbant habitation (Reimer *et al.* 2009). Nonetheless, the numerous finds of anthropogenic indicators in all levels sampled by Van Zeist, including cereal grains (depicted in Neef *et al.* 2012, 409), justify linking the vegetation reconstruction with the period of human exploitation. Two of the S4 drift litter samples were taken at a level higher than the lowest archaeological levels analyzed by Van Zeist and Palfenier-Vegter located along the same stream channel. Apparently, the top of the river bank had silted up to such an extent that drift litter washed ashore at a higher level than the oldest occupation phases. These oldest occupation phases were also located on the top of the river bank, but this was considerably lower by then. This once again confirms the ongoing silting up of the river banks. These samples from higher up in the sequence can also be related to a human occupation phase, as is shown by the recovery of both artefacts and barley rachis fragments (depicted in Cappers & Neef 2012, 285). The analysis of the S3 settlement levels shows the ongoing dominance of pioneer vegetation. Human disturbance also prevented natural succession. There are indications of an initial colonization of the river banks by *Salicornia*-dominated vegetation at the first formation of the river banks, at S3, but these are very weak. Brackish influences were very low from the very start of habitation until the last phases studied archaeobotanically (see 'Salinity'). The identification of an Emmer wheat spikelet fork, dating to about 500 years after the abandonment of the river bank sites in the direct vicinity, suggests that exploitation of the landscape remained possible at a relatively short distance (De Moor *et al.* 2009, 70).

5.6 Cereal cultivation

The discussion about whether or not cereal cultivation was practiced locally has become somewhat moot with the discovery of a tilled field in the S4 excavations (Huisman *et al.* 2009; Raemaekers in prep.a). Nonetheless, the results of the present study enhance our insight into the past environment and hence contribute to our understanding of this cultivation.

The strong presence of, in particular, ruderal communities and weed communities in the S3 settlement samples confirm large-scale vegetation disturbance, which may have included cultivation. A comprehensive discussion of Neolithic crop husbandry practices is presented by Bogaard (2004), who later argued that the species mentioned as potential field weeds by Cappers & Raemaekers (2008) are generalists, and therefore not convincing indicators for cultivation (Bogaard 2008). The present analysis shows that the *combination* of 'generalist' species found in some of the settlement samples clearly points to arable weed communities. These

weed communities lack some characteristic species, but this is to be expected when cereals are cultivated in a landscape where no cultivation is practised nowadays. Farming in an environment where no or little farming is practiced nowadays will lead to non-analogous plant communities. In other words, at Swifterbant, and probably at other wetland sites in prehistory, there will have been a weed community resembling the *Stellarietea* communities, consisting for a large part of species it shares with the *Bidention*, but lacking the 'wetter' species therein. The absence of cereal remains, in combination with the fact that no association from the *Stellarietea mediae* was identified at S25, strengthens the interpretation that cereal cultivation was restricted to the river banks.

The Swifterbant system cannot be compared with any big river floodplain in central Europe, since no upland dry soils are available in the direct vicinity of the Swifterbant sites except for the dunes. It should also be mentioned that riparian vegetation is not at all uniform, but instead dependent on a number of factors, of which stream size, in particular, is relevant to the Swifterbant situation (Dybkjær *et al.* 2011). It is also questionable to speak of 'evidence for crop cultivation at sites of the Swifterbant culture' (Deforce *et al.* 2013, 58). Such claims need to be evaluated per site, or at most, by region (as was done by Out [2009, 179]). A combination of (a) the field weed (associations) evidence, (b) the cereal fragments recovered, and (c) the cultivated field itself proves cereals were grown on the river banks in the direct vicinity of the Swifterbant settlements. It should again be stressed (per Cappers & Raemaekers 2008, 392-393) that this will have been cultivation on a very modest scale.

