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WETLAND FARMING
IN THE AREA TO THE SOUTH OF THE MEUSE ESTUARY
DURING THE IRON AGE AND ROMAN PERIOD.
AN ENVIRONMENTAL AND PALAEO-ECONOMIC RECONSTRUCTION.

contents

1 Introduction

1.1 The problem

The area studied comprises the islands Voorne and Putten, situated in the southern part of the Dutch province of Zuid-Holland. These islands are separated by a small stream, the Bernisse (*fig. 1*). The two islands will henceforth be referred to as "Voorne-Putten". At present, Voorne-Putten is almost completely covered by clayey sediments deposited during medieval times. During the Iron Age and the Roman Period, the landscape was completely different from what we see today.

Archaeological excavations of settlement sites on Voorne-Putten dating from the Early and Middle Iron Age have been carried out by the B.O.O.R. (*Bureau voor Oudheidkundig Onderzoek van Gemeentewerken Rotterdam*; the Office for Archaeological Research of the municipality of Rotterdam) and the R.O.B. (*Rijksdienst voor Oudheidkundig Bodemonderzoek*; the State Service for Archaeology). The excavations of Early and Middle Iron Age[1] sites (ca. 750-200 BC[2]) have demonstrated that these settlements were founded on a peaty subsoil (cf. Van Trierum 1986; Van Trierum *et al.* 1988). During the Late Iron Age (200-25 BC) and Roman Period (on Voorne-Putten ca. 50-270 AD), most settlements were built on clay, but peat still constituted a predominant element in the landscape. Environments completely different from the present one lie buried below the present clay cover (see further *1.2*). Details concerning the archaeological investigations on Voorne-Putten have been included in paragraph *1.3*.

The presence of late prehistoric and protohistoric settlements in peaty environments is noteworthy. It is generally assumed that the agricultural system practised during the Iron Age was based on local subsistence, which implies that the arable and pastoral products were grown as well as consumed locally (e.g. Roymans 1983). The agricultural possibilities for these former societies in the peaty environment to the south of the Meuse estuary is one of the main questions to be addressed in the present study.

The addition of Voorne-Putten to the Roman Empire may have instigated or even imposed dramatic changes in the economic situation. According to Groenman-van Waateringe (1989), the economy of the native inhabitants was modified in phases. During the occupation, food for the Roman army had to be supplied from the hinterland. A period of integration followed, in which the production was changed qualitatively and quantitatively to meet the army's demands. The presence of the Roman army had necessitated a production by the autochthonous inhabitants above their own needs. These developments resemble those during the advent of colonialism, when the occupants also tried to pass on the costs to the native inhabitants. After a more or less consolidated period, destabilisation of the modified economy resulted from a less intense control of the Roman *Limes* and from the final withdrawal of the army.

The second main question was, therefore, whether the arrival of the Roman occupants, and the inclusion of Voorne-Putten in the Roman Empire, had any bearing upon the economic structure of the autochthonous society. This effect may have been qualitative, i.e. expressed in the species of plants cultivated and animals bred, as well as quantitative, i.e. expressed in the amounts or ratios produced.

The main approach to answer these questions is through the analysis of pollen and botanical macroremains from deposits in or related to former settlements. The excavations by the B.O.O.R. and the R.O.B. provided the solid base on which the present study could be founded. Grateful use was furthermore made of the results of archaeozoological research conducted by Dr. W. Prummel and Drs. P.J. van Mensch.

1.2 Geology

The geological development of the western part of the Netherlands during the Holocene is strongly determined by the sea. Melting of the ice caps, formed during the last glaciation, caused a rise of the sea level. This eustatic rise, relative to the earth's centre, was rapid until largest part of the ice caps had melted. Between ca. 4000 BC and 2000 BC, the relative rise of the sea level became much slower. From then on, coastal barriers were formed that could more or less withstand the rising sea level. The oldest still preserved coastal barriers were formed in the early Subboreal period (ca. 3500 BC). Subsequently, new coastal barriers were deposited to the west of the older ones and the coast shifted
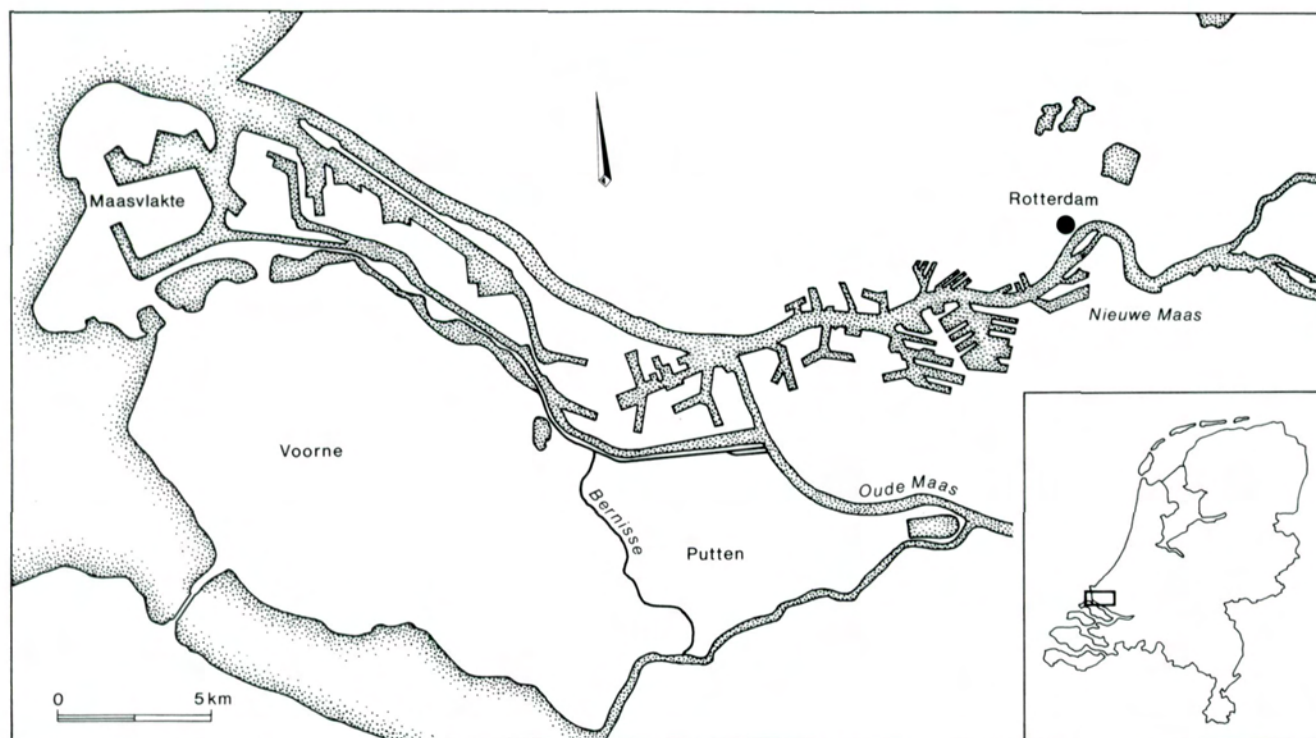
Fig. 1 *Location of Voorne-Putten in the Netherlands.*

in a westward direction. During Subboreal and early Sub-
atlantic times, coastal dunes that remained uneroded could
develop. These dunes were mainly formed before the start of
the Christian era and are called the Older Dunes.

The westward movements of the coast line continued until
ca. 1000 BC. At that time, a more or less closed coast line
had developed, only intersected by some estuarine inlets,
where rivers discharged into the sea. From south to north,
the Scheldt, the Meuse, the Rhine and the Oer-IJ formed the
largest estuaria in the Dutch west coast. Voorne and Putten
were not separate islands, but instead part of a larger area
between the estuaries of the Meuse and the Scheldt (see
fig. 2).

Behind the coastal dunes, the mineral particles that were
transported by rivers were deposited at times of high water
levels, when the river overflowed its banks. The heavier,
sandy particles are deposited immediately on the banks,
clayey sediments are deposited in the hinterland further
away from the river bed. Due to stagnations in the drainage,
peat formation took place locally on these clayey sediments.
This peat is the so-called Holland peat. In the course of the
Subboreal, the frequency of inundation of the hinterland
due to marine and riverine influences decreased and the area
covered with peat expanded. Peat growth did not occur
close to the rivers, but instead levees, consisting of clastic
sediments were to be found.

Although the rise of the sea level slowed down after 4000

BC, there were periods in which the sea temporarily showed
an enhanced activity. These phases of increased marine
influence are called transgression phases. Transgression
phases are followed by periods of decreased marine
influence, the so-called regression phases. The cyclic
alternation of transgressions and regressions has been
described by Pons as follows (see Louwe Kooijmans 1974).

"The transgression phase begins with erosion of the older sedi-
mentation and/or peat areas and the forming of a network of creek
systems. The next phase is that of marine sedimentation, followed
by the gradually silting-up of the creeks. One of the results of the
vanishing of the creeks is the blocking of the drainage of the
sedimentation area. Finally, in the regression phase peat growing
spreads again over the whole area".

Louwe Kooijmans (1974: 59) stated that theoretically only
the erosion phase constitutes the actual landward shift of
the coast line (=transgression), but it is common practice to
include the period of deposition of mineral sediments in the
transgression phase.

The first transgression phases, in the Atlantic period,
occurred during a period of a relatively rapidly rising sea
level. As a result, the corresponding Calais I-III deposits
cover large parts of the western Netherlands. In the Subbo-
real and Subatlantic periods, *the sea level rose more slowly
and coastal barriers formed a strong defence of the hinter-
land. From then on, the sedimentation of clay during trans-*

Fig. 2 Palaeo-geographical reconstruction of the western Netherlands around 2400 BP,
scale 1:1,000,000 (after Zagwijn 1986; drawing W.J. Kuijper). Legend: A = water, B = coastal
dunes and breaches, C = clayey sediments (marine or riverine), D = pleistocene soils, E =
raised bogs, F = drained raised bogs, G = fen peats.

Fig. 3 columns:

Archaeological periods	Conventional ¹⁴C age in years BP	Dendrochronological age (calibrated radiocarbon age in solar years)	Periods of transgression C=Calais, D=Dunkirk / periods of regression (Zagwijn & Van Staalduinen 1975)
Recent	0	1950	
			D III
Middle Ages	1000	1000	
			D II
Roman	2000	0	
			D I
Iron Age			
		1000	
Bronze Age	3000		D 0
		2000	
Late (Neolithic)	4000		
		3000	C IV
Middle (Neolithic)	5000		C III
		4000	
Early (Neolithic)			C II
	6000	5000	
	7000		C I
Mesolithic	8000		
	9000		

(The column between Roman/Iron Age is labelled BC | AD)

Fig. 3 Datings of transgression phases in the western part of the Netherlands (after Berendsen/ Zagwijn 1984).

gression phases (Calais IV and Dunkirk deposits) was more or less restricted to the regions behind the inlets of the rivers mentioned earlier. The transgression phases after 2000 BC are called Dunkirk transgressions. ¹⁴C dates of the peaty layers below and above the mineral sediments related to transgression phases demonstrated that these Calais IV and Dunkirk deposits occurred more or less simultaneously in large parts of the western Netherlands (see *fig. 3*). Variations, mainly due to local conditions, occur as well.

The causes of the later transgression phases have been the subject of many discussions. However, to deal with this subject extensively is beyond the scope of this publication. The reader is referred to the following publications: Jelgersma *et al.* 1970; Behre *et al.* 1979; Roeleveld 1980; Van der Plassche 1982a, 1982b; Zagwijn 1986.

De Jong (1982) pointed out that the lithostratigraphic units Calais I-IV and Dunkirk 0-III indicate an event, not a time unit. They are not meant to represent chronostratigraphic units (see also the discussions in Roeleveld 1974: 51-53; Vos 1983: 8-9). All the same, the defined time span covered by these different prehistoric transgression phases in a restricted area is of great value to chronology and the application is so useful and widespread that it is followed here. The defined time intervals in which the different transgression phases took place, often allows approximate dating of settlement traces on the basis of their stratigraphic position. Unfortunately, however, the standard stratigraphy, as shown in figure 3, is rarely completely represented in one single stratigraphic column. This is due to the variable extension of the clay deposition representing the different transgression phases.

1.2.1 THE GEOLOGICAL DEVELOPMENT OF VOORNE-PUTTEN DURING THE IRON AGE AND THE ROMAN PERIOD

The geological development of Voorne-Putten during the Iron Age and the Roman Period, as part of a region situated directly to the south of the Meuse estuary, was greatly influenced by the Dunkirk transgression phases. The distribution of these Dunkirk deposits and the peat formed during late Subboreal and Subatlantic regression phases (the so-called Holland peat) on Voorne-Putten have been mapped in the framework of the geological map of the Netherlands, sheet 37 West (Van Staalduinen 1979). The eastern part of Putten was not included on this map. The corresponding sheet of the series of geological maps, 37 East, has not yet been published, but it is being prepared by De Groot. The geology of this area, with marine as well as riverine deposits, is thus complex that a distribution map of Holland peat will not be included in the geological map 37 East (Drs. Th. de Groot *pers. comm.*). The southernmost part of Voorne is absent on both 37 W and 43 W maps and a publication in the near future is not envisaged (Drs. L. van der Valk *pers. comm.*).
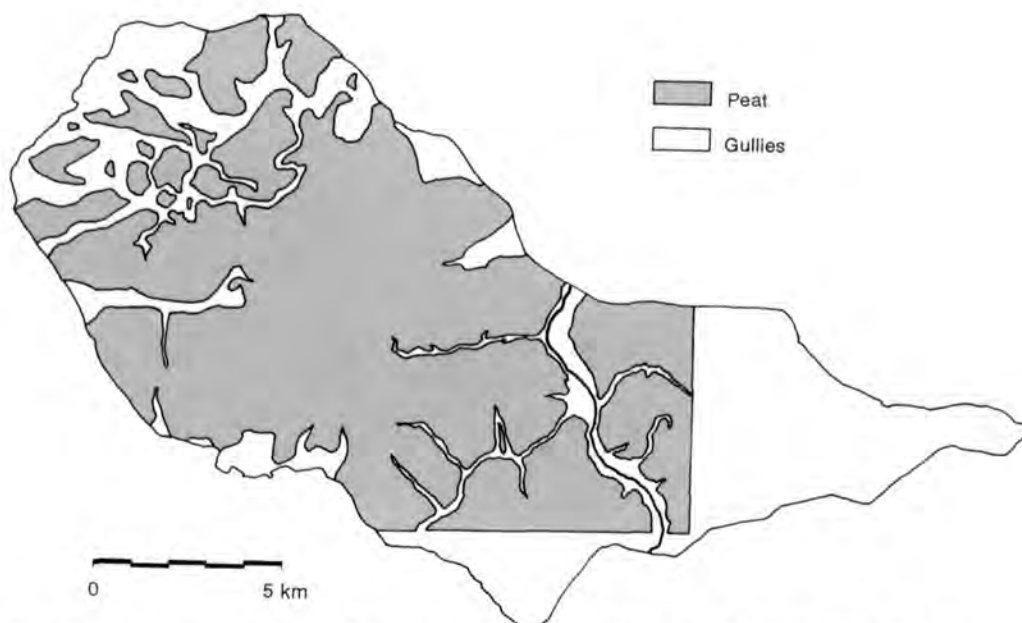
Fig. 4 Palaeo-geography of Voorne-Putten, ca. 2400 BP, scale 1:2000 (after Van Staalduinen 1979).
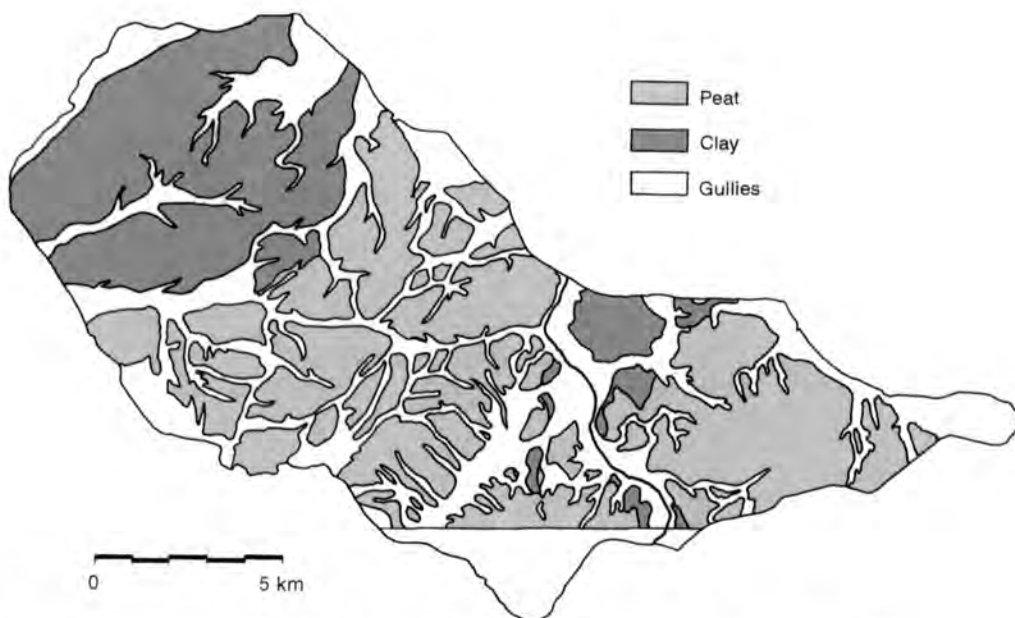
Fig. 5 Palaeo-geography of Voorne-Putten, ca. 2000 BP, scale 1:2000 (after Bloemers 1978).

During the Early Iron Age, between 750 and 500 BC, Voorne-Putten was mainly covered with Holland peat (Van Staalduinen 1979; see *fig. 4*). The predominance of peat still existed during the Middle Iron Age. However, the creek systems formed at the onset of the Dunkirk I transgression phase, around 400 BC, drained the peat over a large area. According to Zagwijn (1986), peat growth on Voorne-Putten only continued in a raised bog near Heenvliet, where peat growth persisted into the Roman Period.

The peaty sediments reach the present-day coast line. Nowadays, they are covered there by the Younger Dunes that were formed from the 12th century AD onwards. The Older Dunes, not indicated in figure 4, were situated more to the west, beyond the present coast line. They were eroded during medieval times, when the coast line of Voorne-Putten shifted eastwards during the Dunkirk III transgression phases. Further to the north, the Older Dunes have not disappeared, while in the extreme south of the Dutch coast there are also some remnants left. The orientation of these Older Dunes led Zagwijn to a reconstruction of their location on Voorne-Putten as represented in figure 2. This map shows the situation during the Dunkirk I sedimentation phase. As Zagwijn's palaeogeographical maps cover the entire Dutch territory, they do not provide the detail preferably wanted for this study.

The situation during the Late Iron Age and the Roman Period is markedly different from the conditions during the Early and Middle Iron Age as described above. The Dunkirk I transgression phase had resulted in the deposition of clayey sediments, which covered part of the peat present on Voorne-Putten. A palaeogeographical map for this period has been published by Bloemers (1978). It includes the areas of the geological maps 37 West and East, but the southernmost part of Voorne-Putten is again absent (see *fig. 5*). Zagwijn's palaeogeographical reconstruction for this period is shown in figure 6.

The Bernisse, separating Voorne and Putten, is supposed to have originated during the Dunkirk I transgression phase (Zagwijn 1986: 40). The Bernisse is assumed to have been a branch of the Scheldt. The increased marine influence during the Dunkirk I transgression phase considerably widened the Meuse estuary and formed a funnel-shaped inlet. Tacitus (Annales II) referred to this inlet as *immensum os* (immeasurable mouth). The same estuary is mentioned as *Helinium* by Plinius (Nat. Hist. IV). On the basis of toponyms and classical references, Hallewas and Van Regteren Altena (1980) pointed out that until medieval times the Meuse was the major factor in the formation of this estuary. The discharge by the Scheldt through the *Helinium*, via the Bernisse, is thought to have been of minor importance.

The extensive system of gullies indicated in figure 5 is partly filled with sediments originating from one of the medieval Dunkirk III transgression phases. However, as

Van Trierum (*in press*) observed, the Roman settlement sites in the area of Nieuwenhoorn and Nieuw Helvoet are seemingly situated along these much younger Dunkirk III creeks. This is an indication that these creeks had their precursors during the Roman Period. These earlier creeks must therefore be of Dunkirk I age.

The formation of the extensive systems of creeks and gullies during the Dunkirk I transgression phase had important implications for the suitability of the peaty area for habitation. These gullies caused a natural drainage of the peat. This will have shaped an environment which was perceived as inhabitable by Iron Age man. Modderman (1952) was the first to postulate this mechanism for an Early Iron Age peat settlement in the Escamppolder just north of the *Helinium*. Hallewas and Van Regteren Altena (1979: 96) assumed the same mechanism could allow habitation of the peat area in the whole Meuse estuary during the Iron Age. The transgression of the sea was not yet at its maximum during this phase of drainage. During periods of maximum marine influence, sedimentation of Dunkirk I deposits occurred on a large scale on Voorne-Putten. The environmental conditions related to this sedimentation thus prevented habitation. Habitation in the peaty environment thus is at first facilitated by the Dunkirk I transgression phase and subsequently habitation became impossible during the maximum inundation. One can debate the question in how far environmental conditions can influence human behaviour. In this publication, it is assumed that the natural conditions do set limits, and that an area with actively growing peat must be considered uninhabitable. For the Iron Age on Voorne-Putten, this hypothesis is supported by the absence of archaeological finds in areas with peat actively growing during the Iron Age (see *1.3*). The absence of habitation traces during maximum inundation by the Dunkirk I transgression phase also illustrates the influence of natural conditions. However, as Van Heeringen (1992: 306) stated,

"the reverse does not always apply, since it is quite possible that [potentially inhabitable] tidal deposits with no occupation remains were not colonized for some other reason".

The raising of dwelling mounds is an example of keeping an area suitable for habitation, but the influence of natural conditions upon human behaviour is evident.