6. Conclusions

This paper presents a detailed reconstruction of the vegetation and related exploitation possibilities of the Swifterbant river system on a plant association level. Bakels & Zeiler eloquently describe the area as a vast swamp transected by creeks (2005, 316). This characterization slightly undervalues the role of the river system as the key component of the landscape in favour of the back swamps. As far as the big picture is concerned, the interpretation published by Van Zeist & Palfenier-Vegter (1981) is found to be mostly correct. The inclusion of data from additional sites that were not available to those authors, together with the application of new methodology, has, however, significantly enhanced our the understanding of the Swifterbant river system as a whole and has also made it possible to compile a more detailed image. The high biomass would have accommodated a wide variety of food sources for humans, as well as grazing for livestock.

Acknowledgements

Notes

1. The aim here is to end the discussion on the geomorphological description of the system. Because of the fact that the tidal difference must have been very limited (~15 cm), the term tidal is rejected in this context. The waterways themselves are referred to as (stream) channels, following Bradshaw and Weaver (1995, 250). By using the term 'river system' rather than 'creek system', the significance of the connection with the river IJssel as well as the differences with coastal creeks are emphasized. Thus insights from this study are combined with points brought forward by dr. Kim Cohen and Peter Vos at the 2012 Dutch archaeology convention (Reuvensdagen).
2. It concerns the following species and syntaxon codes: *Hippuris vulgaris* (08Aa1); *Cicuta virrosa* (08Ba2a); *Thelypteris palustris* (08Bb4d); *Juncus maritimus* (26Ac7); *Fallopia convolvulus* (30Aa2, 30aa1a, 30Bb1b); *Echinochloa crus-galli* (30Bb2a); *Urtica urens* (31Ab1b, 31ab1c) and *Rubus caesius* (43Aa3b).
3. The chances of species-poor communities being 'hidden' behind other communities is a problem well known in archaeobotany. In the salt marsh area, for example, Behre describes the poor visibility of the *Juncetum gerardii typicum* in relation to the more species-rich subassociation *J.g.leontodontetosum* (Behre 1976, 31).
4. Probably *Cyprinidae* species, kindly looked at by Lisette de Vries.
5. Bas van Geel kindly provided help with the identification of coprophilous fungi.

References

Bakels, C.C. & J.T. Zeiler 2005, The fruits of the land: Neolithic subsistence. In: L.P. Louwe Kooijmans, P.W. van den Broeke, H. Fokkens & A.L. van Gijn (eds), *The Prehistory of the Netherlands*, Amsterdam (Amsterdam University Press), 311-335.

Beeftink, W.G. 1965, *De zoutvegetatie van ZW-Nederland beschouwd in Europees verband*, Wageningen (H. Veenman & Zonen).

Behre, K.E. 1991, Umwelt und Ernährung der frühmittelalterlichen Wurt Niens/Butjadingen nach den Ergebnissen der botanischen Untersuchungen, *Probleme der Küstenforschung im südlichen Nordseegebiet* 18, 141-168.

Berendsen, H.J.A. 2004, *De vorming van het land: Inleiding in de geologie en de geomorfologie*, Assen (Van Gorcum).

Bogaard, A. 2004, *Neolithic farming in central Europe: An archaeobotanical study of crop husbandry practices*, London/New York (Routledge).

Bogaard, A. 2008, Comment on R.T.J. Cappers & D.C.M. Raemaekers: Cereal cultivation at Swifterbant? Neolithic wetland farming on the north European plain, *Current Anthropology* 49, 394-395.

Bogaard, A., G. Jones, M. Charles & J.G. Hodgson 2010, Crops and weeds: The role of weed functional ecology in the identification of crop husbandry methods, *Journal of Archaeological Science* 37, 70-77.

Bos, J.A.A., F. Verbruggen, S. Engels & P. Crombé 2013, The influence of environmental change on local and regional vegetation patterns at Rieme (NW Belgium): Implications for Final Palaeolithic habitation. *Vegetation History and Archaeobotany* 22, 17-38.

Bradshaw, M. & R. Weaver 1995, *Foundations of physical geography*, Dubuque (Wm. C. Brown).

Braun-Blanquet, J. 1964, *Pflanzensoziologie, Grundzüge der Vegetationskunde*, 3rd edition, Vienna (Springer).

Brinkhuizen, D.C. 1976, De visresten van Swifterbant, *Westerheem* 25, 246-252.

Brinkkemper, O. 1993, *Wetland farming in the area to the south of the Meuse estuary during the Iron Age and Roman Period*, Leiden (Leiden University).

Brinkkemper, O., M. Brongers, S. Jager, T. Spek, J. van der Vaart & Y. IJzerman 2009, *De Mieden: Een landschap in de noordelijke Friese Wouden*, Utrecht (Matrijs).

Buurman, J. 1996, *The eastern part of West-Friesland in later prehistory: Agricultural and environmental aspects*, Leiden (Leiden University).

Cappers, R.T.J. & R. Neef 2012, *Handbook of plant palaeoecology*, Groningen (Groningen Archaeological Studies 19).

Cappers, R.T.J. & D.C.M. Raemaekers 2008, Cereal cultivation at Swifterbant? Neolithic wetland farming on the north European plain, *Current Anthropology* 49, 385-402.

Casparie, W.A., B. Mook-Kamps, R.M. Palfenier-Vegter, P.C. Struijk & W. van Zeist 1977, The palaeobotany of Swifterbant: A preliminary report (Swifterbant Contribution 7), *Helinium* 17, 28-55.

Coppens, C.F.H. 2009, *Gasleidingtracé Swifterbant–Emmeloord (A-683 en N-500-64) Gemeenten Dronten en Noordoostpolder: Archeologisch vooronderzoek: Een inventariserend veldonderzoek (verkennende en karterende fase)*, Weesp (RAAP-Rapport 1873).

De Moor, J.J.W., J.A.A. Bos, M.T.I.J. Bouman, C. Moolhuizen, R. Exaltus, F.P.A. Maartense & T.J.M. van der Linden 2009, *Definitief archeologisch onderzoek in het tracé van de Hanzelijn in het Nieuwe Land*, Delft (Deltares).

De Roever, J.P. 2004, *Swifterbant-aardewerk: Een analyse van de neolithische nederzettingen bij Swifterbant, 5e millennium voor Christus*, Groningen (Groningen Archaeological studies 2).

De Roever, J.P. 1976, Excavations at the river dune sites S21-22, *Helinium* 16, 209-221.

De Wolf, H. & P. Cleveringa 2005, *Swifterbant: Nat maar begroeid, wonen in een estuarium*. Utrecht (TNO).

De Wolf, H. & P. Cleveringa 2006, *Paleoecologisch diatomeeënonderzoek van twee ontsluitingsprofielen te Swifterbant, Oostelijk Flevoland*, Utrecht (TNO).

De Wolf, H. & P. Cleveringa 2009a, *Paleoecologisch diatomeeënonderzoek van drie ontsluitingsprofielen genomen in 2006 te Swifterbant, Oostelijk Flevoland*, Beverwijk (PalaeoDiat, WMC Kwartair Consultants).

De Wolf, H. & P. Cleveringa 2009b, *Paleoecologisch diatomeeënonderzoek van S4-put 1 (bak 1 en 2) en van het lakprofiel te Swifterbant, Oostelijk Flevoland*, Beverwijk (PalaeoDiat, WMC Kwartair Consultants).

Deforce, K. 2011, Middle and late holocene vegetation and landscape evolution of the Scheldt estuary: A palynological study of a peat deposit from Doel (N-Belgium), *Geologica Belgica* 14, 277-288.