Louwe Kooijmans (*in press*) suggested several other reasons that may also be of relevance to explain the inhabitation of wetlands during the Iron Age. He observed that the shift from a rigid, cattle-dominated mixed farming economy in the Bronze Age towards a more flexible type of mixed farming with a greater diversity in livestock rearing in the Iron Age was one of the factors allowing for the inhabitation of the peaty areas in the Dutch coastal region. Besides, the development of an exchange network during the
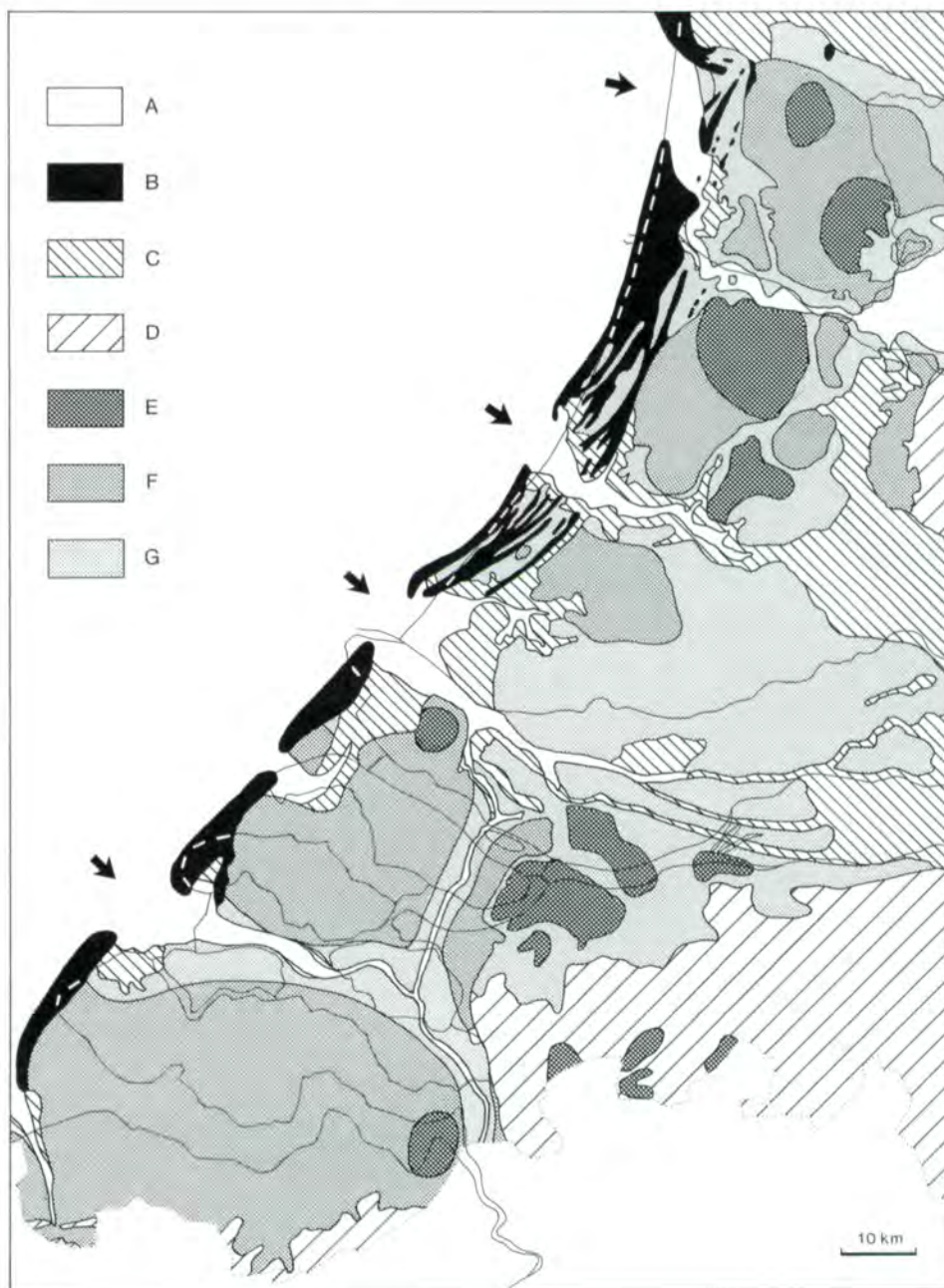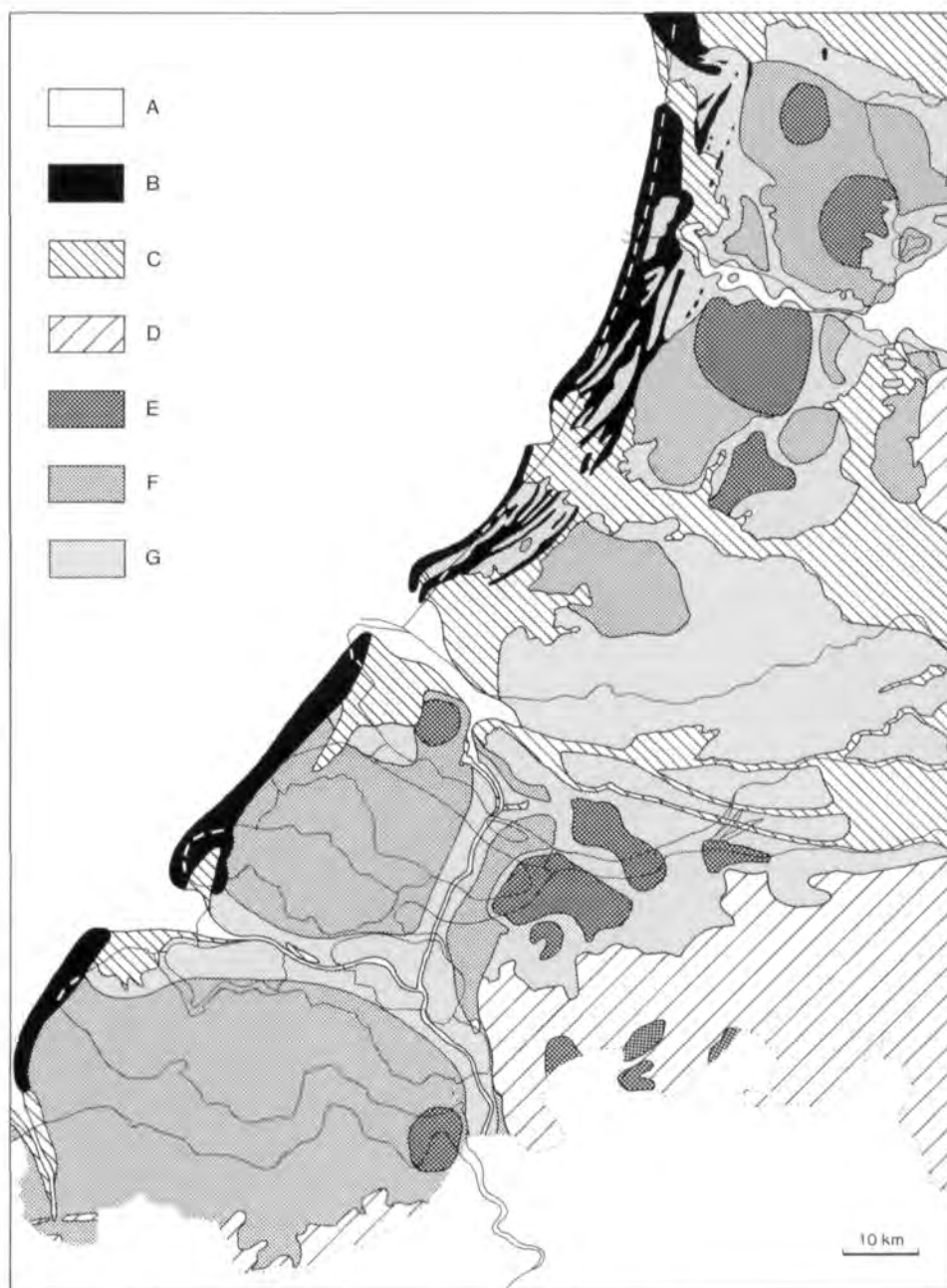
Fig. 6 Palaeo-geographical reconstruction of the western Netherlands around 2000 BP, scale 1:1,000,000 (after Zagwijn 1986; drawing W.J. Kuijper). Legend: A = water, B = coastal dunes and breaches, C = clayey sediments (marine or riverine), D = pleistocene soils, E = raised bogs, F = drained raised bogs, G = fen peats.
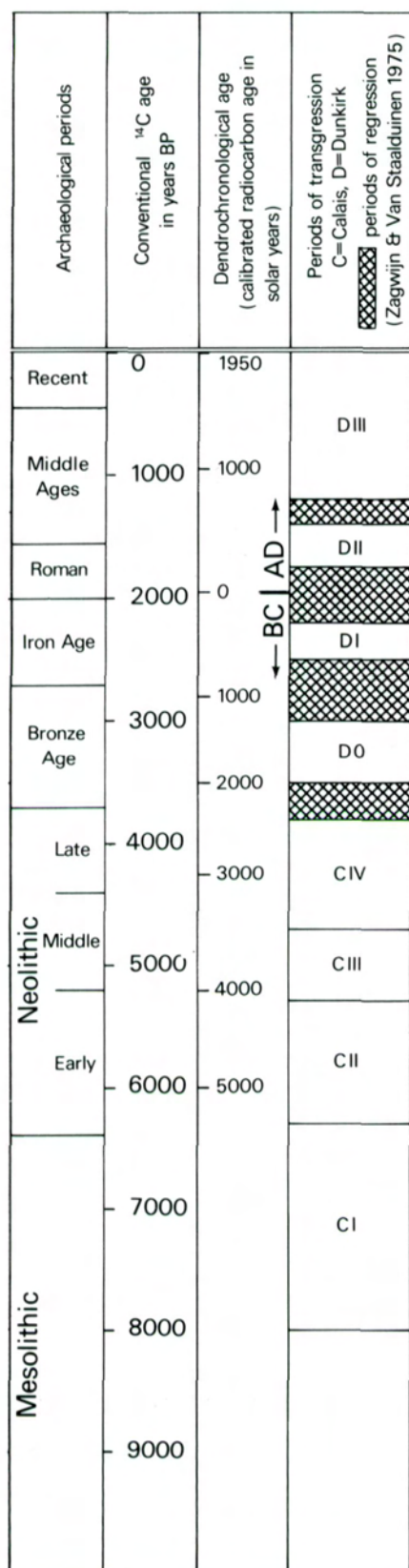
Iron Age may, according to him, also have facilitated inhabitation of areas less favourable for arable farming.

On top of the Dunkirk I sediments, a renewal of peat growth occurred locally, and this peat is referred to as "Roman peat" by Van Staalduinen (1979). The distribution of this "Roman peat", *sensu* Van Staalduinen, has been indicated in figure 7.

1.3   Archaeology.
The archaeological record of Voorne-Putten is largely based upon surveys and excavations performed by the B.O.O.R. The R.O.B. also conducted several excavations on Voorne-Putten. Van Trierum *et al.* (1988) and Van Trierum (*in press*) discuss the state of research.

Before the deposition of Dunkirk sediments, the area was inhabited during Neolithic times on a relatively small scale. Near Hekelingen, inhabitants established themselves on a levee (Louwe Kooijmans 1986). This inhabitation is considered non-permanent (Van Gijn 1989: 132). Near Hellevoetsluis, a fragment of a Late Neolithic flint axe was found, while near Abbenbroek a complete specimen was discovered (Van Trierum *et al.* 1988). No Bronze Age habitation is demonstrated on Voorne-Putten. Van Trierum *et al.* point to the large scale peat growth during these times as an important reason for the lack of Bronze Age habitation. Besides, the subsistence strategy of Bronze Age man may have excluded inhabitation of peaty areas (Louwe Kooijmans *in press*). This picture changes dramatically with the onset of the Iron Age.

Early Iron Age habitation is only known from the area around the Bernisse (see Döbken *et al. in press* and *fig. 8a*). The peat growth stagnated locally in the beginning of the Subatlantic, thus allowing habitation which can be dated between 725 and 525 BC (Van Trierum 1986; Van Trierum *et al.* 1988). All the Early Iron Age settlements known are situated in a peaty environment and the remains are covered with peat as well. Renewed peat growth apparently impeded further habitation. On Voorne-Putten, there is no clear connection between the Early Iron Age habitation and a trans- or regression-phase of the sea.

The next phase of human settlement on Voorne-Putten (phase 2) belongs to the Middle Iron Age. This phase dates between 425 and 200 BC (Van Trierum 1986; Van Trierum *et al.* 1988). There is a hiatus between the Early and Middle Iron Age inhabitation. The Middle Iron Age settlements are located on top of the Holland peat and are mostly covered with clayey Dunkirk I deposits. Almost all the known settlements from this period are also located in the area around the Bernisse, two Middle Iron Age settlements are known from western Voorne (cf. Döbken *et al. in press*; see *fig. 8b*).

After the deposition of Dunkirk I sediments, a third phase of Iron Age habitation on Voorne-Putten took place in the Late Iron Age. This phase can be dated to c. 200-25 BC in

the area concerned. The Late Iron Age settlements do not only occur around the Bernisse, as their Early and Middle Iron Age precursors did; there is also a cluster of Late Iron Age settlements on western Voorne (see Döbken *et al. in press*; *fig. 8c*). According to Van Trierum (*in press*), the material culture of the Late Iron Age habitation is closely linked to that of the Middle Iron Age, which indicates a direct continuity, despite the separating barrier of Dunkirk I deposits. The discovery of these Late Iron Age sites disproves the assumptions of Hallewas and Van Regteren Altena (1979: 97) that the Dunkirk I sediments on Voorne-Putten were not colonized before the Roman Period.

In the northern Dutch coastal area, man defended settlements against the transgressive sea by raising dwelling mounds ("*terpen*") as early as the Middle Iron Age (Waterbolk 1979). On Voorne-Putten, however, no dwelling mounds were raised during the Iron Age. The only increase in height of the inhabited sites arose through the gradual accumulation of settlement waste.

The key position of the Dunkirk I sediments in the stratigraphy of Iron Age sites on Voorne-Putten is summarized by Van Trierum (1986), his schematic stratigraphy is given in figure 9. Van Trierum *et al.* (1988) showed a good correlation between the stratigraphic position of the sites and the pottery assemblages the sites produced. In phase 1, over 35% of the pottery is roughened, this percentages becomes less in phase 2 and nears zero in phase 3. Decoration shows the reverse trend, it increases from phase 1 to phase 2 and is most abundant in phase 3. In phase 1, the rim decoration is located on top of the rims, in phase 2 a few rims show a decoration on the outside, while in phase 3 the majority of the rims have a decoration on the outside.

A combination of stratigraphic and pottery data makes dating of a site possible. This is also the case when a site is only known from surveys and has not been excavated.

As in the Late Iron Age, habitation during the Roman Period is mainly on the Dunkirk I deposits. Apart from these settlements on clay, a few settlements on peat are also known from Voorne-Putten during the Roman Period. Both Voorne and Putten were inhabited during this period (see *fig. 8d*; Van Trierum *in press*). In view of the great differences in hand-made local pottery found on the Late Iron Age sites on the one hand and in Roman contexts on the other, Van Trierum (1986) and Van Trierum *et al.* (1988: 39-40) argued for a distinct discontinuity between the inhabitation during these periods. Van Heeringen (1992) shares this opinion. Apart from local hand-made pottery, the pottery assemblage from the Roman Period is characterized by the presence of imported wheel-turned ware. Van Trierum *et al.*, however, did not exclude the possibility that early Roman sites do not contain imported pottery, but also hand-made pottery would indicate the sites to belong to the Roman Period.
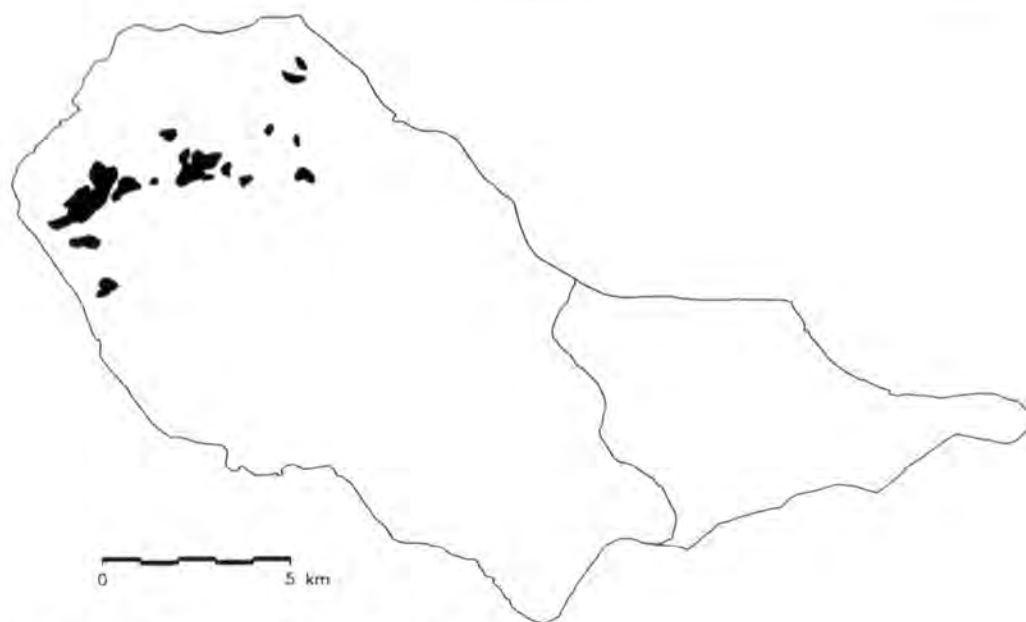
Fig. 7 Location of "Roman peat", scale 1:2000 (after Van Staalduinen 1979).

An important point is the representativity of the distribution of the sites on Voorne-Putten. The detection of sites depends upon several factors. Primarily, the accessibility of an area in pre- and protohistoric times directed where former habitation would be possible. Ideally, this factor directs the patterns on distribution maps of former habitation areas. However, other factors also influence the possibility of discovering an archaeological site in the area. One of these factors is the thickness of the medieval Dunkirk III deposits covering all traces of habitation of the Iron Age and Roman Period. The fact that these deposits are considerably thicker in the western than in the eastern part of the area, decreases the chance of retrieving pre-medieval sites on (western) Voorne. The Dunkirk III sediments not only covered traces of former habitation, the creeks belonging to this system also eroded previous deposits. Especially the banks of the Meuse were completely cleared away. Hallewas and Van Regteren Altena (1980: 193) mentioned that due to the Helinium shifting southeastwards in and after the 12th century, the northern parts of Voorne and Putten were eroded. Iron Age and Roman habitation on the levees of the Meuse can therefore not be demonstrated. Similarly, possible clastic sediments along the Bernisse dating from the Late Iron Age or the Roman Period also can no longer be observed. The widening of the existing water courses during Dunkirk III transgression(s) have eroded the earlier banks of the Bernisse too. Since the Older Dunes have also been destroyed during post-Roman trans-

gressions, only the wetland component of the former landscape is still preserved, and the same holds true for the location of archaeological sites.

A third factor affecting the distribution of sites is the intensity of archaeological research. Excavations have only been conducted on sites that were threatened by building activities, so-called rescue excavations. Furthermore, as a result of the cover of Dunkirk III sediments in the entire area, sites are mainly discovered when intersected by ditches. The presence of these ditches thus is of influence in the distribution of sites discovered through surveys.

One may cautiously conclude that the scarceness of Early and Middle Iron Age sites on western Voorne may be artificial, especially in view of their greater stratigraphic depth.

Based on the stratigraphic record, pottery and often on ^{14}C-datings, 120 sites dating to the periods discussed here are documented[3]. Some of the Roman sites are probably not *in situ*, as they contain redeposited pottery in Dunkirk III creeks.

From the Early Iron Age (phase 1), Van Trierum *et al.* (1988) and Van Trierum (*in press*) presented seven sites, of which five are certain settlements (see *fig. 8a* and *6.6.1*). Three of these sites have been excavated and yielded remains of farmsteads. According to Van Trierum (*in press*) these sites were inhabited for a relatively short time as the farms were hardly or not at all restored or rebuilt. The settlements are located on higher terrains in the peaty landscape, in the
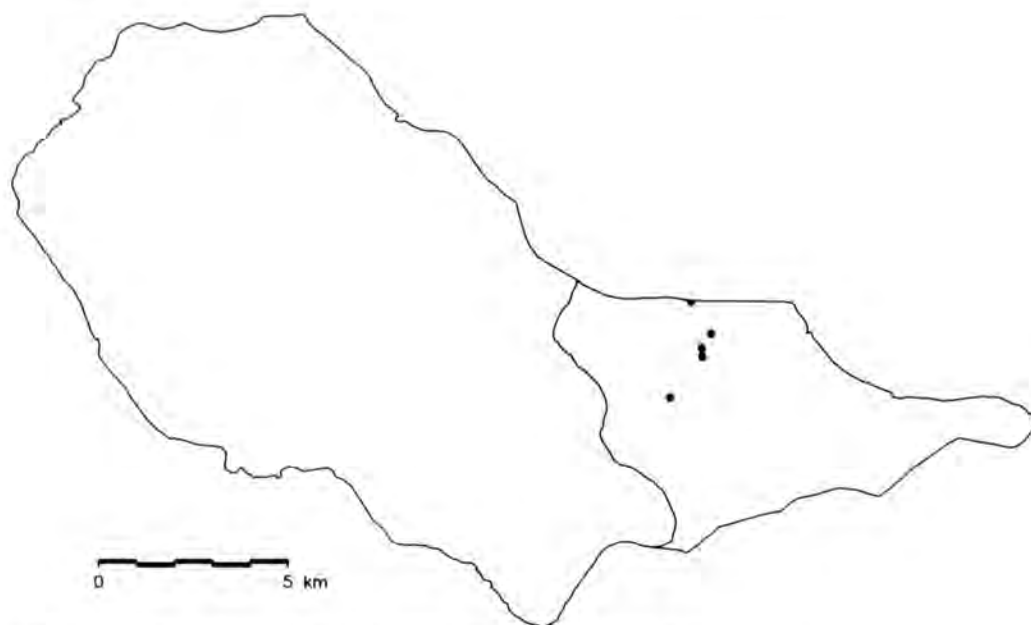
Fig. 8a Location of Early Iron Age settlements on Voorne-Putten (after Van Trierum in press).
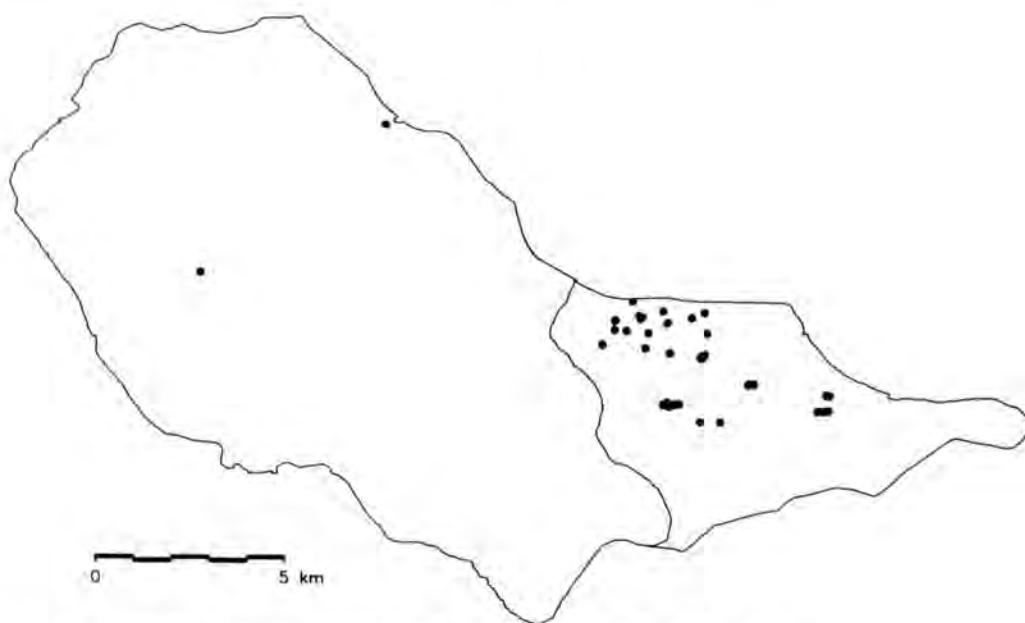
Fig. 8b Location of Middle Iron Age settlements on Voorne-Putten (after Van Trierum in press).

vicinity of small streams. The fact that the Early Iron Age settlements are covered by peat demonstrates that the drainage stagnated, probably precluding further habitation.

Figure 8b presents the distribution of the 35 settlements belonging to the Middle Iron Age (phase 2). According to Van Trierum, the Middle Iron Age sites were inhabited for a

longer period in view of the thick habitation layer that developed here. Furthermore, the excavated site of Spijke-nisse 17-34 showed an extension of part of the farm (see below). The Middle Iron Age sites are again located in the near vicinity of creeks.

Twenty-six settlements are known from the Late Iron Age
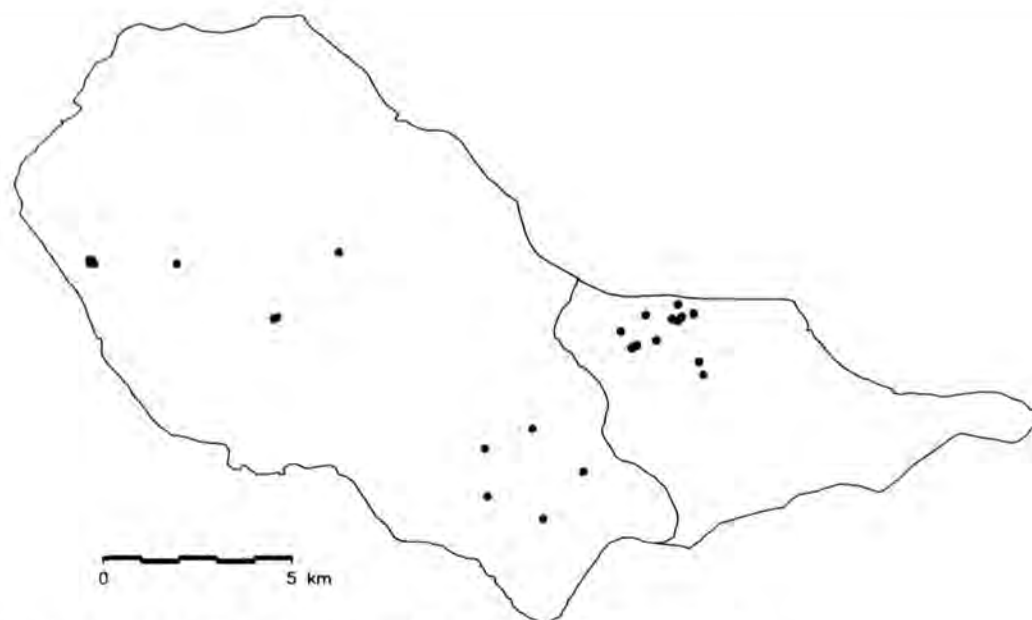
Fig. 8c Location of Late Iron Age settlements on Voorne-Putten (after Van Trierum in press).
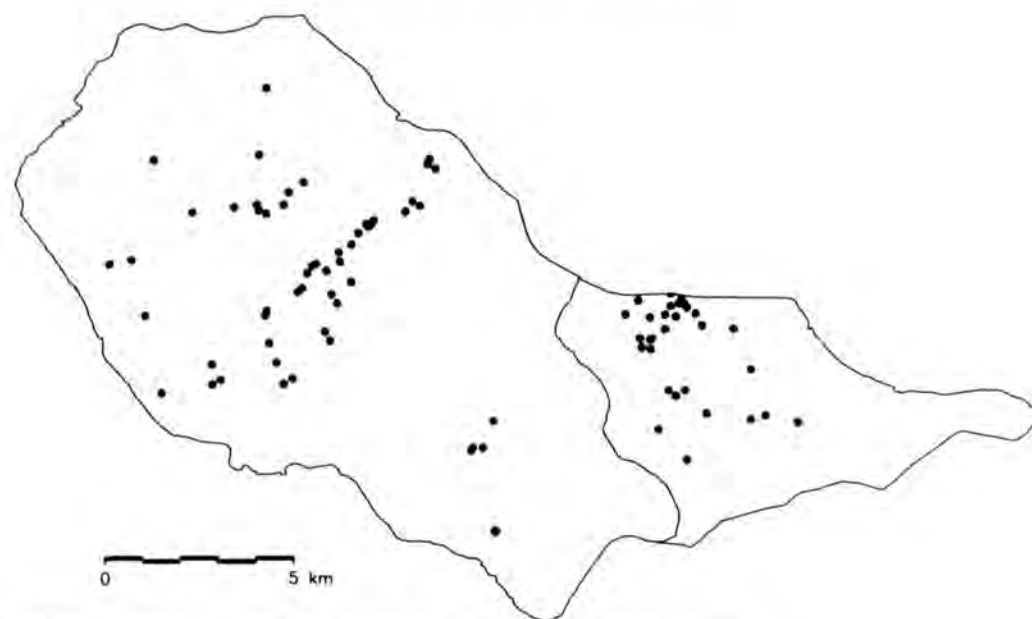
Fig. 8d Location of Roman Period settlements on Voorne-Putten (after Van Trierum in press).

(phase 3). According to Van Trierum, the Late Iron Age habitation has a greater distribution area than that of the Middle Iron Age, mainly in southwestern direction along the Bernisse. The sandier Dunkirk I sediments northeast of the Bernisse show the largest concentration of Late Iron Age habitation. A second cluster of Late Iron Age sites is located in the western part of Voorne (see *fig. 8c*). This area was very sparcely inhabited prior to the Late Iron Age (compare *fig. 8a; 8b*). The settlements in this western part of Voorne are located on peaty soils.

With the onset of the influence of the Roman Empire, drastic changes occurred in the Netherlands. After Caesar's

Fig. 9 The relation between stratigraphy and habitation on Voorne-Putten (after Van Trierum 1986).

1 = Early Iron Age
2 = Middle Iron Age
3 = Late Iron Age or Roman Period
4 = Middle or Late Iron Age or Roman Period
a = Dunkirk IiI
b = Roman Peat
c = Dunkirk I
d = Holland Peat
e = Dunkirk 0
f = Calais IV
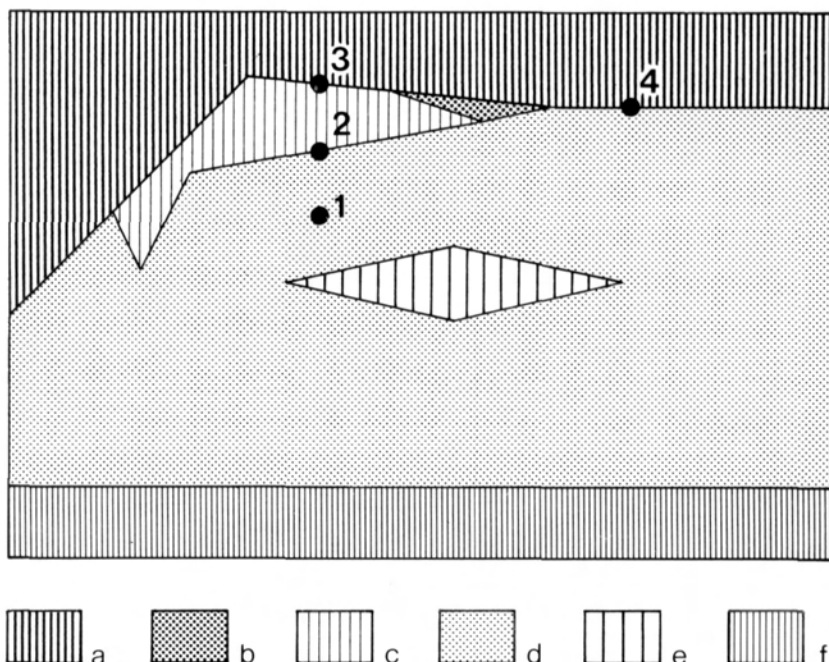
unsuccessful attempts to conquer the northern Gallic tribes (57-52 BC), Augustus' stepson Drusus did succeed. In 12 BC the whole area of the Netherlands was occupied. For the Netherlands, this date can serve as the *caesura* between the (pre-Roman) Iron Age and the Roman Period (Willems 1986). In 47 AD the Romans, after attempting to occupy Germany up to the Elbe, withdrew when Claudius ordered Corbulo to stop his expeditions and to cease his occupation of the northern part of the Netherlands. The Older Rhine, with its estuary near Katwijk (30 km north of the Meuse estuary) was chosen as the frontier (*Limes*) of the Empire. It would last for the following four centuries. Along the *Limes*, a series of military forts (*castella*) were erected. The auto-chthonous settlements of this time are referred to as "native Roman".

Voorne-Putten was included in the Roman Empire from 12 BC onwards. It became part of the administrative province of *Germania Inferior*. The wars appear to have had a strongly disintegrating effect upon the native societies in the occupied area. Numerous new groups settled there, at the expense of the former inhabitants. The new inhabitants of Voorne-Putten probably were the *Sturii* (Van Es 1981; Willems 1986).

The Roman habitation on Voorne-Putten ended between c. 200 and 270 AD (Van Trierum *in press*). The gap between the Late Iron Age and the Roman Period is also apparent in the pottery remains (Van Trierum 1986; Van Trierum *et al.* 1988). The house plans also show distinct differences between the (Late) Iron Age and the Roman Period (see below).

From the Roman Period, a total of 88 settlements are known. Two Roman culverts, which served for drainage, were found as well.

Figure 8 shows the location of the settlements in the respective periods. The Iron Age sites are mainly concentrated around the small area along the Bernisse. In view of these site distributions, it is significant that the Dunkirk I deposits are limited to two separate areas. One is situated on western Voorne and the other one around the Bernisse. In the area in between an extensive area of Holland peat is present (Van Staalduinen 1979: 57). It consists of oligotrophic on top of eutrophic peat (Van Staalduinen 1979: 54). This peaty landscape is likely to have been hostile to habitation because of its wetness (cf. Bloemers 1978: 87). According to Zagwijn (1986), most of this peat growth ceased during the Roman Period. The distribution of Roman sites takes up a considerably greater territory than the Iron Age sites, including parts of the peaty area outside the Dunkirk I sedimentation area.

1.3.1   THE ARCHAEOLOGICAL SITES

Detailed information on settlement structures is available from excavated sites. Before discussing these data, some introductory remarks on former architecture seem appropriate. The remains of the farms that were excavated, had been preserved due to a high water table. As a result, parts of the wooden structure are still found. Mainly the underground remains from the construction elements are preserved. The farms usually consist of a wall and one or more rows of internal posts. It is assumed that the roof was

carried by both the central posts and the wall. In some cases, posts are situated outside the wall and probably served as roof supports as well. If one row of central posts is present, the farm is two-aisled. Two parallel rows of central posts result in a three-aisled farm. Usually, the farms can be subdivided in a living area and a part for housing domestic animals. In this part (byre or barn), partitions (stalls or bays), in each of which two head of cattle or other domesticates could have been housed, are often preserved. Both the living part and the byre are under the same roof. The living area often has wider-spaced roof supporting posts than the barn part. The internal subdivision of the excavated farms does not differ significantly from contemporary upland sites.

All excavated farms are single farmsteads, dense clusters of sites do not occur. Van Trierum (*in press*) provided most of the following details on the excavated settlements.

1.3.1.1   The Early Iron Age.

The three Early Iron Age sites excavated are Rotterdam-Hartelkanaal 10-69; Spijkenisse 17-30 and Spijkenisse 17-35. The site of Rotterdam-Hartelkanaal produced a two-aisled farm, measuring 10 x 4.5-5 m. In the southern part a byre with six stalls can be reconstructed (Van Trierum *in press*). The excavation of Spijkenisse 17-30 resulted in the discovery of a three-aisled farm of 15 x 5 m. In the southeastern part six stalls for housing livestock are present (see also Van Trierum *et al.* 1988). The location Spijkenisse 17-35 also produced a three-aisled construction, measuring at least 17 x 5 m. The full length cannot be reconstructed due to a recent ditch disturbing the site. Ten to twelve stalls are present in the northeastern part of the farm. According to Van Trierum (*in press*), all excavated Early Iron Age sites yielded relatively little settlement waste. A habitation layer could hardly or not be observed. On the site of Spijkenisse 17-30, for instance, only 6.3 kg of pottery fragments were found, which is very little for an uneroded farm. These fragments belonged to a minimum of 17 pieces of pottery, which is an indication for a relatively short time of habitation.

1.3.1.2   The Middle Iron Age.

Seven excavations on Middle Iron Age sites have been conducted to date. They are Spijkenisse 10-28, 10-46, 17-34, 17-35, 18-50 and 18-92/93 and Simonshaven 17-14. Only Spijkenisse 10-28, 17-34 and 18-50 produced parts of farms, the others yielded potsherds, posts and sometimes former ditches. The excavated Middle Iron Age farms are longer than their Early Iron Age counterparts. Spijkenisse 10-28 yielded a three-aisled farm, which measured at least 19 × ca. 5.5 m. Ten stalls were present in the eastern part of the building. This site was not sampled for botanical macro-remains, as this was not yet common practice at the time of

excavation. Spijkenisse 17-34 revealed the remains of a 20 m long house; the width cannot be measured due to a recent ditch, but will not have exceeded 5.5 m. In a second building phase the length was enlarged with 4 m in a north-easterly direction. The living area of this farm is 7.5 m long. The number of stalls in the barn is not known with certainty. At least three stalls can be reconstructed in the central part of the length axis, this part has a length of 5 m. Next to this part, an area of 2 m length, filled with plant material and dung on a relatively clean subsoil occurred. This area may have been a hall. The following area of 5 m length had a corduroy floor of unsplit trunks, and also contained a hearth. The function of the last area is uncertain, it may have been a work area. The site of Spijkenisse 17-34 yielded 73 kg of pottery remains, more than ten times the amount of the Early Iron Age site of Spijkenisse 17-30.

The site of Spijkenisse 18-50, excavated in 1978, only produced part of the byre of a farmstead. The width of the farm measures ca. 5.7 m, the building was probably three-aisled. Samples for botanical macroremains research were not collected.

Observations through detailed corings on settlement sites, as well as through outcropping habitation layers in intersecting ditches and through excavations demonstrated that the inhabited areas do not exceed 40-50 m in diameter (Van Trierum *in press*).

1.3.1.3   The Late Iron Age.

The only excavated complete Late Iron Age farm, unearthed at the final stage of the present research, is Rockanje 08-52 on eastern Voorne. Besides, Wind (1970) described the find of settlement waste in a section near Rockanje (site 08-06). The excavated farm of 08-52 measures 21 x 5.5 m and is three-aisled. This farm is slightly longer than the Middle Iron Age farms. Twelve stalls are present in this farmstead and the orientation is east-west. The site is located on an oligotrophic bog cushion. In the vicinity of this settlement, several other habitation sites were present on similar bog cushions. Remarkably enough, one cushion had remained uninhabited. Excavations in 1991 on this terrain revealed very interesting traces. The stratigraphy of the natural peat deposits was completely destroyed in strips of 6.5 and 13 m width to a depth of c. 30 cm. In some places, pieces of pottery and dung occurred. At either side of the strips, the natural stratigraphy was undisturbed. The boundaries between the destroyed and the undisturbed strips were very often as straight as an arrow. The widths of the disturbed and undisturbed strips was very variable, the length could not be assessed.

In view of the perfectly straight borders of the strips, a natural cause for the destruction of the stratigraphy can be ruled out. Man must have caused this phenomenon. The fact that the overlying Dunkirk I deposit is undisturbed

indicates that the disturbance must have taken place in the (Late) Iron Age.

The first explanation that comes to mind is that we are dealing with cultivated plots or gardens (see also the discussion in Van Trierum *in press*). Palynological investigations could probably offer support for this hypothesis, especially if pollen of cultivated plants are present. However, the few results obtained to date are negative, pollen of crop plants nor those of unambiguous crop weeds could be demonstrated[4]. As an alternative function for these strips has not yet been suggested, small-scale cultivation of some crops on a peaty soil must be considered a possibility.

As has been observed, the "arable fields" as well as the Late Iron Age sites near Rockanje are both covered with Dunkirk I sediments. Two ^{14}C dates from Rockanje are of interest in this respect. The peaty base of the Dunkirk I sediment on top of the site of Rockanje 08-52 has been dated at 2050 ± 30 BP (GrN-18635; see also *2.4.7*). Hallewas and Van Regteren Altena (1979) mentioned a ^{14}C date of 2060 ± 50 BP (GrN-6401) for a wooden post from the Late Iron Age site of Rockanje 08-06. There is possibly hardly any time lag between the abandonment of the settlement and the beginning of the deposition of the Dunkirk I sediments. The fact that the Late Iron Age level occurs below the Dunkirk I sediments on western Voorne contrasts with the situation along the Bernisse on Putten. In the latter case, the Late Iron Age is found on top of the Dunkirk I sediments (see *fig. 9*). As the ^{14}C dates do not indicate a difference in date between the Late Iron Age sites on Voorne and Putten, the deposition of Dunkirk I sediments in the area studied must have been asynchronous (see also Hallewas/ Van Regteren Altena 1979).

1.3.1.4   The Roman Period.

Excavations on native Roman sites in the area produced several houseplans (cf. Van Trierum *et al.* 1988; Van Trierum *in press*). In Nieuwenhoorn, dendrochronologically dated to the first and early second centuries AD (cf. Vermeeren/ Brinkkemper *in prep.*; *3.1.6*), four farms were built one above the other, all were three-aisled and measured 25-33 × 5-7.5 m. Again, there is an increase in size compared to the preceding Late Iron Age. The roof-supporting posts showed a gradual shift towards the walls, resulting in an increasingly wider central aisle. In Simonshaven, two farms on top of each other were found. The older one was the smaller (17 × 4.5 m) and was probably two-aisled. The younger and larger one (22 × 6.5 m) only revealed one heavy central roofpost in the eastern part of the building. It was probably essentially one-aisled (Van Trierum *et al.* 1988; Van Trierum *in press*). Near Rockanje II, three house-

plans were found. Of one, only a corner could be excavated, making the division unclear. The second house was situated at a distance of 15 m from the first one. Two building phases could be distinguished. The older phase revealed an almost square building, which was one-aisled and measured ca. 7 × 6 m. The younger building measured ca. 16 × 7.5 m and was three-aisled. The third house was a one-aisled house with an A-frame, the corner posts standing at an angle of 66°. It measures 12 × 5.5 m. The two posts will have joined at a height of 3.7 m above the ground, thus indicating the height of the farm (Brinkkemper *et al. in press*). The native Roman farms excavated in Rockanje are relatively small.

In comparing the Iron Age sites to those of the Roman Period, some points are of great interest. Firstly, the obvious stalls in the Iron Age houseplans are absent in the Roman Period. Secondly, the excavations of the native Roman sites of Simonshaven and Rockanje have produced large granaries with heavy posts (15 and 16 posts respectively). Their floor area is 22.4 and 16 m[2]. The fact that the excavation of Nieuwenhoorn 09-89 did not produce a granary is not conclusive as the trench did hardly extend beyond the house walls. In contrast, the Iron Age sites of the area did not produce a single granary. Iron Age settlements on mineral soils in the coastal area often did reveal granaries (Van Heeringen 1992: 313-318). The relevance of these differences will be further discussed in relation to the economic reconstructions (see *ch. 6*).

Apart from these clearly native, wooden Roman farmsteads, some finds in the west of Voorne indicate the possible presence of buildings in stone. Hoek (1970) reported on a written source from 1752 by Jan Kluit. He mentioned a stone-built structure found beyond the present coastline, northeast of Oostvoorne. According to Hoek, it probably concerns the remains of a Roman *castellum*. Bogaers (1974) also made plausible the presence of a Roman *castellum* in the area of the *Helinium*, largely based on graffiti on several objects.

Near Rockanje, Bogaers (1952) found tuff stone (with remarkable little mortar), blue building stones, originating from Namen, many fragments of roof tiles (*tegulae* and *imbrices*) and some round *hypocaust* tiles and *tubuli* fragments. The last two are parts of the Roman heating system. This site is dated to the latter half of the second and the first half of the third century AD. It reminds one of the finds on the excavated Roman *villa* near Rijswijk (cf. Bloemers 1978). The aforementioned excavated native Roman site of Rockanje II is situated ca. 3 km south of the site that Bogaers discussed.

notes

1 When the "Iron Age" is mentioned in this publication, it always refers to the "pre-Roman Iron Age". As Voorne-Putten was part of the Roman Empire from 12 BC onwards, this period is referred to as the "Roman Period", which corresponds to the Roman Iron Age outside the borders of the Roman Empire.

2 BC (= Before Christ) and AD refer to calendar years before and after the start of the Christian era, BP refers to uncalibrated, conventional ^{14}C datings.

3 The Maasvlakte, which consists of sand from the Meuse, artificially deposited for industrial purposes, yielded remains from a large range of archaelogical periods. These remains are not *in situ* and will be left out of consideration here.

4 Three samples have been subjected to pollen analysis. They were obtained from the disturbed layers (the "arable fields"). Despite the fact that pollen were well preserved in the uppermost two samples, crop plants, for instance Cerealia-type pollen (larger than 40 μm, with annulus diametre larger than $2 \times$ pore diametre and a clearly bordered annulus) could not be demonstrated.

2.1   Introduction

One of the main approaches in the present study is palynological research. In this research, pollen grains and spores are the objects of study. These particles are produced by flowering plants, ferns and other cryptogams. Pollen grains and spores are identifiable to more or less low taxonomical levels (often to families or genera, sometimes to species). These different taxonomical levels will in the following be referred to as taxa.

A major part of the pollen and spores produced by plants do not fulfil their natural function of fertilization. In an environment deprived of oxygen, they can be preserved for a long time. Examples of pollen-containing sediments are peats and lake-deposits. After chemical treatments, the pollen contained in such deposits can be studied.

The pollen and spores preserved in a sediment are a reflection of the vegetation that prevailed during deposition of the sediment. The composition of a pollen spectrum is largely determined by the composition of the vegetation that produced it, although pollen production and pollen dispersal differ considerably between different taxa (see further 2.3).

The pollen that is transported by air is generally referred to as the airborne component (pollen rain). Part of this airborne pollen derives from the close vicinity of its place of deposition. This component is referred to as local pollen (*sensu* Janssen 1973). It is usually transported less than 25 m. Pollen transported over greater distances, up to several kilometres, is referred to as regional pollen. In our region, such airborne transport over relatively great distances mainly occurs in tree pollen. The share of local and regional pollen in the pollen deposition in any given location depends not only upon the pollen production of the local vegetation but also upon the size of the basin in which the pollen is deposited. In an extensive body of *Sphagnum* peat or a lake, the contribution of the regional pollen deposition is much greater than in smaller basins.

Some pollen types are extremely well adapted to long-distance dispersal (e.g. *Pinus*), relatively low amounts of such pollen types in a deposit may have derived from sources tens to hundreds of kilometres away. This component is referred to as extra-regional.

Apart from airborne pollen, some sediments also contain pollen transported by water (waterborne pollen). The origin of waterborne pollen may be far away from the site of deposition, especially where large river basins are concerned. Waterborne pollen may especially be present in clayey sediments. Owing to its origin far distant from the site of deposition, waterborne pollen distorts the information on the environment of the sampling site as provided by the local and the regional airborne components. As a result, a pollen spectrum from clayey sediments is much more difficult to interpret than one from a raised bog, where waterborne pollen can be excluded. Together with waterborne pollen which is produced just prior to its transportation by water, the water may also contain pollen eroded from older sediments. The presence of pre-Quaternary pollen is indicative of such redeposited pollen.

For palynologically based environmental reconstructions of the Iron Age and Roman Period, pollen containing deposits from these times are required. On Voorne-Putten, the peaty layers present between the different Dunkirk deposits offer good possibilities. The Dunkirk clay deposits themselves also contain pollen, but some of this is waterborne or even redeposited. These factors render the interpretation of pollen spectra from Dunkirk clay much more complicated than those from peat. In places where Dunkirk I sediments are present, no peat is formed during clay sedimentation. Since habitation is often correlated with these Dunkirk I sediments (see 1.3), this is an important restriction. Besides, the top of the peat that predates the clay sedimentation may have been eroded during transgression of the sea and consequential flooding of the peat.

2.2   Previous investigations

In the framework of the investigations relating to the geological map 37 West (Van Staalduinen 1979), several sections containing Holland peat on Voorne-Putten were analysed by the *Rijks Geologische Dienst* (R.G.D.; Geological Survey of the Netherlands).

The questions which the R.G.D. investigations tried to answer were of a geological nature. Dating of the layers of peat and clay were of primary interest. Such dating of Holocene sediments is possible by means of pollen analysis, using the different times of arrival of the tree species after the increase in temperature following the last ice age (Weichselian). Figure 10 shows the palynological criteria

Chronostratigraphy (Palynological periods)	Pollen (sub) zones	Main pollen-analytic features	Archaeological periods	Conventional 14C age in years BP	Dendrochronological age (calibrated radiocarbon age in solar years)	Periods of transgression C=Calais, D=Dunkirk / periods of regression (Zagwijn & Van Staalduinen 1975)
HOLOCENE						
Subatlantic	Vc	Increase of Pinus	Recent	0	1950	
	Vb2	Increase of Secale	Middle Ages	1000	1000	D III
	Vb1	Fagus > ca 5% / Carpinus > 1%	Roman		0	D II
	Va	Carpinus < 1%	Iron Age	2000		D I
Subboreal	IVb	Fagus > 1%	Bronze Age	3000	1000	D 0
	IVa	Ulmus low; agriculture	Late	4000	2000 / 3000	C IV
			Neolithic Middle	5000	4000	C III
Atlantic	III	Ulmus > 5% Alnus and Quercus important; Pinus low	Early	6000	5000	C II
			Mesolithic	7000		C I
Boreal	II	Alnus very low; Pinus dominant; Quercus, Ulmus, Corylus		8000 / 9000		
Preboreal	I	Pinus, Betula dominant Corylus, Quercus etc. very low				

BC | AD

Fig. 10 Palynological criteria for distinguishing the different periods of the Holocene (after Berendsen/ Zagwijn 1984).

used to distinguish the Holocene periods in the Netherlands (after Zagwijn 1975; Berendsen/ Zagwijn 1984). The dispersal of trees after the withdrawal of the last glacial ice cover is the main determining agent to the succession observed. The arrival and spread of *Fagus* is the key characteristic of younger (Subboreal and Subatlantic) deposits. According to the R.G.D. criteria, the start of the Subatlantic period is characterized by a rise of *Fagus* above 5%, relative to a pollen sum comprising all tree pollen (arboreal pollen sum). Within the Subatlantic deposits, the spread of *Carpinus* after the start of the Christian era is significant in the Netherlands. According to the R.G.D. criteria, the presence of *Centaurea cyanus*, *Fagopyrum* and *Secale* characterize deposits dating from the Middle Ages or later. Notwithstanding the fact that occasional earlier finds of *Secale* (cf. Janssen 1972) and *Fagopyrum* (cf. Janssen 1972; Eland 1984) do exist, are the R.G.D. criteria very useful to estimate dates of pollen diagrams.

Several of the R.G.D. pollen diagrams from Voorne-Putten cover part of the Subatlantic period. They are highly relevant to the researches at hand. Especially the diagrams from Geervliet (De Jong 1961), Lodderland (Jelgersma 1957b), Brielle-Tinte (Zagwijn 1955) and Heenvliet (Zagwijn 1955) are important. The first three contain the first part of the Subatlantic. The Holland peat in these sections is covered by Dunkirk I deposits, which terminated peat growth around 2400 BP. In Heenvliet, peat growth continued into the Roman Period, which is exceptional in the southwest of the Netherlands (see 2.7). All data in these diagrams, published in internal R.G.D. reports, have been placed at my disposal by Ing. J. de Jong and Prof. Dr. W.H. Zagwijn.

These R.G.D. diagrams also provided part of the basis for the palaeogeographical reconstructions by Zagwijn (1986) discussed in chapter 1.

2.3   Methods used in the present research

For a detailed reconstruction of the environment during Early and Middle Iron Age habitation, and for any human influence upon vegetation, several sections near excavations were sampled. For sampling, monolith tins, measuring 50 × 5 × 4.5 cm were used, unless otherwise indicated.

In the laboratory, each section was cut into slices of one cm in thickness. Pollen samples were obtained from the central part of these slices. The samples were treated following Fægri *et al.* (1989), a bromoform-alcohol mixture (s.g. 2.0) was used to separate organic and mineral material, thus omitting the corrosive HF. Except for a few samples very poor in pollen, analysis was carried out until at least 300 pollen grains from upland trees were counted. This upland tree pollen constituted the pollen sum. As a rule, every second centimetre of the sampled column of sediment

was counted. This appeared to provide enough detail, rendering the counting of every centimetre unnecessary.

For the identification of pollen and spores, the following publications were used: Fægri and Iversen (1975), Punt (1976), Punt and Clarke (1980, 1981, 1984), Erdtman *et al.* (1961, 1963), Moore and Webb (1978), Culhane and Blackmore (1988) and Van Leeuwen *et al.* (1988). Identifications were additionally checked with the aid of the I.P.L. reference collection. Dr. W. Punt identified and checked some problematic grains. Other microfossils, such as algae, fungi, etc. (Types *sensu* Van Geel 1978), were identified following the publications by Van Geel (1978), Van Geel *et al.* (1982), Pals *et al.* (1980) and Bakker and Van Smeerdijk (1982).

Palaeo-environmental reconstruction, which is the aim of palynology in an archaeological perspective, requires a greater density of spectra within the stratigraphical column than geological investigations usually necessitate. By analysing spectra with small vertical distances, more subtle changes in the pollen record through time, and thus indirectly in the vegetation, can be monitored.

The aims of the investigations also influence the pollen sum which underlies the diagrams. The R.G.D. diagrams are based on a pollen sum comprising all trees. For the present study, it was decided to deviate from this pollen sum. The composition of the vegetation on the mineral deposits (the "upland" component of the environment) and in the peaty landscape ("wetland") are of such relevance to the economic possibilities of prehistoric inhabitants that any changes in both these environments should be as clear as possible in the pollen diagrams. In a pollen sum comprising all trees, changes in wetland components like alder (*Alnus*) influence the percentages of upland trees. Especially when alder is locally present during deposition of a sediment, the disturbing effect may be enormous (see also Janssen 1959). This is considered undesirable in the present study, hence a pollen sum consisting of upland trees only was used as the basis for calculations. A result of this deviation from the R.G.D. pollen sum is that the level of 5% in *Fagus* may be achieved earlier, since the percentages of upland trees will be higher in the pollen sum used in the present study.