Deforce, K., J. Bastiaens, W. van Neer, A. Ervynck, A. Lentacker, J. Sergant & P. Crombé 2013, Wood charcoal and seeds as indicators for animal husbandry in a wetland site during the Late Mesolithic–Early Neolithic transition period (Swifterbant culture, ca. 4600–4000 B.C.) in NW Belgium, *Vegetation History and Archaeobotany* 22, 51-60.

Dresscher, S. & D.C.M. Raemaekers 2010, Oude geulen op nieuwe kaarten: Het krekensysteem bij Swifterbant (Fl.), *Paleo-aktueel* 21, 31-37.

Dybkjær, J.B., A. Baattrup-Pedersen, B. Kronvang & H. Thodsen 2011, Diversity and distribution of riparian plant communities in relation to stream size and eutrophication, *Journal of Environmental Quality* 41, 348-354.

Eggers, T. 1979, Werden und Wandel der Ackerunkraut-vegetation. In: O. Willmans & O. Tüxen (eds), *Werden und Vergehen von Pflanzengesellschaften*, Vaduz (J. Cramer), 503-527.

Ente, P.J. 1976, The geology of the northern part of Flevoland in relation to the human occupation in the Atlantic time (Swifterbant Contribution 2), *Helinium* 16, 15-35.

Gehasse, E.F. 1995, *Ecologische-archeologisch onderzoek van het Neolithicum en de Vroege Bronstijd in de Noordoostpolder met de nadruk op vindplaats P14*, Amsterdam (unpublished PhD dissertation).

Geuverink, J., D.C.M. Raemaekers & I. Devriendt 2009, *Op zoek naar archeologie bij Doug's duin. Kamperhoekweg, Swifterbant, Gemeente Dronten: Inventariserend veldonderzoek door middel van boringen*, Groningen (Grondsporen 4).

Grootjans, A.P., R. van Diggelen, H. Joosten & A.J.P. Smolders 2012, *Restoration of mires.* In: J. van Andel & J. Aronson (eds), *Restoration ecology: The new frontier,* 2nd edition, Oxford (Blackwell Publishing), 203-213.

Hamburg, T., A. Müller & B. Quadflieg (eds) 2013, *Mesolithisch Swifterbant*, Leiden and Amersfoort (Archol rapport 174/ADC rapport 3250).

Hammer, Ø., D.A.T. Harper & P.D. Ryan 2001, Past: Palaeontological statistics software package for education and data analysis, *Palaeontologia Electronica* 4.

Hennekens, S.M., N.A.C. Smits & J.H.J. Schaminée 2010, *SynBioSys Nederland versie 2*, Wageningen (Alterra).

Hillman, G. 1991, Phytosociology and ancient weed floras: Taking account of taphonomy and changes in cultivation methods. In: D.R. Harris & K.D. Thomas (eds), *Modelling ecological change: Perspectives from neoecology, palaeoecology and environmental archaeology,* London (University College London), 27-40.

Hogestijn, J.W.H. 1989, Palaeobotanical analysis of Monnickendam and the salination of the Zuiderzee. In: H.A. Heidinga & H.H. van Regteren Altena (eds), *Medemblik and Monnickendam: Aspects of medieval urbanization in northern Holland,* Amsterdam (Cingula 11), 115-124.

Huisman, D.J., A.G. Jongmans & D.C.M. Raemaekers 2009, Investigating Neolithic land use in Swifterbant (NL) using micromorphological techniques, *Catena* 78, 85-197.

Hullegie, A.G.J. 2009, *Swifterbant S4: Archeo-ichtyologisch onderzoek vlak 3 en 9,* Groningen (unpublished Bachelor's thesis).

Jansen, P. & W.H. Wachter 1930, Grassen langs de Zuiderzeekust, *Nederlandsch Kruidkundig Archief* 40, 231-257.

Joosten, H. & D. Clarke 2002, *The wise use of mires and peatlands*, Jyväskylä (International Mire Conservation Group and International Peat Society).