Contrary to Iversen's upland pollen sum (1947, cited in Janssen 1974), in this study herbs have been excluded from the pollen sum. Nearly all herbaceous pollen types found either played a role in the local succession (although they are often considered "upland" pollen, e.g. Umbelliferae, Compositae) or they possibly indicated marine influence (e.g. Chenopodiaceae). Inclusion of these pollen types in the pollen sum would result in grave distortions of other curves in those parts of the diagrams in which they occur abundantly. By excluding wetland trees and all herbs, changes observed in pollen of upland trees can only be caused by changes in the composition of the upland forests themselves (see also Fægri *et al.* 1989). None the less, changes in the

wetland components can be detected relative to the upland pollen sum.

The curves for each taxon still will be influenced by other taxa in relative pollen diagrams. The following theoretical example may illustrate this point. Two species, A and B, are the only ones present in the pollen sum. Both have a comparable pollen production. In the first spectrum, both types occur in equal quantity, so a score of 50% for each is recorded. Then, the forest composition changes; species A remains steady, there is no change in the number of trees, hence not in pollen production and -deposition either. Species B, however, is twice as common at the time of the second spectrum. Consequently, the pollen spectrum shows 33.3% for A and 66.7% for B. Seemingly there has been a decrease in species A when comparing the two spectra. However, this is entirely due to the increase of species B. In the same way a decrease of species B will result in a relative increase of species A. Evidently, the percentages of the taxa included in the pollen sum are not independent of each other. It can be demonstrated that the same applies to taxa which are not included in the pollen sum (see also Tauber 1965: 44).

To meet these objections, assessments of the absolute number of pollen grains may be made (Benninghoff 1962; Stockmarr 1971), following the procedure described below. For each spectrum, 1 cm³ of sediment is processed. To this volume of sediment (and the pollen contained in it), a known number of exotic pollen or spores (viz. 12,100 *Lycopodium* spores) are added. By means of the number of *Lycopodium* spores retrieved in the analysis, the original number of a given taxon can be assessed as follows:

$$\frac{\text{counted pollen taxon A}}{\text{counted spores } Lycopodium} = \frac{\text{original number of taxon A}}{\text{added number of } Lycopodium}$$

From this equation follows:

$$\text{original number of taxon A} = \frac{\text{counted pollen taxon A} \times 12{,}100}{\text{counted spores of } Lycopodium}$$

Thus, the absolute number of pollen of each taxon per 1 cm³ of sediment can be graphically represented as pollen concentration diagrams. Unfortunately, this method too has a major drawback. The 1 cm³ of sediment used, represents a certain amount of vertical sedimentation which is related to time. Fluctuations in the numbers of a taxon may be caused by fluctuations in its presence in the landscape, but alternatively, it may be due to fluctuations in the rate of sedimentation. By means of a series of radiocarbon datings, possible fluctuations in sedimentation can, at least roughly, be assessed and corrected. This way, the pollen concentration diagram is converted into a pollen influx diagram (cf. Fægri et al. 1989). These pollen influx diagrams are probably the best reflection of pollen deposition. As Fægri et al. (1989) stated,

"conceptually, pollen influx data are much simpler and more direct representations of the natural vegetation, and therefore permit a more penetrating analysis, leading to more meaningful results. It opens the possibility of a (semi-) quantitative evaluation of former vegetation. (...) This does not mean that the old methods have become obsolete or redundant. Percentage presentations are inherent parts of all quantitative numerical pollen analyses and are automatically obtained. To transform them to concentration data costs very little, but to add the datings necessary for influx data may be impossible in some sediments, expensive and cumbersome in others".

As, moreover, relative diagrams dominate the literature (see also Birks/ Gordon 1985), I have decided to present mainly relative diagrams. Only for Spijkenisse 17-30, a pollen influx diagram will be presented.

Both relative pollen diagrams and pollen influx diagrams are based on the deposited numbers of pollen. However, it should be pointed out that there is a large discrepancy between pollen deposition and the number of a species/ taxon in the pollen catchment area of the site. This is due to the differential pollen production of various species. Pollen production is heavily dependent on the pollination strategy of a species. For instance, the pollen production of the insect-pollinated lime (*Tilia*) is substantially lower than of wind-pollinated species like oak (*Quercus*) and alder (*Alnus*), and pollen of pine (*Pinus*) is very well adapted to wind-pollination and long-distance transport.

To investigate the importance of differential pollen production in various tree species, Andersen (1970, 1973) compared the numbers of tree pollen in cushions of moss in Danish forests with the area covered by the crowns in the surrounding vegetation. This research revealed that there is a linear relation between these parameters. The more commonly a species occurs in the vegetation, the more it contributes to the pollen rain. The ratio of pollen percentage/crown area percentage is called the R-value. Trees with a low pollen production thus also have low R-values, a high pollen production similarly results in a high R-value. As a result, these R-values express the over- and under-representation of the species in individual pollen spectra. This difference in representation is exclusively due to differential pollen production.

R-values are not comparable from site to site, because they differ in various combinations of species and vary with the frequency of species (Andersen 1973: 110). Davis (1963) showed that the ratios of the R-values to the R-values of a reference species do offer the possibility of comparing different sites. The example presented by Birks and Gordon (1985: 185) may serve to illustrate this point (see *table 1*).

From this table it will be clear that the taxa have different R-values in different sampling sites, but their R_{rel}-values are the same.

Andersen used *Fagus* as a reference species. The resulting

Table 1. Hypothetical correction factors for pollen production (R-values) for three locations with three taxa each (after Birks & Gordon 1985).

Taxon	Vegetation	Pollen	R-value	R_{rel}-value
A	0.4	0.8	2	10
B	0.1	0.1	1	5
C	0.5	0.1	0.2	1
A	0.2	0.5	2.5	10
B	0.3	0.375	1.25	5
C	0.5	0.125	0.25	1
A	0.68	0.85	1.25	10
B	0.22	0.1375	0.625	5
C	0.10	0.0125	0.125	1

Table 2. Correction factors for pollen production (R_{rel}-values) of various tree species relative to Fagus (after Andersen 1973).

Taxon	R_{rel}-value
Quercus, Betula, Alnus, Pinus	1:4
Carpinus	1:3
Ulmus, Picea	1:2
Fagus, Abies	1:1
Tilia, Fraxinus	1×2

R_{rel}-values can be used for a correction of pollen spectra, in which the percentages of the different trees indicate the crown area percentages. The correction factors found by Andersen are shown in table 2. According to these data, the percentages of Quercus for instance should be divided by four to correct differential pollen production.

The R_{rel}-value of Corylus presents additional problems. For hazel in full light, Iversen (1947, cited in Andersen 1973) suggested a correction factor of 1:4, while under a tree canopy the factor may be 1:1 (Andersen 1973: 111).

Andersen's research related to local pollen deposition within forests. The pollen largely came from vegetation within a 20-30 m[1] radius of the place of sampling. Thus, the pollen production of different trees is of much greater importance than their pollen dispersal. In lakes and bogs, in contrast, the pollen spectra derived from vegetation from a much larger area and consequently, differential pollen dispersal plays a considerably larger role than in Andersen's studies.

In medium or large basins, the share of regional pollen is much greater than the local pollen component (sensu Janssen 1973). One may wonder how far pollen is generally dispersed from its source. According to Birks and Gordon (1985: 233), who cite several sources, medium- or large-sized lakes or bogs (at least 250 m in diameter) have pollen source areas of at least 1000-2000 km[2], which corresponds to a radius of 18-25 km. However, the distance pollen can bridge differs from taxon to taxon. Some produce large amounts of

light pollen, which is widely dispersed (e.g. Pinus, Betula), while others have a low production of heavy pollen, which is poorly dispersed (e.g. Acer, Tilia).

Janssen (1981) described recent pollen deposition in the Vosges (France). He concluded that the local effect of trees is felt over relatively short distances from the forest edge. This local effect is usually negligible at distances beyond 150 m from the pollen source. For herbs, Gramineae probably excluded, this distance is much shorter, usually not more than a few metres.

The pollen deposition in large basins is further complicated by the fact that pollen deposition decreases gradually, rather than abruptly, with distance, and at different rates for different species. These complications necessitate the incorporation of a "background component" in the calculation of R-values. This background component represents pollen produced outside the area for which the tree crown coverage was estimated. The fact that different taxa differ in their pollen dispersal capabilities and depositional characteristics, which are related amongst other things to size, shape and weight, complicates the relation between vegetation and pollen deposition even more (Birks/ Gordon 1985: 186). These authors (p. 187) conclude that

"size and type of the basin should be standardised as far as possible in any attempt to estimate R-values, and should be similar to the sites from which fossil stratigraphical data of interest are available. It is this problem of defining realistic pollen source areas that has perhaps resulted in the R_{rel}-value model being discarded by many palynologists".

One may conclude that at present there are still many difficulties in the use of R_{rel}-values. The results obtained could show a misleading precision. For this reason, I have not used any pollen representation factors to convert my percentage diagrams.

2.4 Pollen diagrams

2.4.1 THE POLLEN DIAGRAM OF SPIJKENISSE 17-30

The location of this section is indicated in figure 11. The section has been sampled near the Early Iron Age site of Spijkenisse 17-30, it lies 6 m northeast of the excavated farmstead. The stratigraphical position of the sampled part of the section is indicated in figure 12. The section had been cut especially to obtain material for palynological research by the excavators of the B.O.O.R. The top of the peat is strongly decomposed, the transition to the overlying clay is gradual.

Figure 13 represents the relative pollen diagram of Spijkenisse 17-30[2]. Throughout the diagram, Gramineae and monolete psilate fern spores (Thelypteris type) are predominant. Sphagnum and Ericales are rare. This shows that we are dealing here with eutrophic fen peat.

The first local zone (A) is characterized by relatively high
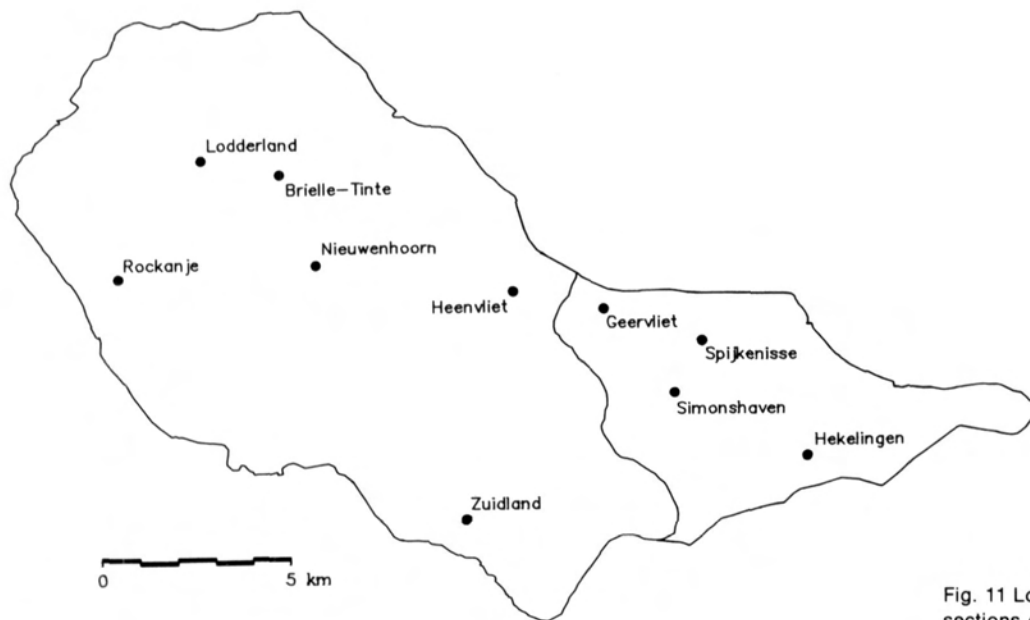
Fig. 11 Location of the palynological sections on Voorne-Putten, scale 1:2000.

proportions of *Quercus* (oak) and *Fagus* (beech). *Corylus* (hazel) is present in lower percentages in comparison with the following zones. Already at the base of the diagram, *Fagus* exceeds 5%. Although the pollen sum used here deviates from that of the R.G.D., most probably the whole diagram can be dated to the Subatlantic period (compare *fig. 10*). This is confirmed by a ^{14}C dating of 2625 ± 40 BP (GrN-15222) from the base of the peat. *Carpinus* does not attain values of 1% in a closed curve, so the whole section predates the Christian era. The algae *Pediastrum* and *Spirogyra* attain their maximum values in the first zone, the same applies to *Lythrum*. The algae indicate the presence of stagnant, fresh water.

In local zone B, *Quercus*, *Fagus* and *Tilia* show a marked decline, *Corylus* increases strongly in the relative diagram. The declining taxa are all trees of primary forests, whereas *Corylus* is a pioneer species of secondary forests (cf. Smith 1978). The remarkable changes in the composition of the upland pollen rain may have several causes.

In view of the peak of Chenopodiaceae pollen at the end of zone A, increased marine influence is the first possible cause of deforestation. A rising water table, connected with increased marine influence, probably had its effect upon the upland trees, which are sensitive to high water tables in the growing season. However, *Corylus* is likely to be affected by these circumstances in the same way. Consequently, the apparent increase of *Corylus* remains unexplained. The drowning of the upland forest would most probably also result in the expansion of *Alnus* in these parts of the land-

scape (see also Willerding 1977). In the pollen diagrams, however, *Alnus* shows a steady decline, more or less following the curve of *Quercus*. A further argument against a wetter phase during zone B is the decline of aquatic taxa like *Pediastrum*, *Spirogyra* and cf. *Potamogeton*, and the increase of Umbelliferae and Compositae tubuliflorae. Similar changes in these taxa occur in the *Assendelver Polder* section, investigated by Witte and Van Geel. They also point to drier local conditions to account for these changes (Witte/Van Geel 1985: 250).

A second option for the interpretation of the changes in upland tree pollen can be found in the study by Van der Woude (1983). His study concerns part of the Rhine-Meuse basin in the Alblasserwaard near the Hazendonk (upstream from Voorne-Putten). Here clayey layers, in comparison to peat, show notably higher values of *Fagus*, *Picea*, *Abies* and, to a lesser extent, of *Pinus*, *Tilia* and *Quercus*. This is explained by river-transported pollen of these six taxa. In periods of inundation, together with the sedimentation of clay, pollen from the hinterland is deposited. Florschütz and Jonker (1939) already postulated aquatic long-distance transport of pollen of *Pinus*, *Picea* and *Abies* to account for high values of these taxa in clayey sediments along the Rhine. In the case of Spijkenisse 17-30, the same might play a role in zone A and termination of riverine influence in zone B would result in the decline of these species. However, several observations invalidate this explanation. Firstly, *Pinus* shows regular percentages throughout the diagram, and *Picea* and *Abies* are hardly or not at all represented.

÷ N.A.P.
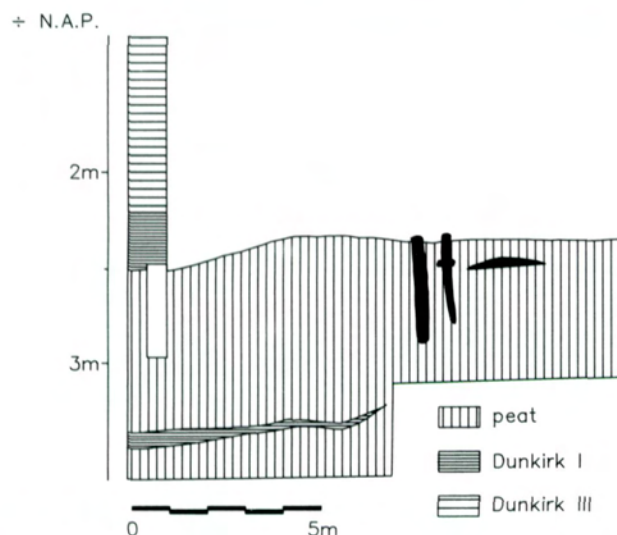
Fig. 12 Position of monolith tin in section of Spijkenisse 17-30. Black = wooden posts.

Secondly, a clayey enrichment of the sediment in zone A could not be found. Besides, pre-Quaternary pollen, often characteristic of redeposition in Holocene sediments (cf. Dimbleby 1985), are lacking in the Spijkenisse diagram.

The third possible explanation points towards an anthropogenic origin. Deforestation by man of the upland area can explain the decline of *Quercus*, *Fagus* and *Tilia*. The rise of *Corylus* in this case may have been due to better flowering or expansion of this light-demanding species, facilitated by the opening up of the formerly closed primary forest. The decline of *Alnus* may also have been due to felling, as this species was very regularly used for construction purposes during the Iron Age (see 3). Furthermore, *Alnus* is a predominating species in the charcoal from hearths (see Brinkkemper/ Vermeeren *in press*). The changes in the forest composition would in this case reflect a phenomenon with many parallels to Iversen's (1941) classic *landnam*.

The radiocarbon dating of the base of zone B, 2435 ± 45 BP (GrN-15223) is in perfect agreement with datings of construction wood belonging to the nearby Early Iron Age site of Spijkenisse 17-30 (c. 2450 BP; Van Trierum 1986). The ^{14}C dates for the pollen diagrams presented here were obtained from the same peaty material as was used for pollen analysis.

In view of these arguments, the changes observed in the composition of the upland forest can, in my opinion, only be attributed to anthropogenic causes.

In zone C, after a slight recovery of *Quercus*, a second decline is represented. The ^{14}C date of 2220 ± 30 BP (GrN-13236; Van Trierum 1986) fits in perfectly with the datings

of wood in Middle Iron Age constructions (c. 2200 BP; cf. Van Trierum 1986). The peak of *Myrica* in this zone may be explained by local peat development. In the sediment concerned, a strong decomposition of the peat can be observed. This is due to drainage of the peat, related to the first influences of the Dunkirk I transgression phase, which culminated in the sedimentation of clay on top of the decomposed peat. *Myrica* grows abundantly on this kind of peat as a result of the higher mineral contents generated by decomposition (see also Denys/ Verbruggen 1989). Thus, the strong increase fits in very well. Bakker and Van Smeerdijk (1982: 131) observed similarly high *Myrica* percentages in decomposing peat. In Behre's (1976b) diagram Ahlenmoor VI, *Myrica* shows high values after a level poor in pollen. This also seems to indicate the spreading of *Myrica* on decomposing peat. Apparently, this phenomenon is not restricted to the Dutch coastal area.

The high percentages of *Corylus* pollen recorded in the present diagram are conspicuous. In Iversen's (1941) publication, where the expression *landnam* is introduced, a peak of *Corylus* occurs during regeneration of the forest, in Iversen's case after *Betula*. Here, *Quercus* was also a major component, which was adversely affected by human influence. The species that play a role in the regeneration will amongst other things depend upon soil factors, which may account for the subordinate role of *Betula* in the present study.

The persistently high values of *Corylus* in the present diagram, however, cannot be explained by regeneration. The phase with hazel in the succession of a regenerating forest would not last several hundreds of years. The prolonged abundance probably points towards longlasting open spaces in the upland forest.

However, the pollen influx diagram reveals some unexpected perspectives in this observation. This diagram is based on absolute values per cm³, with differences in sedimentation rates corrected with the aid of ^{14}C datings. The diagram (*fig. 14*) shows convincingly that the relative maxima of *Corylus* are caused by the falling off of other upland trees. The absolute numbers of hazel pollen deposited per time unit remain constant. Consequently, the net pollen production of *Corylus* did not increase. The positive influence of better light conditions may have been offset by a reduction in the numbers of these shrubs.

The obvious interpretation of these data is that a considerable clearance of the primary forest on mineral deposits (the "upland") took place at the same time as Early Iron Age habitation in the area. After a short period of recovery, the next clearance phase is recorded in the pollen diagrams at the time of Middle Iron Age habitation.

In the last zone (D) of the relative diagram, *Quercus*, *Tilia* and *Fagus* recover again. In this case, the sedimentation of allochthonous pollen together with clay may explain this

phenomenon. In the clayey samples, there need not be any relation with the development of the upland vegetation on Voorne-Putten. The possibly renewed recovery of the forest cannot be observed owing to the sedimentation of clay during the Dunkirk I transgression phase. Therefore, the diagram does not contain information on the Late Iron Age and the Roman Period. Reliable ^{14}C dates cannot be obtained from the clayey sediment of zone D. Consequently, no pollen influx diagram can be drawn for this part of the section.

The changes in the tree pollen values are thus best explained by human influence upon the vegetation. It may be asked whether there are other indicators of human activities in the area discernible in the diagram. The repercussions of human activities in pollen diagrams have been subject to many studies, in which ranges of "anthropogenic indicators" have been suggested. These indicators may belong to two categories. Firstly, they may concern species cultivated by man, which Behre (1990c) referred to as primary anthropogenic indicators. Secondly, a range of non-cultivated anthropogenic indicators is mentioned in the literature on this subject, which Behre called secondary anthropogenic indicators.

As for the cultivated species, the curve of cereal pollen (Cerealia-type) has often been considered to provide useful information (cf. Beug 1986; Teunissen *et al.* 1987). In the diagram of Spijkenisse 17-30, Cerealia-type pollen is only recorded in one spectrum from the upper layer of clay. The absence in the Iron Age spectra is not as strange as it appears at first sight. The cereals cultivated during the Iron Age, viz. wheat species, barley and probably oats (cf. Van Zeist 1970; *ch. 4*), are all autogamous. As Iversen (1941, 1949) already observed, cereal pollen remains enclosed between the bracts, resulting in self-pollination. Only rye (*Secale cereale*) is a wind-pollinated species with good pollen dispersal. This species, however, did not come into large scale cultivation before medieval times (cf. Behre 1976a; Pals/ Van Geel 1976), although it does occasionally occur in the 3rd or 4th century (Behre/ Kučan 1986).

Regarding the Iron Age cereals, Heim (1970) demonstrated in recent situations that at a distance as short as 50 m from the fields, cereal pollen can no longer be demonstrated. Diot (1992) studied the pollen dispersal of bread wheat (*Triticum aestivum*) and the wild ancestor of emmer wheat (*T. boeoticum*). Within a cultivated field, ca. 10% of cereal pollen was found in the uppermost centimetre of the soil. This percentage decreased to ca. 3% at 10 metres' and 1.4% at 50 metres' distance. Hall (1988) even reported a drop in grain pollen to 1% at a distance of only 1 m from the edge of cultivated fields.

In the plough marks of a Bronze Age field near Haarlem (the Netherlands), C. Vermeeren (*pers. comm.*) found only three Cerealia type pollen grains (1%), amidst reasonably

well-preserved material. In the peaty sediments next to this field, she could not demonstrate any cereal pollen at all.

As Ralska-Jascewiczowa (1968) already demonstrated, most of the pollen of autogamous cereals is released during threshing. Considerable numbers of cereal pollen (except *Secale*) in pollen diagrams mostly, if not always, consist of this "threshing pollen" (see also Robinson/ Hubbard 1977). This phenomenon is very convincingly demonstrated by Vuorela (1973), who monitored the pollen rain around cultivated fields (with the cereals *Hordeum* and *Avena*). By means of pollen traps inspected monthly, she established that most cereal pollen is found in the latter part of August, i.e. harvest time. During flowering time, hardly any cereal pollen was found. The combine harvester, by scattering the chaff, dispersed the pollen. Welten (1967) published pollen diagrams from a transect leading away from a Neolithic lake-village in the Burgäschisee. In the settlement, he recorded 114% of Cerealia pollen, whereas at a distance of 29 m only 0.4%. The high amounts of Cerealia pollen in the settlement cannot have come from an arable field. They must be interpreted as threshing pollen and/or pollen from faeces.

Furthermore, cereal pollen cannot always be identified with certainty (see *2.4.8*). All in all, the very few Cerealia-type pollen grains found in the pollen diagram of Spijkenisse 17-30, whose sizes never exceed ca. 50 μm, may have come from coastal wild grasses. Their significance should correspondingly not be overrated.

Apart from cereals, some other cultivated species occur in the Iron Age. Linseed (*Linum usitatissimum*), gold of pleasure (*Camelina sativa*), cabbage species (*Brassica* spec.) and several pulses must be taken into consideration. *Linum* produces very characteristic pollen. However, this species is predominantly self-pollinated (Zohary/ Hopf 1988: 114) and thus very rare in pollen diagrams. The absence in the present diagram cannot be seen as evidence for a minor role of *Linum*. *Camelina* and *Brassica* produce pollen, which at present cannot be distinguished from several other Cruciferae species (cf. Behre 1981). Besides, *Camelina* is also self-pollinated (cf. Plessers *et al.* 1962). The different pulses (*Vicia faba*, *Pisum sativum* and *Lens culinaris*) do produce characteristic pollen. These legumes are insect-pollinated, so their pollen is also poorly dispersed, and very rare in pollen diagrams. In summary, we arrive at the conclusion that cultivated plants are very difficult to attest in pre-medieval pollen diagrams. Since medieval times, *Secale* has provided better opportunities.

Apart from these cultivated primary anthropogenic indicators, several other pollen types have been recognized as secondary anthropogenic indicators. Although not cultivated, these plants were favourably influenced by human activities. Behre (1981) gave a considerable stimulus to the use of these secondary anthropogenic indicators in

pollen diagrams. This theme is elaborated on by the various authors in the volume edited by Behre (1986a). In general, *Plantago lanceolata, Plantago major, Rumex acetosa,* Ranunculaceae and sometimes *Calluna* are regarded as indicators of pastoral farming. *Centaurea cyanus, Polygonum convolvulus, Spergula arvensis* and *Scleranthus annuus* are useful indicators of arable farming.

In the present diagram, the arable weeds are conspicuously absent. A closer examination of the species concerned reveals that, with the exception of *Spergula,* all belong to wintercrop weeds (equivalent to the present syntaxonomical class Secalietea). The study of botanical macroremains on Iron Age sites on Voorne-Putten demonstrated that only summercrop weeds (the present Chenopodietea) occurred. Seeds of *Spergula arvensis* have not been found either (see *ch. 4*). Thus, the absence of these arable indicators in the pollen diagram does not allow any conclusions to be drawn on the arable component of the economy as revealed by the pollen deposition. The scarcity of the "pastoral" indicators is probably linked to the type of soil. The species listed are useful in mineral environments. In the landscape around the Iron Age sites near the Bernisse, reed swamps and drier heathlands are the most likely environments for grazing (see also Witte/ Van Geel 1985). Here, the "pastoral" indicators probably could not play an important part. Behre (1976b) noted similar objections to pasturing on very poor soils. On such soils, extensive heathlands have been used for grazing sheep, but *Plantago lanceolata* does not occur in grazed heathlands.

Apart from these qualitative approaches of indicator species, quantitative ratios have been proposed by a number of authors as well. A very simple ratio is presented by Steckhan (1961) and Lange (1971). Cereal pollen forms the arable component and *Plantago lanceolata* the pastoral one. Their mutual share in pollen spectra was used to calculate the importance of arable and pastoral farming. However, as Behre (1981) pointed out, *Plantago lanceolata* may be absent in some types of pasture (heathlands, grazed forests, "*Hudewälder*"). Besides, *Plantago lanceolata* can recolonize fallow land, thus being an indirect indicator of arable land, especially before the introduction of the mouldboard plough, since the perennial *Plantago lanceolata* was probably not eradicated by the ard.

Turner (1964) proposed an arable/pastoral index, which is the ratio of *Plantago* grains relative to the total of *Plantago,* Compositae, Cerealia, Cruciferae, *Artemisia* and Chenopodiaceae. She claims that in recent situations,

"with one or two exceptions it is below 15% in the arable region and above 50% in the pastoral region" (Turner 1964: 81).

In his discussion on this ratio, Maguire (1983: 13) observed that on pollen sites close to the coast, *Elymus farctus* (= *Agropyron junceum*: Cerealia type pollen), *Aster tripolium*

(Compositae) and *Plantago maritima*[3] greatly influence the ratio, whereas none of them is indicative of anthropogenic activities. Besides, the same applies to Chenopodiaceae, a family also containing a whole range of salt marsh plants, and to *Artemisia maritima* (see also Behre 1976b: 113). Since the present pollen diagram originates from an area where coastal influences cannot be neglected, the calculation of this pollen ratio is hazardous.

Calculation of Turner's (1964) index for the spectra 277-281 cm (Early Iron Age) and 265-269 cm (Middle Iron Age) for the diagram of Spijkenisse 17-30 would result in ratios of 2.1% and 2.7%, which would indicate almost complete specialization in arable farming. In fact, these low ratios result from the low values of *Plantago* and the high ones of Compositae and Chenopodiaceae only.

Kramm (1978: 26) proposed a completely different approach. He established the proportions of Cerealia and (non-cultivated) Gramineae. He found a relative increase of Cerealia towards medieval times. The presence of *Secale* in medieval samples, however, seriously distorts the picture obtained.

Kramm's ratio would produce values of almost 100% pastoralism in the case of Spijkenisse 17-30. However, the local presence of *Phragmites* and the predictable scarcity of Cerealia do not hold much hope for the representativeness of these values either.

Riezebos and Slotboom (1978) modified Kramm's ratio, using:

(Gramineae + Papilionaceae + *Plantago lanceolata*) / (Gramineae + Papilionaceae + *Plantago lanceolata* + Cerealia + *Fagopyrum* + *Rumex* + *Artemisia* + *Centaurea*)

The objections raised by Maguire also apply to this index. As Behre (1981: 236) observed, the inclusion of *Rumex* in the arable component of this ratio is not undebated. Berglund (1969 cited in Behre 1981) for instance regarded *Rumex* as a pastoral indicator. For Spijkenisse, this ratio scores over 90% pastoralism during Early and Middle Iron Age.

To all these ratios, the reservations expressed by Groenman-van Waateringe (1988a: 10) are in force. She observed that

"as long as the criteria for identifying arable and pastoral indicators are not clearly defined, and directly relevant to prehistoric agriculture, it is impossible to expect to be able to translate an arable/pastoral ratio in terms of past economies or subsistence practices".

Behre (1981: 240) vented similar reservations. According to him, a precise assessment of the relative proportions of crop and animal husbandry has so far been not possible by pollen analysis alone. The applicability of these ratios for Voorne-Putten will be given further attention in the discussion on the economy of the sites (*ch. 6*).

2.4.2   THE POLLEN DIAGRAM OF SPIJKENISSE 17-34

The section of Spijkenisse 17-34 was sampled by the
B.O.O.R. with monolith tins. The section is located ca. 12 m
east of a Middle Iron Age site. The distance towards the
pollen section of Spijkenisse 17-30 is ca. 250 m. As in
Spijkenisse 17-30, the section consists of fen peat, covered
with clay. The top of the peat is strongly decomposed, the
transition to clay is gradual. The location of the monolith
tins in the section is indicated in figure 15.

In the diagram (*fig. 16*), *Quercus* shows only one distinct
minimum at 268-260 cm below NAP[4], *Tilia* and *Ulmus*
show synchronous minima. Again, *Corylus* at the same time
shows a (relative) increase. [14]C dates of the peat in the
upper part of the diagram show a reversed sequence, the
uppermost sample has an older dating (2485 ± 40 BP;
GrN-14176) than the lowermost (2330 ± 60 BP; GrN-
14175), the middle sample also has the middle dating (2415
± 50 BP; GrN-16328). We are dealing with a period of
strong wiggles in the ^{14}C calibration curve (cf. Baillie/ Pil-
cher 1983), which results in all three datings spanning a
range between ca. 750 BC and 400 BC. Baillie and Pilcher
(1983: 58) in this respect stated that the calibration curve is
essentially flat between 800 and 400 BC. The dates in the
pollen diagram only allow the conclusion that the top of the
section is not younger than 400 BC.

An argument for assuming that peat growth ceased before
the Middle Iron Age is presented by archaeological research.
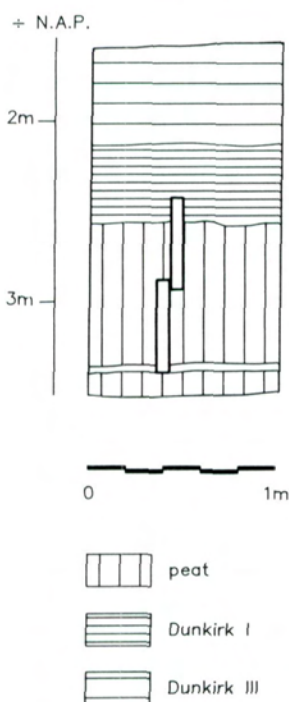
Fig. 15 Position of the monolith tins
in section of Spijkenisse 17-34.

The traces of habitation in the nearby Middle Iron Age site
of Spijkenisse 17-34 were on top of a thin layer of clay. This
indicates that sedimentation of the clay started before hab-
itation took place, and thus that the peat under the clay was
formed before the Middle Iron Age (i.c. before c. 2200 BP).
The decline of *Quercus* in the pollen diagram of Spijkenisse
17-34 thus seems to have occurred during the Early Iron
Age.

During this oak decline, a transition can be observed in
the stratigraphy from peat to clay. The possibility of rede-
posited pollen (deposited with the clay) must thus be taken
into consideration. As stated above, redeposition of pollen is
often characterized by increasing values of *Pinus*, *Picea*,
Abies, *Quercus*, *Fagus* and/or *Tilia*. In the diagram, *Picea*
and *Abies* are absent, *Pinus* is constant and *Quercus*, *Fagus*
and *Tilia* show a decline. Redeposition thus fails to explain
the shifts observed in the tree pollen percentages. In view of
the proximity of the Spijkenisse 17-30 diagram, the same
anthropogenic influence may be expected here. The Middle
Iron Age *landnam* is not represented, as peat formation
ceased prior to habitation. As in Spijkenisse 17-30, the
anthropogenic indicators are hardly discernible in Spijke-
nisse 17-34.

2.4.3   THE POLLEN DIAGRAM OF HEENVLIET

The pollen diagrams discussed above are both from an area
situated close to human settlements. In order to assess the
extent to which human influence occurred, another site for
pollen analysis had to be selected. This site should prefer-
ably be at some distance from settlements. It was therefore
decided to sample a section near Heenvliet. Despite several
surveys, no traces of Iron Age or Roman habitation have
been found here.

Heenvliet is the site where Zagwijn's palaeo-geographical
map of the Netherlands shows a raised bog area during the
Iron Age and where peat accumulation did occur during the
Roman Period. This appears to be a unique situation in the
southwest of the Netherlands, most of the peat being desic-
cated before the Christian era during Dunkirk I influences.
Near Heenvliet, only DIII deposits occur on top of the peat.
The complete lack of traces of Iron Age habitation in the
Heenvliet polder is in accordance with continuous growth of
Sphagnum peat. In consequence, by analysing the pollen
contents of this peat, an insight into the environmental
development of an uninhabited area may be gained. It
should also offer data on the landscape during the Roman
Period. The presence of *Sphagnum* peat further indicates
that all pollen recorded will be airborne, if not originating
from the local vegetation.

For the diagram which resulted from the R.G.D. invest-
igations (Zagwijn 1955), ^{14}C dates have been obtained from
the bottom and the top of the peat. The spectra mostly have
distances of 5 cm. Both these facts render this diagram less

suitable for detailed and dated reconstructions of human influence. The decision to sample this site anew was thwarted as the location of the Heenvliet section studied by the R.G.D. is not exactly known (Zagwijn/ De Jong *pers. comm.*).

For sampling it was deemed best to select a site where (sub)recent disturbances could be ruled out. A medieval site lying *in situ* on top of the peat would demonstrate that the peat could not have been disturbed after the medieval habitation. In practice, it appeared that the exact location of the selected site (Heenvliet 10-75; Van Trierum *et al.* 1988) could no longer produce useful samples as it had been trench-ploughed only a few weeks before our arrival. As an alternative, the peat below the neighbouring meadow was sampled. The upper part of the section could be examined in the slope of a ditch. The top of the peat below the Dunkirk III sediments did not show any disturbance and the site was sampled by means of a corer for taking peat samples (Ø 6 cm).

The diagram (see *fig. 17*) shows considerable fluctuations in the curves of *Quercus* and *Corylus*. Before *Fagus* attains values over 5%, *Quercus* shows an obvious decline, compensated by *Corylus*. The Subboreal ^{14}C dates of this part of the diagram are in accordance with the *Fagus* curve. The Holocene mean sea level curve of Van der Plassche (1982b: 176) shows a gradually rising mean sea level between 3900 and 3800 BP, corresponding to the Calais IVb transgression phase. The changes in the composition of the upland forest can be thus accounted for. The rise of *Alnus* would be in agreement with the environment becoming wetter.

However, an alternative explanation may be given for these changes in the tree pollen. The ^{14}C dates point to the synchroneity of this oak decline with habitation during the Vlaardingen culture. The oak decline was therefore probably caused by man. Neolithic occupation of the Rhine-Meuse estuary is known from levees only (cf. Louwe Kooijmans 1974). Along the Meuse, these levees are no longer present owing to medieval erosion by Dunkirk III transgressions (see *2.5.2*). Neolithic habitation can therefore not be attested. The natural vegetation of these levees will have consisted of upland forests containing oak. The forests were probably felled by the neolithic inhabitants. However, it is beyond the scope of the present study to investigate this Subboreal oak decline any further.

After the first oak decline, the upland forest recovered again. Then a series of fluctuations in the *Quercus*, *Corylus* and *Fagus* curves can be observed. Unfortunately, ^{14}C datings reveal that the upper 45 cm of the diagram shows a repetition of the chronological sequence. Apparently, peat growth stopped during the Early Iron Age and redeposition of a vast amount of peat occurred. The only possible explanation (apart from highly improbable laboratory failures)

is that an island of peat, after being torn loose during a rising water table, has floated to the pollen site and settled there as a result of lowering of the water table.

Floating peat has often been noticed in pollen diagrams during periods of increased marine influence (first by Polak 1929). Normally, the floating peat mat remains attached to the main body of peat and only hinges. This mechanism results in intercalated layers of clay, deposited under the floating peat. These layers of clay are much younger than the peat below and above them (so called *Klapp-Klei*: Behre 1970; Grohne 1957a: 26; Jelgersma 1960). In such cases, the stratigraphy of *Sphagnum* peat is only interrupted by a clayey layer. Above the clay, the sequence continues. Even today, this phenomenon of floating peat can be observed in the Sehestedter Moor (Behre 1990a: 92, 1991c: 51).

In the Heenvliet diagram, in contrast, no intercalated clay has been observed and the ^{14}C dates do not show a continuing sequence. This can only be explained by redeposition of an island of peat right upon a contemporaneous body of peat. The absence of clay in between is very remarkable in view of this explanation.

Later, a second attempt was made to sample peat formed during the Roman Period near Heenvliet in the hope that the phenomenon described above would be of spatially restricted importance. Before chemically treating the samples and the subsequent time-consuming counting of pollen, it was decided to await the ^{14}C date of the top of the peat. This appeared to be 2395 ± 30 BP (GrN-18054), so further processing of this core was abandoned.

In view of these two experiences, the upper ^{14}C date of the R.G.D. pollen diagram near Heenvliet (1830 ± 110 BP) was given additional attention. It was measured before the Suess-effect became known (cf. Vogel/ Waterbolk 1963). The reference number of the Heenvliet dating is Gro-308 (De Jong *pers. comm.*). It must be corrected by 0 ± 20 years to account for the Suess-effect (Vogel/ Waterbolk 1963). Calibration[5] of 1830 ± 130 BP results in a 1σ interval of 30-340 AD and a 2σ interval of 110 BC-460 AD and 480-530 AD. As a result, the top of the peat in the R.G.D. section indeed is -in an absolute sense- younger than the top in the present two sections, since their 2σ ranges span 762-402 BC (for 2425 ± 35 BP) and 754-398 BC (for 2395 ± 30 BP). Regrettably, this peat-growth during the Roman Period could not be re-analyzed in the present study.

2.4.4   THE POLLEN DIAGRAM OF SIMONSHAVEN
This section was analysed by L.I. Kooistra (1984). It was sampled by means of two monolith tins (50 × 5 × 5 cm) in a section at ca. 70 m distance from the excavated Roman site of Simonshaven 17-24 (see also Van Trierum 1986).

The *Sphagnum* peat at the base of this diagram shows relatively high percentages of *Fagus*, which indicates a

Subatlantic age for this base (see *fig. 18*). Next to *Fagus*, *Quercus* and *Corylus* are the predominating upland trees. *Pinus* shows low values, its pollen will have arrived through long-distance transport. *Alnus* has relatively high percentages. *Myrica* shows a remarkable maximum in the top of the *Sphagnum* peat. This is a strong indication of decomposition of the peat. Most likely, this decomposition is caused by desiccation owing to the increased marine influence that finally resulted in the deposition of the clayey layer on top of the *Sphagnum* peat. The high values of Chenopodiaceae in this clay deposit are in agreement with this observation.

The *Sphagnum* peat has been ^{14}C-dated at two levels. One date was obtained from a level with abundant fungal spores and hyphae. Kooistra (1984) assumed that this level would represent the Early Iron Age surface, which is covered by renewed peat growth as was already known from excavation of Early Iron Age sites around the Bernisse (see *ch. 1*). The ^{14}C date, viz. 2490 ± 30 BP (GrN-12217; cf. Van Trierum 1986), indicates that the level does indeed correspond to the Early Iron Age. The top of the peat yielded a date of 2355 ± 30 BP (GrN-12216).

The clayey deposit covering the *Sphagnum* peat belongs to the Dunkirk I sediments. The high percentages of *Pinus* and Cerealia-type in the clayey sediment illustrates the effects of aquatic long-distance transport. The peat on top of this deposit is fen peat in which *Phragmites* roots predominate. Alder (*Alnus glutinosa*) seeds are also present. The very high maximum of *Alnus* pollen is another indication of the local presence of alder carr on this site. It is the reason why *Alnus* has been excluded from the pollen sum. The upland tree pollen percentages in this part of the diagram show fluctuating values of *Quercus*, low numbers of *Corylus*, and a relatively high share of *Fraxinus*. *Pinus* values sometimes exceed 10%. *Carpinus* shows a continuous curve above the 1%-level, which is indicative of a dating after the beginning of the Christian era. The calibrated ^{14}C dates obtained from this *Phragmites* peat reveal that it was deposited between 248-384 (base) and 608-668 AD (top; both 2σ ranges; see *2.6*). Thus, the peat was mainly formed after the Roman inhabitation on Voorne-Putten.

The upper clayey layer again shows increased values of Chenopodiaceae, confirming the marine origin of this deposit, which belongs to a Dunkirk III transgression phase.

2.4.5   A POLLEN SPECTRUM FROM ZUIDLAND

A section from Zuidland was sampled by means of a corer. The analysis has not yet been completed. Since the spectrum from the top of the peat is relevant to the reconstruction of the environment during the Early and Middle Iron Age (see *2.5*), this spectrum has been included in the present study (see *table 3*, which concerns counted numbers).

Table 3. Pollenspectrum from Zuidland. Analysis W.J. Kuijper.

Spectrum	150
Upland trees	
Quercus	54
Corylus	17
Tilia	–
Ulmus	6
Fraxinus	33
Betula	63
Fagus	36
Pinus	8
Carpinus	12
Pollensum	229
Wetland trees	
Alnus	307
Myrica	99
Salix	–
Herbs	
Artemisia	1
Chenopodiaceae	3
Cruciferae	1
Cyperaceae	95
Ericaceae	184
Gramineae	42
Plantago lanceolata	3
Rubiaceae	1
Sparganium erectum	5
Urtica	1
Spores	
Monoletae psilatae	23
Sphagnum	9

2.4.6   THE POLLEN DIAGRAM OF ROCKANJE II [6]

This section was sampled with a corer (Ø 3 cm) at ca. 350 m southeast of the excavated settlement of Rockanje II. The section was studied by L. Duistermaat (1986). The main goal of the investigation of this section was to provide data about the development of vegetation during Roman habitation. This information was to have been obtained by analysis of a section through the so-called "Roman peat" near the excavation (see further *2.6*).

The lowermost part of the section, which consists of *Sphagnum* peat, was not the part of greatest interest in the original study. However, it does provide data that are relevant to the present research. Although no ^{14}C dates have been obtained from this *Sphagnum* peat, it is of Subatlantic age, in view of the *Fagus* percentages and the fact that the peat is covered by Dunkirk I sediments.

The strongly declining *Quercus* values in the lower part of the section (see *fig. 19*) are reminiscent of the pollen diagrams from Spijkenisse. However, Early and Middle Iron Age habitation has not or only sparsely been demonstrated on western Voorne. The pollen of *Quercus* most likely originated from oaks in the Older Dunes (see *2.5*), which

were situated further west than the present coast line of
Voorne (see *ch. 1*). To the south and north of Voorne, these
Older Dunes were demonstrated to have been relatively
densely inhabited during the Iron Age (Van Heeringen
1992). It is highly probable that the Older Dunes on Voorne
were inhabited, too. This habitation may have caused the
decrease of pollen production of oaks, through felling. As in
Spijkenisse, *Corylus* shows a (relative) increase. Whether this
is in fact only a relative increase cannot be proved, absolute
countings have not been undertaken. The familiar peak of
Myrica just prior to the sedimentation of Dunkirk I deposits
can also be observed in this diagram.

The high values of *Rumex acetosa*-type that occur during
the decline of *Quercus*, also point to an anthropogenic
influence. As the pollen of this herb will not be dispersed
far, this is an indication that human influence did occur in
the western part of Voorne during the Early or Middle Iron
Age. The maxima of *Lotus uliginosus* and *Hydrocotyle vul-
garis* coincide with the *Quercus*-minima. The same correla-
tion can be observed in the diagram of Spijkenisse 17-34.
Probably, these herbs are also favourably influenced by
anthropogenic activities.

As the ¹⁴C dates demonstrate, the upper peat is mainly
"post-Roman", as in Simonshaven (see further *2.6*). The
upland trees in the post-Roman peat show a decrease in
Corylus pollen and an increase of *Fagus*. The upper clayey
sediment shows a higher level of *Corylus*, but this is most
likely redeposited. Chenopodiaceae also reach a high
percentage in this upper spectrum.

The large numbers of *Menyanthes* pollen in the post-
Roman peat indicate mesotrophic conditions in this peat.

2.4.7   EIGHT POLLEN SPECTRA FROM NIEUWENHOORN
Another attempt to obtain palynological information about
the Roman Period was made near Nieuwenhoorn. In the
vicinity of an excavated Roman settlement, peat occurred on
top of Dunkirk I sediments, corresponding to Van Staaldui-
nen's "Roman" peat. The section was sampled by means of
a corer (Ø 6 cm), the stratigraphy is given in figure 20. The
eight spectra analysed (see table 4) show that the spectra
from 256 cm upwards are of Subatlantic age, seeing the
share of *Fagus*. The corresponding ¹⁴C date is rather old. In
view of the relatively high share of *Pinus*, part of the *Fagus*
pollen in this spectrum may have derived from aquatic long-
distance transport. ¹⁴C dates further demonstrate the upper
peaty sediment to belong to the peat formed after the
Roman inhabitation. Again, an attempt to obtain truly
"Roman" peat failed.

2.4.8   THE POLLEN DIAGRAM OF ROCKANJE 08-52
This section was sampled by means of a monolith tin (50 ×
15 × 10 cm). The section is located at a distance of ca. 2 m
outside the excavated houseplan on this site. There was ca.
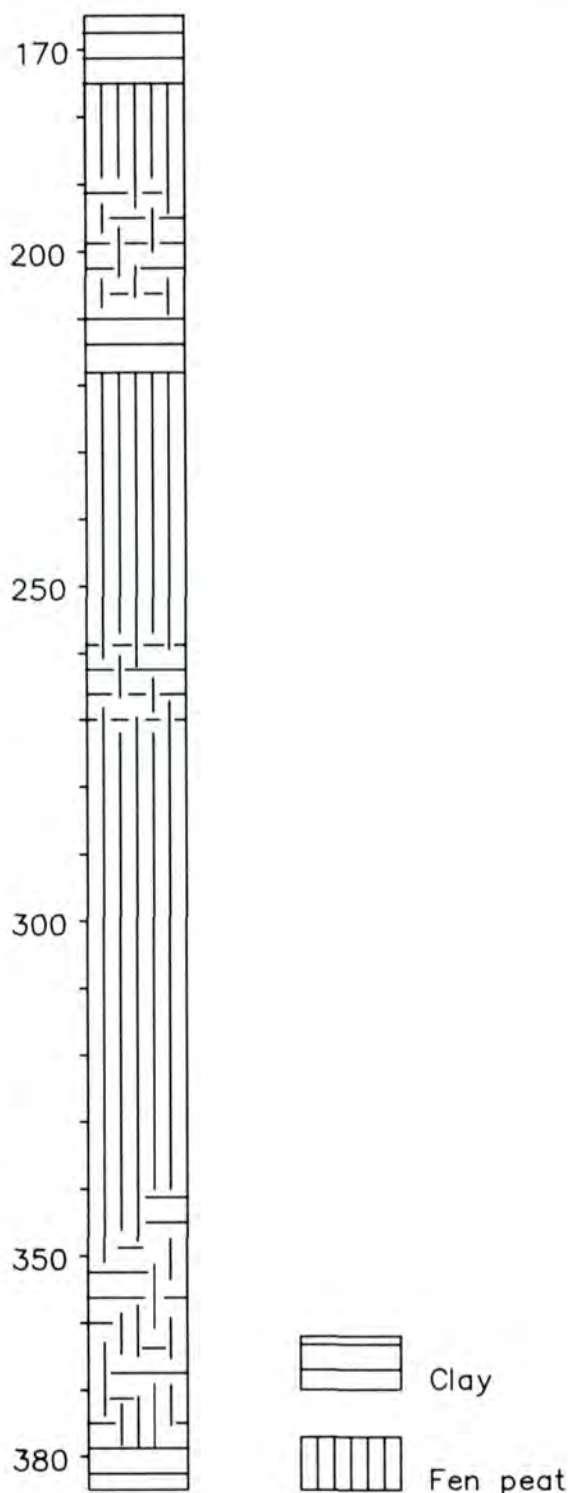
Fig. 20 Stratigraphy of the coring of Nieuwenhoorn.

Table 4. Pollen spectra from Nieuwenhoorn. To each spectrum, one tablet containing 12,100 *Lycopodium* spores was added.