Knörzer, K.H. 1971, Urgeschichtlichen Unkräuter im Rheinland: Ein Beitrag zur Entstehungsgeschichte der Segetalgesellschaften, *Vegetatio* 23, 89-111.

Kreuz, A. & E. Schäfer 2011, Weed finds as indicators for the cultivation regime of the Early Neolithic Bandkeramik culture?, *Vegetation History and Archaeobotany* 20, 333-348.

Louwe Kooijmans, L.P. 1993, Wetland exploitation and upland relations of prehistoric communities in the Netherlands. In: J. Gardiner (ed.), *Flatlands & wetlands. Current themes in East Anglian Archaeology*, Norwich (East Anglian Archaeology 50), 71-116.

Louwe Kooijmans, L.P. 2005, Hunters become farmers: Early Neolithic B and Middle Neolithic A. In: L.P. Louwe Kooijmans, P.W. van den Broeke, H. Fokkens & A.L. van Gijn (eds), *The prehistory of the Netherlands*, Amsterdam (Amsterdam University Press), 249-271.

Maurer, A. 2011, *Een studie naar de oevervegetatie van de Swifterbantvindplaats S-25 (Oostelijk-Flevoland) (6700–3700 v. Chr.)*, Groningen (unpublished Master's thesis).

Mauquoi, D. & B. van Geel 2007, Mire and peat macros. In: S.A. Elias (ed.) *Encyclopedia of quaternary science*, Oxford (Elsevier), 2315-2336.

Meltzer, J. & V. Westhoff 1942, *Inleiding tot de plantensociologie*, 's Graveland (G.W. Breughel).

Nales, T. 2010, Archeologisch bureauonderzoek & inventariserend veldonderzoek, verkennende fase Project Rivierduingebied, Swifterbant, Gemeente Dronten, Noordwijk (Becker & Van de Graaf-rapport 951).

Neef, R., R.T.J. Cappers & R.M. Bekker 2012, *Digital atlas of economic plants in archaeology*, Groningen (Groningen Archaeological Studies 17).

Out, W.A. 2009, *Sowing the seed? Human impact and plant subsistence in Dutch wetlands during the Late Mesolithic and Early and Middle Neolithic (5500–3400 cal BC)*, Leiden (Archaeological Studies Leiden University 18).

Out, W.A. 2010, Firewood collection strategies at Dutch wetland sites in the process of Neolithisation, *The Holocene* 20 (2), 191-204.

Peeters, J.H.M. 2007, *Hoge Vaart-A27 in context: Towards a model of Mesolithic–Neolithic land use dynamics as a framework for archaeological heritage management*, Amersfoort (Rijksdienst voor Archeologie, Cultuurlandschap en Monumenten).

Peeters, H., W.-J. Hogestijn & T. Holleman 2004, *De Swifterbantcultuur: Een nieuwe kijk op de aanloop naar de voedselproductie*, Abcoude (Uniepers).

Prummel, W., D.C.M. Raemaekers, S.M. Beckerman, J.N. Bottema-Mac Gillavry, R.T.J. Cappers & P. Cleveringa 2009, Terug naar Swifterbant: Een kleinschalige opgraving te Swifterbant-S2 (Gemeente Dronten), *Archeologie* 13, 17-45.

Raemaekers, D.C.M 1999, The articulation of a 'New Neolithic'. The meaning of the Swifterbant Culture for the process of neolithisation in the western part of the North European Plain (4900–3400 BC), Leiden (Archaeological Studies Leiden University 3).

Raemaekers, D.C.M. 2005, Het Vroeg- en Midden-Neolithicum in Noord-, Midden en West-Nederland. In: J. Deeben, E. Drenth, M.-F. van Oorsouw & L. Verhart (eds), *De steentijd van Nederland*, Zutphen (Archeologie 11–12), 261-282.

Raemaekers, D.C.M. (ed.), in prep.a, *The excavation of the Neolithic river bank site Swifterbant S4*, Groningen (Groningen Archaeological Studies).