Spectrum (depth ÷ N.A.P.)	390	364	334	304	286	254	238	218
¹⁴C date				3355	2910	2515		1695
				± 40	± 40	± 40		± 30
GrN-number				15224	15225	15226		15227
Upland trees								
Quercus	54.9	28.4	39.7	43.2	15.5	22.0	18.6	37.8
Corylus	12.6	13.6	27.6	24.0	11.3	35.0	5.1	14.3
Tilia	4.0	6.8	0.9	2.6	–	1.0	–	1.0
Ulmus	1.1	–	2.6	2.6	4.2	3.0	2.5	–
Fraxinus	8.6	3.4	3.4	5.7	2.8	11.0	1.7	7.1
Betula	4.6	34.1	20.7	21.9	45.1	16.0	61.9	31.6
Fagus	0.6	1.1	–	–	7.0	6.0	3.4	6.1
Pinus	12.6	12.5	5.2	–	14.1	6.0	6.8	1.0
Picea	0.6	–	–	–	–	–	–	–
Carpinus	–	–	–	–	–	–	–	1.0
Hedera	0.6	–	–	–	–	–	–	–
Pollensum (n)	175	88	116	192	71	100	118	98
Lycopodium (n)	42	31	181	36	44	32	7	33
Wetland trees								
Alnus	16.6	75.0	44.8	42.7	139.4	61.0	84.7	79.6
Myrica	6.3	3.4	6.0	2.6	–	–	–	–
Salix	1.1	–	–	2.6	–	2.0	6.8	–
Herbs								
Artemisia	1.1	1.1	0.9	1.0	5.6	2.0	1.7	3.1
Calystegia	3.4	–	–	–	–	–	–	2.0
Caryophyllaceae	–	14.8	18.1	–	–	1.0	0.8	1.0
Chenopodiaceae	8.6	25.0	–	51.6	42.3	8.0	28.0	6.1
Compositae lig.	–	1.1	–	–	–	6.0	13.6	–
Compositae tub.	1.1	1.1	–	3.6	4.2	3.0	11.9	2.0
Cruciferae	–	4.5	–	8.3	1.4	1.0	1.7	–
Cyperaceae	136.0	28.4	59.5	41.1	142.2	28.0	17.8	91.8
Ericaceae	1.1	10.2	–	0.5	4.2	64.0	48.3	7.1
Filipendula	0.6	–	–	–	–	–	0.8	–
Gramineae	165.7	68.2	87.1	103.1	400.0	132.0	55.9	479.6
Lotus uliginosus	1.1	–	–	–	–	–	–	–
Lythrum	2.3	–	–	–	–	–	–	1.0
Malvaceae	–	2.3	–	–	–	–	–	–
Mentha-type	1.1	–	–	–	–	–	–	–
Monoletae psilatae	22.9	39.8	24.1	31.2	15.5	12.0	–	1.0
Plantago lanceolata	1.1	–	–	–	–	–	0.8	3.1
Plantago major/media	–	–	–	–	1.4	–	–	–
cf Potamogeton	5.1	–	–	–	–	–	–	1.0
Rubiaceae	18.9	–	2.6	1.0	–	–	–	–
eu-Rumex	–	1.1	–	–	–	–	–	10.2
Rumex acetosa-type	–	1.1	2.6	–	–	–	–	–
Sparganium emersum-t.	–	–	–	0.5	–	–	–	–
Sparganium erectum	10.9	4.5	1.7	–	–	–	2.5	5.1
Sphagnum	–	2.3	–	3.6	5.6	–	39.8	2.0
Stachys-type	0.6	–	–	–	–	–	–	–
Succisa	–	1.1	–	–	–	–	–	–
Triletae psilatae	2.3	–	–	3.1	–	–	–	–
Typha latifolia	0.6	–	0.9	–	–	–	–	–
Umbelliferae	–	4.5	2.6	0.5	–	–	2.5	5.1
Urtica	–	–	–	–	–	–	0.8	1.0

Additional ¹⁴C date: 178 cm below surface: 1500 ± 30 BP (GrN-15228)

55 cm of *Phragmites* peat on top of a Calais IV clay deposit
below the sampled part of the section. Then followed 25 cm
of Dunkirk 0 clay, which was covered by 30 cm of fen peat
with *Phragmites*. Upon this fen peat came a 7 cm thick layer
of slightly decomposed *Sphagnum* peat. This layer in its turn
was covered by a layer of strongly decomposed *Sphagnum*
peat of 14 cm in thickness. The upper 6 cm of this strongly
decomposed *Sphagnum* peat was present at the base of the
sampled part of the section. Above this strongly decom-
posed *Sphagnum* peat occurred a 19 cm thick deposit of
settlement waste.

On top of this anthropogenic deposit lay a Dunkirk I
sediment, which was peaty at its base. The presence of a
Dunkirk I deposit above a Late Iron Age level is of great
chronostratigraphic importance. The implications were dis-
cussed in *1.2.1.3*. The Dunkirk I deposit in the pollen sec-
tion became more clayey towards the top. These Dunkirk I
sediments contained Roman pottery sherds in the upper
part. Above this sediment, another peaty layer occurred,
which was covered by Dunkirk III deposits. This peaty layer
is presumably equivalent to the "post-Roman" peat that
was already investigated in the diagrams from Simonshaven
and Rockanje II (see *2.4.4*; *2.4.6*). It has therefore not been
included in the present diagram.

The presence of the strongly organic Dunkirk I sediment
between a Late Iron Age deposit and one from the Roman
Period provided a means of obtaining palynological in-
formation on the decades around the beginning of the
Christian era. In view of the rarity of this period in pollen
diagrams on Voorne-Putten, it has been included in the
present study. It should be kept in mind that the layer
concerned is clayey, which implies that part of the pollen
may have been transported by water over a long distance.
Redeposition of pollen may potentially have occurred, too.

The inclusion of the present section, which was sampled
in October 1991, was only possible thanks to Mrs. Drs. M.J.
Alkemade-Eriks, who undertook the counting of most of the
samples. The resulting diagram is shown in figure 21.

The base of the diagram, which consists of *Sphagnum* peat
(zone A), shows relatively low values of *Quercus*. *Betula*
reaches high values compared to the diagrams discussed
above. *Fagus* shows a decline, which continues through the
following zone (B), consisting of the anthropogenic deposit.
Alnus shows high percentages at the base of the diagram.

The anthropogenic deposit shows high values of Compo-
sitae, Cruciferae, Umbelliferae and Gramineae, all of which
most probably have their origin in synanthropic vegetation
types. Partly they may have been brought to the site by
man. Remarkable is the occurrence of several indicators of
high salinity, such as *Plantago maritima*, *Spergularia* and
Foraminiferae. Apparently, the environment has a saline
component in the vicinity of the site. Most strikingly, the
spores of *Sphagnum* hardly occur in the *Sphagnum* peat and
strongly increase in the anthropogenic deposit.

The peaty base of the Dunkirk I deposit (zone C) shows
increased values of *Quercus*. Unfortunately, *Pinus* shows
values between 12 and 25%, an indication that part of the
pollen is transported by water. The marine type 116 is
another indication for transport by water. This type is found
numerously in zone C. This may also apply to the *Quercus*
pollen, especially in view of the corresponding trends in the
curves of *Quercus* and *Pinus* from the second zone onwards.
The consequence of this observation is that the increased
values of *Quercus* between the Late Iron Age and the
Roman Period cannot be considered a reliable indication of
the greater importance of oak on Voorne in this period.
Therefore, this pollen diagram does not permit a reliable
reconstruction of the vegetation during the Roman Period.

The Dunkirk I deposit shows relatively high values of
Cerealia-type. The interpretation of this Cerealia-type need
not simply that we are dealing here with grain. As was
already concluded by Firbas (1937: 463-464), cereal pollen
can readily be demonstrated, if hexaploid wheat species
(with comparatively large pollen grains), such as bread- and
clubwheat (*Triticum aestivum* s.l.) or if *Secale* and *Avena
sativa* are present. However, more uncertainties arise, where
barley (*Hordeum vulgare/distichum*) and emmer (*Triticum
dicoccum*) are concerned, because their pollen resembles that
of some wild grasses. Einkorn (*Triticum monococcum*) is
even more similar to wild grasses (see also Diot 1992). Thus,
the Iron Age cereals, mainly barley and emmer, do not
differ much in size from particular wild grasses. Later
investigations into this problem made use of phase contrast
microscopy. Here, not only size, but also microsculpture of
the grain has been considered (Grohne 1957b; Beug 1961).
However, no unambiguous identification criteria for cereal
pollen have so far been drawn up.

According to Beug, *Hordeum* type amongst other things
comprises cultivated and wild *Hordeum* species, *Agropyron*
species, *Glyceria fluitans* and several *Bromus* species. *Triti-
cum* type comprises *Ammophila arenaria* and probably some
Bromus species and some grains of *Elymus arenarius*. *Avena*
type includes only species of this genus, but also the wild
Avena fatua. *Zea mays* and *Secale cereale* can be recognized
unambiguously, although a small number of *Secale* grains
belong to the *Hordeum* type. Küster (1988: 17) also dealt
extensively with the identification of Gramineae pollen.
According to him, most of Beug's cereal-like grass pollen
(*Bromus*, *Glyceria*) can be distinguished from true cereals.
He also separates *Elymus* from cereals which, however, is
not supported by material in our reference collection.
Ammophila is not included in his study. Andersen (1979)
also stated that *Ammophila arenaria*, *Agropyron* species, *Ely-
mus arenarius* and *Glyceria* species cannot be distinguished
from *Hordeum*-type pollen, which furthermore includes *Hor-
deum vulgare* and *Triticum monococcum*.

In view of the proximity of the coast near Rockanje, the
Cerealia-type pollen grains may well have originated from

wild grasses. Besides, aquatic long-distance transport of Cerealia-type pollen may have occurred as well.

2.5 Reconstruction of the Early and Middle Iron Age environment.

2.5.1 THE LOCAL ENVIRONMENT AROUND THE IRON AGE SITES

Peat near two excavated Iron Age sites near Spijkenisse (17-30 and 17-34) has been analysed for pollen. Both these sites are situated in the vicinity of the Bernisse. The palynological data provided by these sections will be used as models for all Early and Middle Iron Age sites around the Bernisse.

Local environment can be reconstructed with the pollen diagrams of Spijkenisse 17-30 and 17-34. Supplementation of these data is possible with botanical macroremains recovered in the various sites. These will be discussed in a following chapter (*ch. 4*).

Local vegetation can be reconstructed by means of the pollen deposition it produced. In the peaty area concerned, local pollen mainly originates from herbaceous plants. The pollen diagrams of Spijkenisse reveal that Gramineae and Cyperaceae are the most important herbs throughout the sections, ferns are also well represented. Ericaceae and *Sphagnum* are scarce. These data indicate that we are dealing with eutrophic fen peat here. Especially the macroremains indicate the presence of reed vegetation types (Phragmitetea).

There are three possible developments in the natural vegetation succession of eutrophic fen peat (Westhoff *et al.* 1971: 71-76). Firstly, this type of peat may develop into an alder carr. There, alder (*Alnus*) occurs as a local component, leading to *Alnus* percentages into several hundreds if outside the pollen sum, or a complete domination of the pollen sum if included in it. Secondly, eutrophic fen peat vegetation may show a development into oligotrophic raised bogs, especially during lowering (!) of the water table, which brings the vegetation out of reach of the mineral-rich ground water (Behre 1987, 1990a). Thirdly, a natural development of ruderal vegetation types may occur.

The development of an alder carr is not recorded in either diagram; local alder carrs did not occur near Spijkenisse. A raised bog, which would show high values of Ericaceae and *Sphagnum*, was clearly not present near Spijkenisse either in the period concerned. The development of ruderal vegetation types will mainly express itself in an increase in tall herbs (e.g. *Lythrum salicaria*, *Valeriana officinalis* and *Thalictrum flavum*: Westhoff *et al.* 1971), which does not show up clearly in the pollen diagrams, although the peak of *Lythrum salicaria* in both diagrams of Spijkenisse may point to such a development. Continuous presence of fen peat is only found when a steadily rising water table occurs. If this

rise stagnates, oligotrophic bog would develop, if the water table rises too fast, the fen peat is drowned, as can be seen in the top of the two Spijkenisse diagrams.

Apparently, man had settled in those parts of reed swamps which had fallen dry. These swamps were part of an open landscape, in which trees did hardly or not occur within several hundred metres of the site. These dried-out reed swamps were to be found along the natural water courses that caused the drainage. All the known Iron Age sites around the Bernisse are situated in the vicinity of creeks (Van Trierum *in press*). These creeks apparently did not drain the peat to such an extent that peat formation ceased everywhere during the Early Iron Age. This is demonstrated by the continued peat growth in the sections of Spijkenisse 17-30 and Simonshaven.

Total drainage of the peat is connected with the Middle Iron Age. Decomposition of the peat gave rise to large-scale colonization by *Myrica gale*. This phenomenon is probably indicative of the approaching transgression. Increasing marine influence finally resulted in the deposition of Dunkirk I sediments in the area around the Bernisse.

Near Heenvliet, the transition to an oligotrophic raised bog did take place. Already before the start of the Subatlantic, a raised bog dominated by *Sphagnum* and Ericaceae had developed here.

Since the pollen dispersal of practically all herbs is limited, it is very difficult to assess the horizontal distribution of eutrophic reed swamps, oligotrophic raised bogs and the intermediate mesotrophic peat types, amongst other things characterized by *Menyanthes* and Cyperaceae. Only by means of a dense grid of corings in combination with ^{14}C datings, can this problem be (partly) solved.

To what extent *Alnus* occurred locally in the peaty landscape is another important topic. As is shown by the section of Simonshaven (see *2.4.4*), during the first half of the first millenium AD local alder carr developed at that site, resulting in 1295% of *Alnus* pollen (of course excluded from the pollen sum). Such high values have not been recorded in the diagrams discussed above. Only one of the pollen diagrams of Voorne-Putten produced by the R.G.D. shows extremely high *Alnus* values. In their diagram "Spijkenisse" (Jelgersma 1957a), *Alnus* reaches values exceeding 80% (within the pollen sum) in carr peat. Alder predominated here from Subboreal times onwards into the Subatlantic up to the Roman Period.

In view of the scarcity of Subatlantic diagrams with high *Alnus* values, the landscape during the Early Iron Age in all probability showed a very patchy distribution of *Alnus*, depending upon factors such as human influence and the distribution of *Sphagnum* peat, where *Alnus* does not grow (cf. Grosse-Brauckmann 1976). Reed swamp vegetation types in an early stage of succession will also have been too wet to allow growth of *Alnus*.

2.5.2 THE LOCATION OF UPLAND FORESTS

The upland forests will have been restricted to mineral soils, with relatively low water tables during the growing season. These drier, mineral soils are very interesting from an arable point of view. The landscape during the Early and Middle Iron Age on Voorne-Putten was dominated by peat. It is highly probable that the mineral soils were the only soils suited to the cultivation of some arable products (see *ch. 6*). The location of these mineral soils in relation to the Iron Age sites is crucial for the economic possibilities of these sites. Therefore, the following reasoning, developed by Turner (1975) is of great interest. She argued that the share of a particular type of vegetation in the pollen rain is large close by this vegetation and diminishes with increasing distance. If pollen diagrams from different sites are compared, the curves for a particular (set of) species can give hints for their location in relation to the pollen sites. The following example, focussed on the situation on Voorne-Putten, may serve to illustrate this.

If we assume that the upland forests, where oak and hazel predominate, are located in the dune area on western Voorne (see *ch. 1*), the share of the upland trees relative to the wetland species will decline in pollen spectra from west to east. The most important upland component is oak (*Quercus*), whereas alder (*Alnus*) is the dominant wetland tree species represented in the pollen diagrams. Since the upland trees constitute the pollen sum, they do not decline from west to east in the example given, but in this case *Alnus* increases.

To investigate the location of the upland forests, twelve pollen diagrams are now available. Apart from the eight discussed above, we also have the diagram from Hekelingen, analysed at the I.P.L. (Schuller 1981), as well as the R.G.D. diagrams from Geervliet, Brielle and Lodderland. Unfortunately, it is impossible to compare the twelve diagrams directly, the data must be made more manageable first.

Firstly, a synchronous and relevant time-slice has to be selected. Eight of these diagrams have produced ^{14}C dates roughly between 2400 and 2500 BP. In most cases, we are concerned with the top of the peat below Dunkirk I sediments. Only in two places, Spijkenisse 17-30 and Rockanje 08-52, has peat growth continued considerably after 2400 BP. For this reason, the top of the peat below DI sediments in the sections that have not been ^{14}C-dated are considered as being of comparable age. This time-slice has an additional advantage in that it represents the situation at the start of Iron Age habitation on Voorne-Putten.

The time factor has another effect. In one year, the weather may be (dis)advantageous to a particular species, resulting in a difference in the yearly pollen production. Fortunately, since the spectra used cover generally a time span of at least 20 years, such effects are smoothed out.

After we have chosen a time-slice, indicative taxa still have to be selected. Following Turner's (1975) reasoning, I have used the percentages of *Alnus* and *Quercus* as keys here. The relevant pollen diagrams were produced by different institutes and this has resulted in different pollen sums, relating to the underlying questions. To circumvent the difficulties in the comparison of these diagrams, the ratio of *Quercus* and *Alnus* is calculated for the spectra concerned. This is of great practical value, since this ratio is not influenced by the pollen sum (nor by the use of absolute numbers of pollen grains), as the following example will show. At a given pollen sum, the percentages are the numbers of *Quercus* (X) and *Alnus* (Y) found, divided by the pollen sum (ΣP) and multiplied by 100. Thus the ratio is:

$$\frac{X.100}{\Sigma P} : \frac{(X+Y).100}{\Sigma P} = X : (X + Y)$$

The use of *Quercus*, the dominant upland component, and *Alnus*, the dominant wetland component, in a ratio has another advantage in that their pollen production seems to be comparable. Their representation factor, according to Andersen (1973) is 1:4 relative to *Fagus* for both species.

Another factor which is important in the interpretation of these ratios is the dispersal capacity of the taxa concerned. If for instance pollen of *Alnus* is on average dispersed further than that of *Quercus*, and both are located in one single area, the number of *Alnus* relative to *Quercus* will increase with distance from this area. As Fægri *et al.* (1989: 122) stated,

"to control the effects of different dispersal one must also establish gradients from the pollen source outwards. Such data are not freely available anywhere".

Pollen dispersal over greater distances would also result in a greater "background component" in R-value models, incorporating such components. Direct measurings of background levels in R-value models are unknown to me. The pollen dispersal capacity of *Alnus* and *Quercus*, however, is indirectly indicated in some publications.

One parameter that has a great influence on pollen dispersal is the weight of the pollen grains. According to Janssen (1974), the average weight of *Quercus robur* pollen is 18.16 µg, that of *Alnus glutinosa* 9.37 µg. The falling speed of *Quercus* is also almost 1.5x greater than that of *Alnus*. Both these data suggest a better pollen dispersal on the part of *Alnus*.

Contrasting results have been obtained by several other investigators. Randall *et al.* (1986) studied the recent pollen rain on a treeless island in the Outer Hebrides, west of the Scottish mainland. They observed in total eight *Alnus* grains, in four samples, while the nearest forest with this tree is 40 km away. *Quercus* was recorded nine times, in two samples and the nearest location is more than 50 km away.

This is an indication that *Quercus* is dispersed at least not worse than *Alnus*.

Heim (1970: 158 ff) discussed the contribution to the regional pollen rain of tree species in Belgium. He regarded pollen that travelled distances of 500 to 10,000 m as regional pollen. On the basis of 552 locations for *Alnus* and 232 for *Quercus*, he concluded that *Alnus* on average contributes 1.8% (0.1-3.3%) to the regional pollen rain, while *Quercus'* share is 5.9% (0.6-12.0%). As in the study of Randall *et al.*, *Quercus* would seem to have better dispersal capacities than *Alnus*. Heim compared his data with those obtained by Janssen (1966) in the U.S.A. and found a seemingly great similarity. However, knotty problems arise when the question is asked what these contributions to the regional pollen rain in fact mean. They will be mainly determined by the abundance of the relevant species in the "regional" environment. If *Quercus* is ten times as common as *Alnus* in the regional vegetation, and the contribution to a location's regional pollen rain is twice as high for *Quercus*, than *Alnus* has a five times higher background component, provided that their pollen production is truly the same, as Andersen found it was. In view of the unknown quantities in the regional vegetation, the corresponding data for Belgium and the U.S.A. do not indicate a world-wide constant contribution to the regional pollen rain, but a mere coincidence.

Kalis (1984) published highly relevant data on pollen dispersal in the French Vosges. He compared the recent distribution of the tree species with the pollen deposition in a transect. He stated (p. 282) that *Alnus* pollen is present in comparable percentages in the whole transect, both in areas with many *Alnus* trees as well as in areas where they are lacking. This points to very good wind dispersal capacities of *Alnus* pollen. The relatively high pollen percentages in relation to the rather small distribution area of *Alnus* trees also points to large pollen emission for *Alnus*[7].

For *Quercus*, Kalis (1984: 293) observed that the dispersal capacity is extremely efficient. From the tree limit to the top of the "Kastelberg", the relative proportion of *Quercus* in the pollen deposition rises from 12% to 30%. At 5-15 km distance from forests with oak, *Quercus* pollen still reach 8-16%. The pollen emission (= pollen production s.l.) of *Quercus* is only moderate, according to Kalis. He also stated that the combination of a moderate pollen emission and the extremely good dispersal renders the interpretation of pollen percentages virtually impossible. Only percentages higher than ca. 20% can, according to Kalis, be interpreted with some certainty as an indication of the presence of *Quercus* in the surrounding forests, at least within forested areas and in the present circumstances. In conclusion, the pollen dispersal of *Alnus* and *Quercus* are both very good. However, in view of the contrasting data, it must be concluded that the precise effect of dispersal cannot be assessed at present.

The proportions of *Quercus* and *Alnus* in pollen diagrams

might also be influenced by differential preservation of both species. Havinga (1984) published results of a 20-year study of the differential corrosion in various soil types. He concluded that *Quercus* is more susceptible to corrosion than *Alnus*. Havinga also demonstrated that corrosion is the least in *Sphagnum* peat. Six of the sites discussed here comprise this *Sphagnum* peat. For all relevant samples I have seen, the pollen preservation is good, also in fen peat. Only the R.G.D. material has not been checked in this respect. An additional indication of the minor role of corrosion is presented by Geervliet and Heenvliet, situated close to each other. In Geervliet, we have *Phragmites* peat and in Heenvliet *Sphagnum* peat. Still, both sections produced highly similar ratios. Furthermore, the *Sphagnum* peat sections have a more southerly distribution. If selective corrosion of *Quercus* should play a role, this would result in lower ratios in the northern fen peat diagrams. This is the exact opposite of what is recorded in the present study (see below).

2.5.3   RESULTS AND CONCLUSIONS

In table 5, the locations as well as their *Quercus*/ *Quercus* + *Alnus* ratios are given. In figure 22, the lithology and ^{14}C dates, as well as the location of the pollen spectra analysed, are presented. Besides, a visual representation of these ratios is given in figure 22. Except for Heenvliet and Geervliet, these data show similar ratios for sites in east-west transects. In contrast, on Putten a steady decline of *Quercus* can be observed from north to south.

From the ratios it can be concluded that the upland forests in which oak occurred, were located in the north of Putten, stretching from east to west. Only if the dispersal of *Alnus* is significantly better than that of *Quercus*, this conclusion cannot be maintained.

Elevated levees along the Meuse are the only likely candidates for supporting these upland forests in the north of the area. The smaller levees along the Bernisse originated during the Dunkirk I transgression phase, so they did not yet exist during the time-slice discussed here. There is a deviation in the ratios in Heenvliet and Geervliet (located close to each other). This will be discussed below. The situation on Voorne will have differed owing to the vicinity of the Older Dunes. The low share of *Quercus* near Rockanje is remarkable. The *Quercus*/ *Quercus* + *Alnus* ratio in the uppermost spectrum of the peat of Rockanje 08-52 is exactly equal to the ratio of Rockanje II. This ratio is lower than the other ratios on Voorne, although Rockanje is situated closest to the dune area. The ^{14}C date of the spectrum from Rockanje 08-52 reveals that this spectrum is the youngest in the series chosen (see *fig. 23*). This may explain the lower share of *Quercus* in this spectrum.

Of course, *Quercus* is not the only species present in the upland forests. *Fagus*, *Corylus*, *Tilia* and *Ulmus* are also important constituents. Apart from *Corylus*, however, they
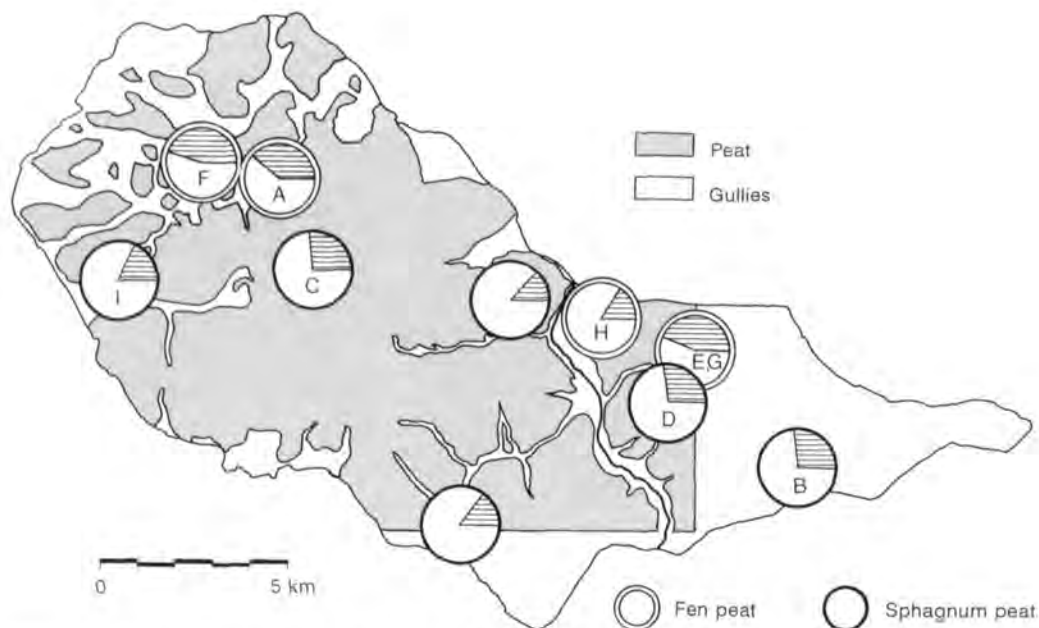
Fig. 22 *Quercus/Alnus* ratios of the pollen diagrams on Voorne-Putten, scale 1:2000. A - I: see table 5.
Hatched = *Quercus*, White = *Alnus*.

occur in relatively small amounts, and do not offer a solid base for calculating a ratio. To obtain yet another ratio, with a profound base, the ratio *Alnus/ Alnus + Quercus + Corylus + Fagus + Tilia + Ulmus* has been calculated. Of course, this ratio should show a reverse trend when compared to the previous one. An increase of the ratio at increasing distances of the upland part of the landscape is expected. As table 5 reveals, the results of the *Quercus/ Quercus + Alnus* ratios are confirmed, only Hekelingen shows a considerable deviation. Most likely, the *Corylus* curve in this diagram still contains a high share of *Myrica*. The discrimination between these taxa presented great difficulties during the counting of this diagram (Vermeeren *pers. comm.*).