Raemaekers, D.C.M. (ed.), in prep.b, *Standaardrapportage Swifterbant S25*, Groningen (Groningen Archaeological Studies).

Raemaekers, D.C.M., I. Devriendt, R.T.J. Cappers & W. Prummel 2005, Het Nieuwe Swifterbant Project: Nieuw onderzoek aan de Mesolithische en Neolithische vindplaatsen nabij Swifterbant (provincie Flevoland, Nederland), *Notae Praehistorica* 25, 119-127.

Reimer, P.J., M.G.L. Baillie, E. Bard, A. Bayliss, J.W. Beck, P.G. Blackwell, C. Bronk Ramsey, C.E. Buck, G.S. Burr, R.L. Edwards, M. Friedrich, P.M. Grootes, T.P. Guilderson, T.P. Hajdas, T.J. Heaton, A.G. Hogg, K.A. Hughen, K.F. Kaiser, B. Kromer, F.G. McCormac, S.W. Manning, R.W. Reimer, D.A. Richards, J.R. Southon, S. Talamo, C.S.M. Turney, J. van der Plicht & C.E. Weyhenmeyer 2009, IntCal09 and Marine09 radiocarbon age calibration curves, 0–50,000 years cal BP., *Radiocarbon* 51(4), 1111-1150.

Rintjema, S., T.H.L. Claassen, H. Hettema, U.G. Hosper & E. Wymenga 2001, *De Alde Feanen: Schets van een laagveenmoeras*, Leeuwarden (It Fryske Gea).

Rodwell, J.S. 1998, *British plant communities volume 1 – Woodlands and scrub*, Cambridge (Cambridge University Press).

Schaminée, J.H.J., A.H.F. Stortelder & E.J. Weeda 1996, *De vegetatie van Nederland. Volume 3,* Uppsala (Opulus).

Schaminée, J.H.J., A.H.F. Stortelder & V. Westhoff 1995a, *De vegetatie van Nederland. Volume 1,* Uppsala (Opulus).

Schaminée, J.H.J., E.J. Weeda & V. Westhoff 1995b, *De vegetatie van Nederland. Volume 2,* Uppsala (Opulus).

Schaminée, J.H.J., E.J. Weeda & V. Westhoff 1998, *De vegetatie van Nederland. Volume 4,* Uppsala (Opulus).

Schaminée, J.H.J., K. Sýkora, N. Smits & M. Horsthuis 2010, *Veldgids plantengemeenschappen van Nederland,* Zeist (KNNV).

Schepers, M. & I. Woltinge in prep., Landscape development and stratigraphy. In: D.C.M. Raemaekers (ed.) *Swifterbant S4: The excavation of the Neolithic river bank site Swifterbant S4* (Groningen Archaeological Studies), Groningen.

Schepers, M. & N. Bottema-Mac Gillavry in prep., Archaeobotanical remains. In: D.C.M. Raemaekers (ed.) *The excavation of the Neolithic river bank site Swifterbant S4.* (Groningen Archaeological Studies), Groningen.

Schepers, M., J.F. Scheepens, R.T.J. Cappers, O.F.R. van Tongeren & R. Bekker 2013, An objective method based on assemblages of plant macro-remains to reconstruct past natural vegetation: A case study at Swifterbant, the Netherlands, *Vegetation History and Archaeobotany* 22, 243-255.

Shepherd, K.A., T.D. Macfarlane & T.D. Colmer 2005, Morphology, anatomy and histochemistry of Salicornioideae (Chenopodiaceae) fruits and seeds, *Annals of Botany* 95, 917-933.

Smits, L. & H. van der Plicht 2009, Mesolithic and Neolithic human remains in the Netherlands: Physical anthropological and stable isotope investigations, *Journal of Archaeology in the Low Countries* 1, 55-85.

Stortelder, A.H.F., J.H.J. Schaminée, P.W.F.M. Hommel 1999, *De vegetatie van Nederland. Volume 5,* Uppsala (Opulus).