Nowadays, the levees reconstructed above, are not present along the Meuse. This can be ascribed to erosion during one or more Dunkirk III transgressions in medieval times. Further upstream, this erosion did not occur, and remains of levees are still discernible (Th. de Groot *pers. comm.*).

The actual natural vegetation of levees, and its pollen production, could provide important data for comparison with the past situation. It is a great pity that the natural vegetation types of the higher parts of levees in Europe have become very rare. This is due to the excellent arable conditions on these levee soils, where regular flooding causes natural fertilization. As a result of deforestation, recent parallels are hardly found, so we have to rely on reconstructions. In the northwest German coastal area, such a recon-

struction has been possible. Thanks to excellent conditions for preservation and to detailed research, forest vegetation could be reconstructed in great detail (Behre 1985, 1988). Here, the levees have not suffered large-scale erosion. The levee along the Ems was deposited during Dunkirk 0. It has a width of 1-2 km and was first inhabited during the Early Iron Age (Behre 1984a). Directly below the settlement
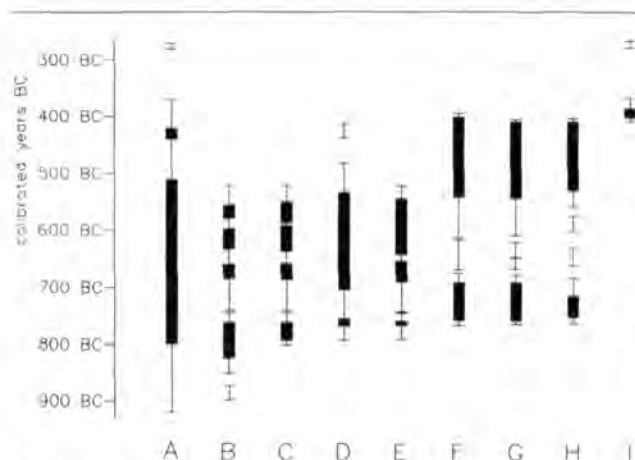
Fig. 23 Calibration of ¹⁴C dates used in table 5 and fig. 22 (symbols as in table 5). Black = 1σ interval; line = 2σ interval.

Table 5. Pollen ratios in Early Iron Age peat on Voorne-Putten. * = probably too low (see text).

	Site	Depth ÷ NAP	^{14}C date (BP)	GrN- number	Q/Q+A	A/A+ΣAP	Reference
A	Brielle-Tinte	159 cm	2510 ± 130 yr	304	0.39	0.51	Zagwijn 1955
B	Hekelingen	271 cm	2580 ± 60 yr	10431	0.27	0.33*	Schuller 1981
C	Nieuwenhoorn	250 cm	2515 ± 40 yr	15226	0.27	0.48	This publication
D	Simonshaven	310 cm	2490 ± 30 yr	12217	0.27	0.46	This publication
E	Spijkenisse 17-34	265 cm	2485 ± 40 yr	14176	0.44	0.37	This publication
F	Lodderland	192 cm	2405 ± 65 yr	104	0.45	0.46	Jelgersma 1957
G	Spijkenisse 17-30	279 cm	2435 ± 45 yr	15223	0.44	0.27	This publication
H	Heenvliet	280 cm	2425 ± 35 yr	16333	0.13	0.66	This publication
I	Rockanje 08-52	180 cm	2310 ± 30 yr	18635	0.13	0.61	This publication
	Geervliet	290 cm			0.16	0.59	De Jong 1961
	Zuidland	210 cm			0.15	0.74	This publication
	Rockanje II	250 cm			0.18	0.72	Brinkkemper *et al.* in press.

Boomborg/Hatzum on this Ems levee, 22 tree stumps were found, which had obviously been felled to clear the ground for settlement. Of the 22 stumps, 18 belonged to *Alnus*, one to *Quercus*, one to *Ulmus* and two to *Fraxinus* (Behre 1970). Furthermore, Behre (1985) published a list of trees found near Rade on a levee of the Weser (northern Germany). Of the 71 stumps that were found there, seven were of *Ulmus*, *Quercus* occurred six times, *Fraxinus* 22 and *Alnus* 36 times. Three ^{14}C dates revealed that the trees were of Late Subboreal age. Apparently the levees were densely forested, although at present they are completely treeless. The vegetation appears to have consisted of several belts parallel to the river. Nearest to the river, there were reed vegetation types. The low-lying levels next to these reed belts were covered with willow shrubs (*Salix*), flanked by willow trees. The still higher lying forest (German: *Hartholz-Aue*) is mainly characterized by ash (*Fraxinus*) on lower and oak (*Quercus*) and elm (*Ulmus*) on higher grounds.

According to Behre (1970), *Fagus* did not grow regularly on the levees in northern Germany, as it is absent in the wood spectra of sites in the Ems area. He assumes the same for *Tilia* (Behre *pers. comm.*). This is in contrast to the observation presented here that *Quercus*, *Fagus* and *Tilia* decline simultaneously. It is highly probable that they also occurred in the same vegetation. In this respect, palynological research in a comparable area further to the north, near Swifterbant is significant. On the levees where Neolithic settlement has been attested, *Tilia* is also assumed to have occurred (Casparie *et al.* 1977: 50) in a landscape, which will have been quite similar to that in the Meuse Estuary. The absence of *Fagus* in Swifterbant, both among wood and pollen, will be a result of the Atlantic/Subboreal date of the deposit.

According to Behre (1985), the *Hartholz-Auen* occupied the elevated levees along the river banks downstream as far as the transition to brackish conditions. In this respect, the strong decline of the *Quercus*/*Quercus + Alnus* ratio between Spijkenisse and Geervliet deserves further attention. It can be explained by assuming that the transition from fresh to brackish conditions during the Iron Age must be sought here. This area is situated at ca. 20 km from the former coast line. These data are well in agreement with those of Zonneveld (1960), when a high river discharge (to today's standards) is assumed. The upland pollen component in the diagrams on Voorne will mainly have come from the Older Dunes, since the levees there were in the salt to brackish tidal area.

Because of the scarcity of modern equivalents of these vegetation types, it is hardly (or even not at all) possible to collect modern pollen data and to relate them to modern vegetation. The pollen representation factors (to transform amounts of pollen to crown coverage in vegetation) can only be used with some confidence, if the modern situation closely matches the one in the past. Thus, for the present data, no adequate R_{rel}-factors can be obtained. As a consequence, reconstructions of former crown coverages are out of reach at the present state of research.

Behre (1970) published three pollen diagrams situated along a transect from the Ems levee into the backswamp area. Unfortunately, very few ^{14}C dates were obtained, so the only possibility of designating synchronous levels is with palynological datings. Behre's section RL7 is situated closest to the levee. Here, peat growth stopped at the onset of the Subatlantic period. In this spectrum, the *Quercus*/ *Quercus + Alnus* ratio is 39.4%. Behre's section RL 29 is located at ca. 5.3 km distance from RL7, the corresponding ratio at the Subboreal/Subatlantic boundary is 34.4%. Pleistocene deposits are at a distance of ca. 3 km from RL29, while a small Pleistocene "island" is ca. 1.5 km away. A third diagram has been obtained from the vicinity of this "island" (RL37). Remarkably enough, its ratio at the Subboreal/ Subatlantic transition is lowest, reaching 25.5%. It may be concluded that some diminishing trends in the *Quercus*/ *Quercus + Alnus* ratio in a transect away from the levee seem

Table 6. ^{14}C-dates of "Roman peat" on Voorne-Putten.

Site	^{14}C-date	GrN-number	Reference
Rockanje II (base)	1790 ± 65 BP	GrN-14594	Brinkkemper *et al. in prep.*
Lodderland	1725 ± 65 BP	GrN-1093	Jelgersma 1961
Simonshaven (base)	1720 ± 25 BP	GrN-12215	This publication
Nieuwenhoorn (base)	1695 ± 30 BP	GrN-15227	This publication
Nieuwenhoorn (top)	1500 ± 30 BP	GrN-15228	This publication
Rockanje II (top)	1470 ± 60 BP	GrN-14593	Brinkkemper *et al. in prep.*
Simonshaven (top)	1395 ± 30 BP	GrN-12214	This publication

to present themselves. The nearness of Pleistocene deposits probably bring about the relatively small decline in the ratio.

The ratio from RL7 is still rather low in comparison to the ratios found near Spijkenisse, in the northern part of Putten. This may be explained by the age of the deposits concerned. The Ems levee consists of Dunkirk 0 deposits (see above), the soils are thus relatively immature at the start of the Subatlantic period. This coincides with the small share of *Quercus* in the tree stumps found in Boomborg-Hatzum. On Voorne-Putten, the levees are most likely of greater age. In view of the scarcity of Dunkirk 0- and the commonness of Calais IV deposits, the levees were probably Calais IV deposits, which will have been much more matured in the period concerned. This will have allowed a greater extension of the "*Hartholz-Aue*" forests and a more common occurrence of *Quercus*, and probably of *Fagus* and *Tilia* as well.

2.6   Environmental reconstructions for the Roman Period.

The pollen diagrams discussed in paragraph 2.4 mainly cover the Subatlantic period up to c. 2200 BP. In most locations, peat formation ceased after the Middle Iron Age, preventing environmental reconstructions for the Late Iron Age and Roman Period. The scarcity of peat formation after deposition of Dunkirk I sediments has a parallel in the northwest German coastal area. Behre (1986b: 46) described the dominance of large-scale soil development in areas near the coast during this period. Further inland, a transition from eutrophic fen peats to oligotrophic bogs occurs on a large scale. Both these phenomena can be attributed to lowering water tables, correlated with a regression of the sea. Van Staalduinen (1979: 55) presented a map with the distribution of "Roman Peat" (see *fig. 7*), seemingly a good source of information about the Roman Period. So far, four of these locations with "Roman Peat" on Voorne-Putten have produced ^{14}C dates (see *table 6*).

Calibration of the data (see *fig. 24*) reveals that peat formation did not start before ca. 200 AD. Roman habitation on Voorne-Putten continued to 260 AD at the latest. Therefore, peat formation started at the very end of or even after Roman habitation of the area (see also Van Trierum *et*

al. 1988). No palynological data on the landscape during the Late Iron Age, nor those on the influence of the beginning of Roman occupation, can be obtained. The term "post-Roman" peat would thus be more appropriate, at least from an archaeological point of view.

Environmental development after Roman habitation can be reconstructed by means of the diagrams of Simonshaven and Rockanje II. This is still relevant to the present research, since they may show regeneration of the forest. The top of the peaty sediment in these sections has been dated, 1395 ± 30 BP (GrN-12214) in Simonshaven and 1470 ± 60 BP (GrN-14593) in Rockanje II. Both diagrams show declines of *Corylus*, while *Carpinus* and *Fraxinus* increase in both diagrams. In Rockanje II, *Quercus* shows a gradual rise, and *Fagus* a conspicuous one, which is much less clearly expressed in Simonshaven. *Tilia* shows very low percentages in both diagrams, but is not absent. *Ulmus* shows a gradual rise in Rockanje II. In conclusion, the primary upland forest elements recover in both diagrams, more markedly so in Rockanje II. Rockanje is relatively close to the dune area, whereas Simonshaven is far from any upland parts of the landscape. This is supported by the large rise in *Alnus* in Simonshaven (up to 1295%). Near Rockanje II, *Alnus* also increases, but not beyond 90%.

The rising values of the primary forest elements *Quercus*, *Fagus* and *Ulmus* in Rockanje indicate that these trees had occupied considerably less than their potential area during peat growth at the base of the "Roman peat", i.e. the latter part of the Roman Period. Although the environment became increasingly wet, as is demonstrated by peat growth, the upland trees mentioned could increase. It is tempting to impute the reduction of the area of primary forest during the Roman Period to human activities. *Quercus* and to a lesser extent *Ulmus* are important construction elements in some Roman settlements (see *ch. 3*). Furthermore, it has been shown by dendrochronological research on the oaks of the native Roman settlement in Nieuwenhoorn that these oaks most probably came from mineral soils on Voorne-Putten. For the construction of the last house on this site, the inhabitants had to use oaks with a much more irregular growth, which points to worse growing conditions. This may point to exhaustion of the oaks of better quality (see *3.2*).

A last possibility for obtaining information on the "miss-
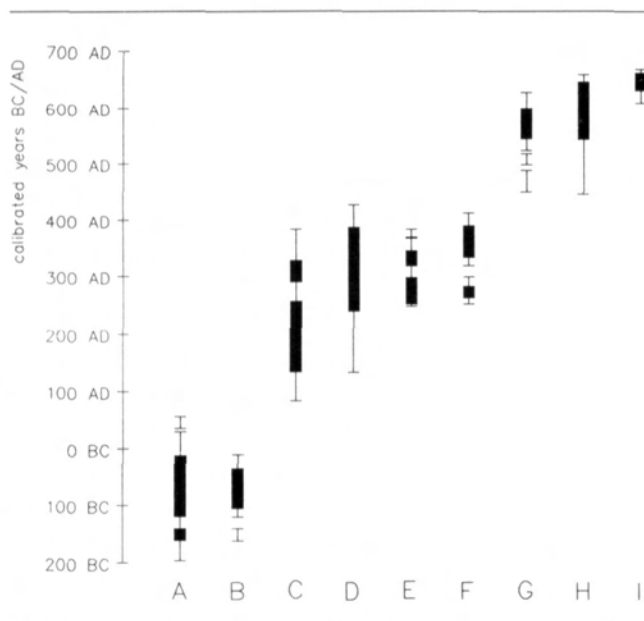
Fig. 24 Calibration of ^{14}C dates of a Late Iron Age post, the peaty base of the Dunkirk I deposit at Rockanje 08-52 and of "Roman peat". Black = 1σ interval; line = 2σ interval.
A = Rockanje 08-06   (2060 ± 50 BP; GrN-6401)
B = Rockanje 08-52-I   (2050 ± 30 BP; GrN-18634)
C = Rockanje II (base)   (1790 ± 65 BP; GrN-14594)
D = Lodderland   (1725 ± 65 BP; GrN-1093)
E = Simonshaven (base)   (1720 ± 25 BP; GrN-12215)
F = Nieuwenhoorn (base)   (1695 ± 30 BP; GrN-15227)
G = Nieuwenhoorn (top)   (1500 ± 30 BP; GrN-15228)
H = Rockanje II (top)   (1470 ± 60 BP; GrN-14593)
I = Simonshaven (top)   (1395 ± 30 BP; GrN-12214)

ing period" (Late Iron Age and Early Roman Period) is offered by the R.G.D. diagram from Heenvliet, where a ^{14}C date of the top of peaty deposit of 1830 ± 130 BP was obtained. Apart from the base of the peaty sediment, no further datings have been carried out. This diagram, which was kindly placed at my disposal by Ing. De Jong, is presented in figure 25. The lower part of the Heenvliet diagram analysed in the present study (see 2.4.3) has been dated more thoroughly, but the sequence stops at 2425 BP. A possible solution to this problem is offered by comparing both diagrams by means of statistical methods. Birks and Gordon (1985) gave several examples of similar approaches in comparing two diagrams. Their method of sequence-slotting could not be used for the two Heenvliet diagrams since the software needed was not at our disposal. In the data sets of Birks and Gordon, Principal Components Analysis yielded results comparable to sequence-slotting. Unfortunately, this method appeared unsuitable for the two Heenvliet diagrams. Virtually all the spectra were located in one large cluster in which 41 of the 49 spectra occurred. This does not give a reliable indication about which spectra in both diagrams are most similar, since practically all the spectra are similar.

Therefore, it was investigated whether cluster analysis could yield results that were easier to interpret. Details on this method will be discussed in paragraph 4.7.1. In the present situation, the Euclidean distance was used for calculating the similarity between the samples. The results can be represented in a dendrogram, which shows clusters of variables (in this case pollen spectra) that are more similar to

each other than to variables in other clusters within the same dendrogram.

The dendrogram for the two Heenvliet sections is given in figure 26. Additionally, ^{14}C dates obtained from either of the two sections have been indicated next to the spectrum concerned. Subsequently, it has been assumed that a ^{14}C date for a given spectrum of my Heenvliet diagram can be assigned to a spectrum in the R.G.D. diagram if it occurs in the same cluster. Thus, spectrum "RGD60" is "dated" at 2425 ± 25 BP, "RGD75" as 2820 ± 50 BP and "RGD150" as 3945 ± 45 BP. The spectrum "HEEN158" (from my diagram) occurs in a cluster with two R.G.D. spectra (83 and 100). If the corresponding date of 3895 ± 45 BP was attributed to "RGD83", the stratigraphical lower sample "RGD88" would be younger. Therefore, this date has been assigned to RGD100. Apart from this ambiguity, all other inferred datings of the R.G.D. diagram are in stratigraphical order.

The spectra "HEEN148" and "HEEN134" correspond most closely with "RGD95" and "RGD88" respectively, but the very long branches of the dendrogram indicate that these spectra are not very similar. In consequence, these datings were not used, although both would fit in with the stratigraphical sequence of the datings that have been used. The original R.G.D. datings of the diagram are indicated by black rectangles, all indirect datings of the R.G.D. diagram are indicated without black rectangles.

The gratifying outcome of this exercise is that the uppermost, prolonged decline of *Quercus* in the R.G.D. diagram can be assigned to the Iron Age, while earlier, smaller
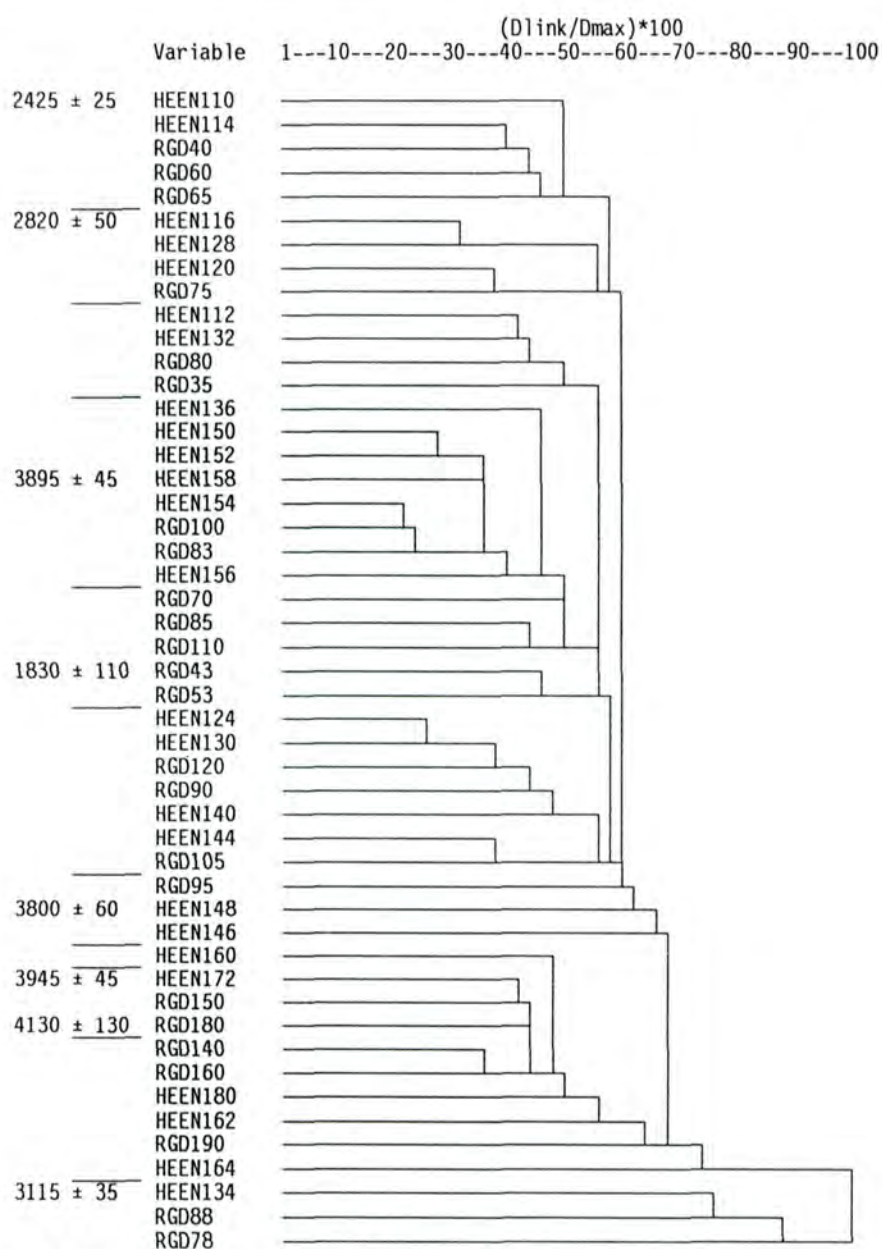
Fig. 26 The dendrogram of the cluster analysis of both Heenvliet diagrams.

declines are older. Furthermore, the diagram shows that after the Iron Age oak decline a gradual increase of oak occurred. However, the main rise occurs in the clayey sediment and part of the pollen may have been transported by water.

The Roman Period is covered by four spectra only in this diagram. This implies that it does not offer a reliable basis

for the reconstruction of the landscape during Roman inhabitation.

2.7   Conclusions

The pollen diagrams discussed in the present chapter have revealed the presence of elevated levees along the Meuse, where forests of oaks, elms and other characteristic trees of

the so-called *Hartholz-Aue* forests occurred. During the Early and Middle Iron Age, the former primary forest was felled to a considerable extent. Since the levees concerned were eroded in medieval times, it cannot be assessed whether they were inhabited during the Iron Age and/or whether arable fields were laid out.

In the wetter part of the landscape on Voorne-Putten, trees were very scarce. It was an open landscape, which showed a mosaic of vegetation types, such as reed swamps and raised bogs.

Peat formation ceased practically everywhere on Voorne-Putten after increased marine influence. This marine influence is connected with a Dunkirk I transgression phase, which took place in the last centuries before the Christian era. Locally, peat growth recovered from c. 200 AD onwards. As a result, the reconstruction of the Iron Age and Roman environment after deposition of Dunkirk I sediments is not possible. Notwithstanding that, the pollen diagrams that have been obtained from this "post-Roman" peat do show an increase in trees from primary forests. This implies that during the Roman habitation these trees occupied considerably less than their potential area.

Two sections, which were situated close to excavated Iron Age habitation sites, did not reveal any Cerealia-type pollen grains. Apparently, large-scale threshing of grain did not take place, at least not during the Early Iron Age.

notes

1 In the present study, "m" stands for metre(s), not mile(s).

2 Raw data of all pollen diagrams analysed in the I.P.L., including rare taxa, will be stored in the regional Dutch pollen database. Besides, raw data can be requested from the author.

3 Pollen of *Plantago maritima* closely resembles that of *P. lanceolata*, although the latter species has on average more pores (cf. Faegri *et al.* 1989).

4 NAP = *Normaal Amsterdams Peil*; Dutch Ordnance Datum.

5 All calibrations have been made by means of a computer programme (cf. Van der Plicht/Mook 1987).

6 Owing to the fact that "upland" herbs like Chenopodiaceae were excluded from the pollen sum, the diagram presented here (see fig. 19) is somewhat different from the diagram of the same section presented by Brinkkemper *et al.* (*in prep.*).

7 Kalis distinguishes between pollen production (sensu stricto) and pollen emission. *Tilia* is a moderately large pollen producer, but owing to the small emission of this insect-pollinated tree, it is a bad pollen producer in the conventional sense.

3 Wood-remains in constructions dating to the Iron Age and Roman Period

3.1 The sites on Voorne-Putten

Due to high watertables, the organic material, including wood, is very well preserved in most of the excavated sites on Voorne-Putten. The conditions for preservation are comparable to similar situations along lake shores and on dwelling mounds (German: *Wurten*).

Up to now, wood remains of seven pre- and protohistoric excavated sites have been investigated. The results are being published (Brinkkemper/ Vermeeren *in press*). Houseplans with the locations of the different species found have been given in that publication as well. The results will be summarized here. They concern Rotterdam-Hartelkanaal 10-69 and Spijkenisse 17-30 (both Early Iron Age); Spijkenisse 17-35 (Early and Middle Iron Age); Spijkenisse 17-34 (Middle Iron Age) and Nieuwenhoorn 09-89, Simonshaven 17-24 and Rockanje II (all Roman Period). The locations of these sites on Voorne-Putten are indicated in figure 27.