Van Asselen, S. & I. Bos 2009, Veen in de Rijn-Maas delta: Groei, afbraak en compactie, *Grondboor & hamer* 3–4, 54-61.

Van Beurden, L. 2008, *Vegetatie en ontwikkelingen in het rivierengebied in de Bronstijd,* Zaandam (BIAXiaal 331).

Van der Laan, J. 2011, *'Uit het goede hout gesneden': Een materiaalonderzoek aan het nat-geconserveerde hout van Swifterbant vindplaats S25,* Groningen (unpublished Bachelor's thesis).

Van der Linden, M. 2008, *Mesolithische en Vroeg-Neolithische bewoningssporen bij Swifterbant. Pollenonderzoek op vindplaats 5 in het kader van de aanleg van de N23 tussen Lelystad en Dronten.* Zaandam (BIAXiaal 365).

Van der Meijden, R. 2005, *Heukels' flora van Nederland,* Groningen (Wolters-Noordhoff).

Van der Veen, Y. 2008, *Palynologisch onderzoek aan de akker van Swifterbant S4,* Groningen (unpublished student report).

Van der Waals, J.D., H.T. Waterbolk 1976, Excavations at Swifterbant – Discovery, progress, aims and methods, *Helinium* 16, 4-14.

Van der Waals, J.D. 1977, Excavations at the natural levee sites S2, S3/5 and S4, *Helinium* 17, 3-27.

Van Geel, B. 1978, A palaeoecological study of Holocene peat bog sections in Germany and the Netherlands, based on the analysis of pollen, spores and macro- and microscopic remains of fungi, algae, cormophytes and animals, *Review of Palaeobotany and Palynology* 25, 1-20.

Van Goor, A.C.J. 1922, De halophyten en submerse phanerogamen. In: H.C. Redeke (ed.) *Flora en fauna der Zuiderzee: Monografie van een brakwatergebied,* Helder (Nederlandsche Dierkundige Vereeniging), 47-53.

Van Haaster, H. & O. Brinkkemper 1995, RADAR, a relational archaeobotanical database for advanced research, *Vegetation History and Archaeobotany* 4, 117-125.

Van Rooij, J.A.G. 2007, *Botanische resten uit Swifterbant S4,* Groningen (unpublished student report).

Van Zeist, W. & R.M. Palfenier-Vegter 1981, Seeds and fruits from the Swifterbant S3 site (Final reports on Swifterbant IV). *Palaeohistoria* 23, 105-168.

Vandenbussche, V., F. T'Jollyn, A. Zwaenepoel, E. van den Balck & M. Hoffman 2002, *Systematiek van natuur-typen voor Vlaanderen: 12. Slik en Schor,* Brussel (Instituut voor Natuurbehoud).

Visscher, J. 1949, *Veenvorming,* Gorinchem (J. Noorduijn en zoon).

Vissinga, A. 2007, *Swifterbant (Fl.) – Noordertocht H37: Een inventariserend archeologisch veldonderzoek,* Zuidhorn (Steekproefrapport 2007-05/07).

Vos, P.C. & H. de Wolf 1988, Methodological aspects of palaeoecological research in coastal areas of the Netherlands, *Geologie en Mijnbouw* 67, 31-40.

Vos, P. & P. Kiden 2005, De landschapsvorming tijdens de steentijd. In: J. Deeben, E. Drenth, M.-F. van Oorsouw & L. Verhart (eds), *De steentijd van Nederland*, Zutphen (Archeologie 11–12), 7-37.

Weeda, E.J., R. Westra, C. Westra, T. Westra 2003, *Nederlandse oecologische flora: Wilde planten en hun relaties* 5. Amsterdam (KNNV).

Weijdema, F., O. Brinkkemper, H. Peeters & B. van Geel 2011, Early Neolithic human impact on the vegetation in a wetland environment in the Noordoostpolder, central Netherlands, *Journal of Archaeology in the Low Countries* 3, 31-46.

Wetzel, R.G. 2001, *Limnology: Lake and river ecosystems*. San Diego (Academic Press).

Wheeler, B.D. & M.C.F. Proctor 2000, Ecological gradients, subdivisions and terminology of north-west European mires, *Journal of Ecology* 88, 187-203.

Woldring, H. & E. Kleine 2008, Pollenanalyse van de mestlagen: Aanwijzingen voor intensivering van de begrazing in de Romeinse tijd. In: J. Dijkstra & J.A.W. Nicolay (eds), *Een terp op de schop: Archeologisch onderzoek op het Oldehoofsterkerkhof te Leeuwarden*, Amersfoort (ADC Monografie 3), 259-267.

Zeiler, J.T. 1986, Swifterbant: Dwelling place for a season or throughout the whole year? An archaeozoological contribution. In: H. Fokkens, P. Banga & M. Bierma (eds), *Op zoek naar mens en materiële cultuur*, Groningen (Groningen University), 85-95.

Zeiler, J.T. 1997, *Hunting, fowling and stock-breeding at Neolithic sites in the western and central Netherlands*, Groningen (Archaeobone).

Appendices

Results of the macrofossil analysis of the top of the peat in the back swamps

Taxon	Plant part	Coring number					
		202	22	197	94	13	29
Not identified	wood	x					
Lophopus chrystallinus	statoblast	x					
Daphnia	ephippium	x	x				
cf. *Cyprinidae*	tooth		x				
Foraminifera	lining		x				
Humulus lupulus	fruit		x				
Typha	fruit		x				
Lythrum salicaria	seed		x		x		
Atriplex patula/prostrata	fruit			x			
Chara	oospore		x		x		
Cladium mariscus	fruit with exocarp			xx			
Sphagnum	leaf	x	x	x	x	x	
Alnus	wood			x	x		
Carex pseudocyperus	utricle		x		xx	x	
Cladium mariscus	fruit		x	x	x	x	x
Schoenoplectus tabernaemontani	fruit		x				x
Comarum palustre	fruit				x		
Berula/Cicuta/Apium	fruit				x		
Alnus glutinosa	fruit		x		x		x
Oenanthe aquatica	fruit				x		
Betula	fruit					x	
Callitriche	fruit					x	
Apiaceae	fruit					x	
Alnus glutinosa	cone					x	
Urtica dioica	fruit					x	
Alisma	fruit					x	x
Hydrocotyle vulgaris	fruit						x
Lycopus europaeus	fruit						x
Mentha aquatica/arvensis	fruit						x
Ranunculus subg. *batrachium*	fruit						x
Bolboschoenus maritimus	fruit						x
Not identified	charred wood						x

Appendix table 1 macro remains from the top of the peat in the back swamps. The data presented are arranged by seriation, using PAST (Hammer et al. *2001). x=present; xx=many.*

coring number	top	bottom	volume
13	195	215	140
22	210	230	140
94	135	160	175
197	160	180	140
202	200	220	140
29	165	180	105

Appendix table 2 Volume and depth below surface of the samples. At all locations, we sampled the top of the intact peat. The presented volume is based on the not completely correct assumption that a perfect round cylinder was sampled out of a 3cm soil auger ($\pi r^2 = \sim 7$, 7*height=volume).

Coring number	X	Y	Z
13	171994	509754	-4.5
22	171502	509659	-4.5
94	171418	509744	-4.7
197	171614	509940	-4.7
202	171808	509991	-4.6
29	171773	509731	-4.6

Appendix table 3 Location of the corings (Dutch grid). The location of the corings is extracted from Nales 2010. The reader is referred to this report for a description of the lithology. We relocated the corings with a handheld Garmin Etrex GPS. This device is less accurate than the original measurements, which may explain some of the difference in depth of the peat layer.