The wood research was conducted to ascertain which species were used for building, whether particular species were selected for special purposes, and if so, whether there is a relation between present-day standards of wood quality and prehistoric application. Finally, the data provided by the wood identifications are compared to those provided by palynological research.

The results obtained from the sites are rather heterogeneous. A summary of these data is presented below.

3.1.1 ROTTERDAM-HARTELKANAAL 10-69

This excavation laid bare the remains of a two-aisled farm, measuring 10 × 4.5-5 m with a N-S orientation (cf. Van Trierum *in press*). Six stalls can be reconstructed in the southern part of the building. A total of 44 specimens were identified by Drs. R. van der Berg. For one post, *Salix* spec. (willow) has been used, it concerns a post of the wickerwork between two stalls. All other timbers belong to *Alnus* spec. (alder). The central posts are the thickest, averaging 13.7 cm. The remaining posts are on average 7.0 cm thick.

3.1.2 SPIJKENISSE 17-30

On this site, remains of a three-aisled farm were excavated. The plan measures 15 × 5 m and its orientation is SE-NW. In the southeastern part, six stalls are present (cf. Van Trierum *et al.* 1988; Van Trierum *in press*). In all, 195

identifications were conducted by Drs. L.I. Kooistra. In seven cases, the central posts of the farm can be assigned to *Fraxinus excelsior* (ash), four belong to *Acer* spec. (sycamore), two to *Ulmus* spec. (elm) and one to *Alnus* spec. The remaining posts in the wall as well as the ones surrounding the farm all belong to *Fraxinus excelsior*. These last mentioned outer posts probably supported the eaves. Again, the central posts are thicker than the wall posts, the average diameters are 10.9 and 7.4 cm respectively. The wall of the farm is composed of wickerwork. For this wickerwork, ash and *Corylus avellana* (hazel) were used.

3.1.3 SPIJKENISSE 17-35

The location revealed the remains of a three-aisled farmstead with SE-NW orientation. The building can be dated to the Early Iron Age. Ten to twelve stalls are present in the northwestern part. As a result of a recent disturbance, a ditch, the living-area in the southeastern part was only excavated to a very limited extent. The width of the construction is 5.5 m, its length is probably 17 m (see also Van Trierum *in press*). The total number of wood identifications of the Early Iron Age amounts to 224.

For the central roof supports, eleven elms (*Ulmus* spec.), three ashes (*Fraxinus excelsior*) and one sycamore (*Acer* spec.) were used. For the smaller posts, alder (*Alnus* spec.), oak *(Quercus* spec.) and ash (*Fraxinus excelsior*) could be demonstrated. The thickness of the central posts is on average 15 cm. The wall posts are considerably thinner, except for two half ash posts flanking the entrance in the short wall. These have diameters of 18 and 17 cm. The wickerwork is of ash. The palissade surrounding the farmstead mainly consists of oak and ash. Radially split timber was used, the original diameter of the oaks could be calculated as having been up to 36 cm. Attempts to date these oak-timbers by dendrochronology, in cooperation with Drs. E. Jansma (I.P.P.), were unsuccessfull. The reason for this unsuccessfull attempt may have been that the curve used as reference was the German mean chronology of Hollstein (1980). This curve is based on one single measured tree for a large part of the Early Iron Age. In consequence, individual, non-climatic fluctuations are not suppressed in this average-curve, thus possibly resulting in too low a correlation with the average curve of the oaks from
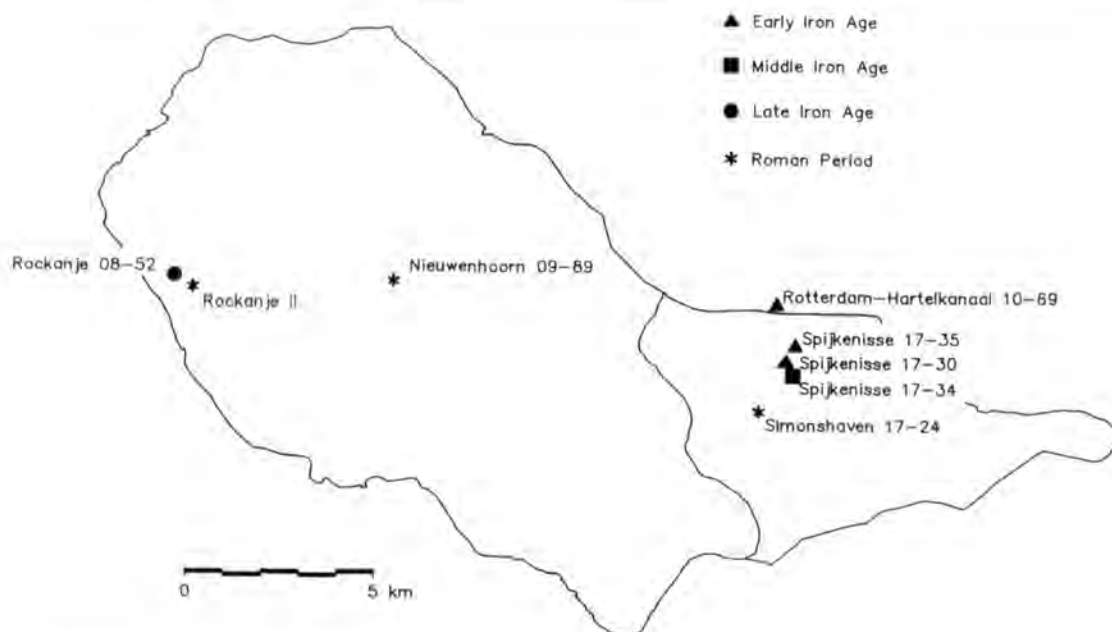
Fig. 27 Location of the sites studied for wood on Voorne-Putten, scale 1:2000.

Spijkenisse 17-35. Different specimens from the site
did show high mutual correlations in their ring widths
(Student t'-values of 8.88 and 6.133, R-values 0.73 and 0.67,
α < 0.001).

The Middle Iron Age traces on this site consisted of
several posts, without recognizable function. Fourteen speci-
mens were identified with ash as the most common species
(6 ×), followed by alder (3 ×), willow (2 ×), buckthorn
(*Rhamnus catharticus*: 2 ×) and *Prunus* spec. (1 ×).

3.1.4   SPIJKENISSE 17-34
This site produced the remains of a Middle Iron Age farm.
A recent ditch caused that only a limited part of the original
width could be excavated. The length of the construction
measured 24 m, the width probably ca. 5.5 m. The number
of stalls could not be counted, but amounted at least to six
(cf. Van Trierum *in press*). A total of 394 identifications
revealed that *Alnus* spec. is the dominant species, while
Fraxinus excelsior and *Salix* spec. are also occurring
commonly. One thick post, a central roof support, is of
Acer. Other certain roof supports are of alder (3 ×) and ash
(1 ×). For wickerwork, mainly alder and willow were used.
The five certain roof supports have an average thickness of
11.2 cm, the wall posts are on average 8 cm thick.

3.1.5   SIMONSHAVEN 17-24
On this site, two farms dating to the Roman Period were
found. Due to a comparatively high position in relation to

the water table, the organic remains are preserved rather
badly. The traces reveal east-west orientated buildings,
which are not contemporaneous. The second building was
erected on top of the first one. The older construction
measures 17 × 4.5 m, the younger 22 × 6.5 m. A heavily
founded granary was also discovered (cf. Van Trierum *et al.*
1988). In total, 141 specimens of this site were identified.

For the older house, mainly *Fraxinus excelsior* and some
Alnus spec. could be demonstrated. Only eight pieces be-
longing to the younger building could be identified and
another three tentative identifications could be listed. Three
timbers are of *Quercus* spec., among which is the only still
remaining central roof support. Some certain and some ten-
tative alder- and ash-timbers were present as well. The
foundation of the granary was of oak in five cases, while the
other post holes did no longer contain any wood.

3.1.6   NIEUWENHOORN 09-89
On this site, four farms dating to the Roman Period were
built over each other (cf. Van Trierum *et al.* 1988). All four
building phases produced substantial amounts of oak tim-
bers, which made dendrochronological research possible.
The dendrochronological investigations were conducted in
cooperation with Drs. E. Jansma (I.P.P.). The oldest trees
were felled in the calendar year 57 AD, the younger ones at
63 AD, 84 AD and 107 AD respectively (see Vermeeren/
Brinkkemper *in prep.*). The archaeological and dendrochro-
nological reconstructions of the three oldest buildings differ

in detail. Secondary use of the timbers cannot always account for these discrepancies. If wood is used secondarily, it is older than the date of the building in which it is applied. In Nieuwenhoorn, however, some oaks that do not fit in with the archaeological reconstruction are too young. Individual houseplans can therefore not yet be reconstructed. Nonetheless some major trends are apparent among the 1161 identified specimens.

The roof supports in the oldest building are made of *Acer* spec. and *Ulmus* spec., whereas in the younger phases *Quercus* spec. predominates strongly, mostly in the form of radially split timbers. The remaining construction wood belongs to a whole range of species. Arranged in declining order of occurrence, the most important are *Alnus* spec., *Fraxinus excelsior*, *Quercus* spec., *Acer* spec., *Ulmus* spec. and *Salix* spec. For wickerwork, mostly alder and willow were used.

The felling dates of the timbers used in the four building phases demonstrate that on this site a house could stand for 20-25 years at most. Bakels (1978) assembled extant data on durability of wood, provided by T.N.O. (*Toegepast Natuurwetenschappelijk Onderzoek*; Applied Scientific Research; see *table 7*). These data also suggest that oak wood under wet circumstances lasts for 10-25 years, which thus corresponds closely to the datings from Nieuwenhoorn. In the farmsteads, the wood was protected against direct weather influence by the roof, which might seem to point to a dry substrate. However, the conservation of waterlogged botanical material on the sites demonstrate that the conditions were all but dry.

3.1.7   ROCKANJE II

Excavations by the R.O.B. revealed remains of four Roman farms on different parts of the site. Of two of them, wood has been identified. Only one corner of the first house could be excavated. Twelve posts were all of *Fraxinus excelsior*. The second house had a remarkably constructed, A-shaped frame (Brinkkemper *et al. in press*). The most important timbers from a constructional point of view were *Fraxinus excelsior*. Besides, only *Alnus* spec. was demonstrated. The site also yielded a granary, consisting of sixteen very heavy alder posts with diameters of 25-35 cm. These were surrounded by thinner ash posts, which most likely supported the roof.

Table 7. Durability of wood species in permanent contact with a damp subsoil (I) and a dry substrate (II).

	Durability I	Durability II	Susceptibility to damage by insects
Quercus	10-25 yr	25-50 yr	small
Acer, Ulmus	5-10 yr	12-25 yr	moderate
Alnus, Fraxinus, Salix	< 5 yr	6-12 yr	strong

3.1.8   PREFERENCE FOR PARTICULAR SPECIES FOR CERTAIN CONSTRUCTION ELEMENTS

A summary of the results discussed above is presented in table 8. In table 9, the use of species for the different construction elements is presented. In several sites, a selection in favour of more durable wood species for the roof supporting central posts can be observed. During the Iron Age, this selection mainly focussed on elm, ash and sycamore, while alder and willow are more important in the less crucial construction elements and for specific purposes such as wickerwork. An exception is formed by Rotterdam-Hartelkanaal 10-69, where alder strongly dominates. This is also the smallest building and the only two-aisled one. Spijkenisse 17-34 did not yield many central posts. A single sycamore was found and alder dominated among the few central posts present. The only perceptible selection on this site was in favour of thicker trunks for the central posts.

It is remarkable that pollen diagrams concerning the Iron Age (see *ch. 2*) did reveal declines of oak correlated with the Iron Age inhabitation. Apparently, the trees were not applied in the constructions.

During the Roman Period, oak is more prominently used. This difference cannot exclusively be attributed to a higher level in technology during the Roman Period, since in one Iron Age site (Spijkenisse 17-35) very thick oaks were used for the palissade.

3.2   The origin of the wood.

The Early and Middle Iron Age sites are located in a peaty landscape (see *1.3*). From the recorded tree species, *Alnus* spec. and *Salix* spec. may have grown in the wet surroundings of the sites. *Fraxinus excelsior* can grow on mineralized peaty soil, a soil which may have resulted from drainage of peat. The main distribution of ash, however, most probably was on mineral soils. *Acer* spec., *Ulmus* spec. and *Quercus* spec. cannot have occurred in the peaty ecosystems around the settlements. These trees should be sought on drier, mostly mineral soils, with low water tables during the growing season. The levees along the Meuse, reconstructed on palynological data (see *2.5.3*) offer ideal conditions for the growth of these trees, at least within the reach of the freshwater tidal area. These levees were situated at a distance of ca. 3 km from the settlements, which distance apparently did not exclude the use of trees growing there. To overcome difficulties in the transport of the massive trunks, the wood supply probably took place over water. All Iron Age settlements are situated in the close proximity of creeks (Van Trierum 1986). In view of this, the absence of oak wood in the Iron Age farms is relevant. According to Pryor and Taylor (*pers. comm.*), fresh oak wood sinks in water. Roughly about a year after felling, this species will float and can be transported over water. This sinking does not occur in other native tree species. If this

Table 8. Relative occurrence of different wood species in the sites studied.

Site Dating	RH.10-69 EIA	Sp.17-30 EIA	Sp.17-35 EIA	Sp.17-34 MIA	Si.17-24 RP	Nh.09-89 RP	Ro.II RP
Quercus spec.	—	0.5%	33.5%	—	10.6%	20.0%	—
Ulmus spec.	—	2.1%	6.3%	—	—	8.9%	—
Acer spec.	—	3.1%	0.4%	0.5%	—	6.2%	—
Prunus spec.	—	—	—	0.5%	—	0.1%	—
Fraxinus excelsior	—	70.2%	40.2%	20.6%	29.8%	30.9%	59%
Alnus spec.	98%	20.0%	13.8%	60.7%	23.4%	26.8%	41%
Salix spec.	2%	—	3.6%	16.0%	0.7%	4.1%	—
Rhamnus catharticus	—	—	—	1.0%	—	—	—
Betula spec.	—	—	—	—	—	0.1%	—
Corylus avellana	—	1.5%	—	—	—	0.7%	—
Viburnum opulus	—	—	—	—	—	0.1%	—
cf *Ligustrum vulgare*	—	—	—	—	—	0.1%	—
Indeterminatae	—	—	2.2%	0.9%	26.2%	1.4%	—
# Identified	44	196	224	394	141	1161	86

Table 9. The use of wood for central posts and other elements per site, arranged in decreasing importance.

		Central posts	Other elements
Rotterdam-Hartelk. 10-69	EIA	*Alnus*	*Alnus, Salix*
Spijkenisse 17-30	EIA	*Fraxinus, Acer, Ulmus, Alnus*	*Fraxinus, Corylus, Alnus, (Quercus)*
Spijkenisse 17-35	EIA	*Ulmus, Fraxinus, Acer*	*Fraxinus, Quercus, Alnus, (Ulmus)*
Spijkenisse 17-34	MIA	*Alnus, Fraxinus, Acer*	*Alnus, Fraxinus, Salix, (Prunus, Rhamnus)*
Simonshaven 17-24	RP	*Quercus*	*Fraxinus, Alnus, (Quercus)*
Nieuwenhoorn 09-89 (1)	RP	*Acer, Ulmus, (Alnus)*	*Alnus, Fraxinus, Acer, Quercus, (Ulmus, Salix)*
Nieuwenhoorn 09-89 (2-4)	RP	*Quercus,* (others)	*Alnus, Fraxinus, Quercus, Ulmus, Salix,* (others)
Rockanje	RP	*Fraxinus*	*Fraxinus, Alnus*

phenomenon was important, the species used in the farms must all have been felled within one year, the year of building the farms. This implies that it was not considered necessary to anticipate the building of farms one year beforehand, as far as the selection of wood is concerned. Alternatively, for constructional purposes, oak wood possibly was not preferred to the same extent in the Iron Age as in the Roman Period. The presence of oaks in the palissade of Spijkenisse 17-35, and not in the house itself, is striking. This palissade may have been erected later than the building itself, thus allowing for water transport of oak trunks. The construction of a dendrochronological curve for ash, at the moment in progress (E. Jansma *pers. comm.*), may in the future provide additional data concerning this hypothesis, since ash is present in both the house-construction and the palissade.

The landscape during the Roman Period is considerably less well known than its Iron Age counterpart. This is due to the rarity of peat formation during Roman times (see 2.6). The preceding Dunkirk I transgression phase resulted in large-scale sedimentation of clay. These deposits dominated the inhabited landscapes during the Roman Period. The mineral soils probably enlarged the areals of trees like *Quercus* spec., *Ulmus* spec. and *Acer* spec. However, to what extent these trees could expand remains unknown. The

freshly deposited, clayey sediments will certainly not have been as favourable for these trees as the levees were.

It seems probable that the oaks applied in the native Roman farms in Nieuwenhoorn were obtained from nearby the settlement or from the dune area. As the palynological investigations demonstrated (see 2.5), the levees along the Meuse will have been within the sphere of influence of brackish water in this western part of Voorne-Putten, thereby preventing the development of a riverbank forest with oaks.

Dendrochronological investigations revealed that the oaks of Nieuwenhoorn show a high correlation with the middle-curve of the Rhein-Main area. Jansma obtained dendrochronological data from oaks that had grown in a peaty environment near Abcoude (prov. of Utrecht, the Netherlands). It appears that these oaks show a curve contrary to the curve of the Rhein-Main area. Probably, dry conditions were suitable to the "peat-oaks" near Abcoude, whereas wet conditions stimulated the ring width in the German oaks (Jansma *in prep.*). The fact that the oaks from Nieuwenhoorn follow the German curve means that these oaks grew on mineral soils and not on peat. Furthermore, the oaks of the subsequent building phases all showed high mutual correlations in their ring widths. This indicates that they originate from one and the same area. The greater fluctuations in ring

patterns of the trees of the last building phase and the occurrence of extremely small rings (down to 0.013 mm!) can be seen as evidence that more marginal developing trees were selected. This might be attributed to exhaustion of the stands of oaks in the surroundings of the site (see also Vermeeren/ Brinkkemper *in press*). This lack probably accounts for the absence of *Quercus* spec. in Rockanje, which can be dated to the second century AD, i.e. later than Nieuwenhoorn (cf. Brinkkemper *et al. in press*).

3.3   Comparison with investigations concerning wood on other sites

As far as the Iron Age is concerned, only a few excavated wetland sites in the Netherlands have been subjected to wood-research. The most important one is site Q in the Assendelver Polders (Therkorn *et al.* 1984). This three-aisled Early Iron Age farm measured 18.5 × 6-6.5 m and contained eight stalls. It is located on a raised bog cushion surrounded by extensive reed marshes. The roof posts in the living area of the farmstead were in three cases made of quarters of the same oak (*Quercus* spec.), the fourth roof post was missing, but probably was the remaining quarter. The roof supports in the byre area are all of ash (*Fraxinus excelsior*). The wall had been constructed with wood of alder, ash, birch (*Betula* spec.) and willow (*Salix* spec.). Willow was almost exclusively used in the living area. Therkorn *et al.* (1984: 362) in this respect point to the medieval belief that cows would become dry after contact with willow. The fact that willow does occur regularly in the byre parts of the farms on Voorne-Putten and in those in the northern German Ems-area (see below) indicates that the avoidance of willow in byres was not widespread during the Iron Age and the Roman Period.

Another Early Iron Age farm near Assendelft has been documented by Hallewas (1971). He mentions the use of *Quercus* spec. (3 ×), *Fraxinus excelsior* (18 ×) and *Alnus* spec. (47 ×). Although the function of the different species in the construction was not indicated, these results agree well with those of Assendelft site Q.

Closer to Voorne-Putten lies the Early Iron Age site Vlaardingen-Holy. Havelaar (1970) published this excavation. It concerns a farm, measuring 17.6 × 8.1 m, which was probably three-aisled and contained eight stalls. The wood has been studied superficially and is mostly alder, while some oak planks were also found. Havelaar suggests import for these oaks. Vlaardingen is situated some kilometres north of the Meuse. The levees along the Meuse probably provided a suitable location for these "imported" oaks.

An area very similar to Iron Age Voorne-Putten, regarding both environmental conditions and preservation by waterlogging, is present in the estuaries in northern Germany. Especially the Ems estuary has been studied in great detail and Haarnagel (1984) provided an extensive review. Boomborg-Hatzum is the Iron Age site that produced most data concerning wood in this area. No fewer than 37 more or less complete houseplans were unearthed here. Most farms are three-aisled and have stalls. The roof supporting posts are predominantly made of alder, ash and elm, while in later phases split oak is exceedingly important. The wickerwork is mostly of willow, also in the byre parts of the buildings. Behre (1969) published a sector diagram of the wood in Boomborg-Hatzum (excluding wood of wickerwork), where *Alnus* spec. scores 58.1%, *Fraxinus excelsior* 14.5%, *Ulmus* spec. 12.3% and *Quercus* spec. 10.3%.

All these investigations have produced results quite similar to those of Voorne-Putten. The scarcity of oak on Voorne-Putten, however, contrasts with the other sites. The German sites are located on levees, so that transportation of trunks over water was not necessary. However, it is questionable whether the sites in Assendelft and Vlaardingen had such close access to oak wood.

Data concerning wood in native Roman settlements in the Netherlands are as scarcely published as those concerning the Iron Age. Groenman-van Waateringe *et al.* (1961) described a three-aisled farm found near Krommenie, dating to the 1st century AD. The most common wood species are ash and alder, while willow, *Rhamnus catharticus* (buckthorn) and *Betula* spec. (birch) were also found. A preference for certain species for the different construction elements is not indicated. Casparie (1970) mentioned wood remains found in Roman Paddepoel (phase I-III); *Quercus* spec. (12 ×), *Acer* spec. (8 ×), *Alnus* spec. (6 ×), *Betula* spec. (1 ×), *Ulmus* spec. (1 ×) and *Salix* spec. (1 ×). More data on wood in this dwelling mound are not available. From a farm near Spijkenisse (2nd century AD), Trimpe Burger (1973) only mentions a thick central roof support of *Quercus* spec.

These data are still in favourable contrast with other Dutch sites, where not a single wood identification has been published, despite house-plans full of wood.

For the northwest German coastal area during the Roman Period, the famous Feddersen Wierde offers the best comparison. Haarnagel (1984) reviews the results. On this site, dating from the 1st century BC to the beginning of the 5th century AD, eight habitation-phases were distinguished, with in total 205 house-plans. Three-aisled farms predominate again. The roof supports are mostly of (split) oak. Behre (1969) gave a sector diagram for this site (again without wickerwork). The dominant species is *Quercus* spec. (55.1%), followed by *Salix* spec. (23.2%), *Fraxinus excelsior* (14.4%) and only 7% *Alnus* spec.

The selection of oak during Roman times, observed on Voorne-Putten, is clearly supported by the above data, with the exception of Krommenie. Several reasons may explain the difference between the Iron Age and the Roman Period.

Firstly, it can be a technological matter. However, as has been observed already, the occurrence of thick oaks in the palissade of the Early Iron Age site Spijkenisse 17-35 does seem to plead against this explanation. Secondly, the quality of oak wood may have been rated higher during the Roman Period. Thirdly, the availability may be of influence. To allow for statements concerning the availability of the different tree species, palynological data will be used in the following paragraph.

3.4   Comparison of the wood and pollen data

Groenman-van Waateringe (1988b) compared wood and pollen data from sites in the province of Noord-Holland. She constructed rank lists of the importance of the different taxa, both for the palynological data and for those concerning wood. The pollen data were corrected for differential pollen production using Andersen's R-values (see further *2.3*). Similar corrections were made in an article on the wood remains found on Voorne-Putten by Vermeeren *et al.* (*in prep.*). Below only the results are presented.

The Early and Middle Iron Age sites on Voorne-Putten figuring in this chapter are all situated near the Bernisse. The palynological sections Spijkenisse 17-30 and Spijkenisse 17-34 have been sampled at close distance from these sites. The diagrams both include the Early Iron Age, whereas the Middle Iron Age is only represented in the 17-30 diagram.

In the spectra corresponding to the Early Iron Age, *Quercus* (oak), *Alnus* (alder) and *Corylus* (hazel) are dominant among the tree pollen. After correction for differential production, *Fraxinus* (ash) is next in importance, followed by *Fagus* (beech). These data clearly indicate that the virtual absence of oak (except in the palissade of Spijkenisse 17-35) in the Early Iron Age wood spectra cannot be explained by a low availability. The dominance of *Alnus* in the wood of Rotterdam-Hartelkanaal, notably the site closest to the levees, is particularly striking.

The Middle Iron Age pollen spectrum shows a dominance of *Corylus*, followed by *Alnus*, *Quercus* and *Fraxinus*. *Alnus* strongly dominates among the wood of the excavated Middle Iron Age site Spijkenisse 17-34.

The Roman Period is hardly represented in the pollen diagrams from Voorne-Putten. Only the R.G.D. diagram from Heenvliet showed peat formation during the start of the Roman Period. The other diagrams only provided information on the vegetation after interference by man during the Roman inhabitation. Heenvliet is at a considerable distance from Nieuwenhoorn, the most important site for wood research. Thus it was decided to obtain a pollen spectrum from the basal part of the anthropogenic deposit at Nieuwenhoorn. Behre (1970: 33-34) observed a great similarity between a similar spectrum from organic settlement layers of the Iron Age site Boomborg-Hatzum in Northern Germany and a contemporaneous natural peat de-

posit. Only *Corylus* scored a much higher percentage in the settlement layers. In view of this observation, the pollen spectrum from the anthropogenic deposit at Nieuwenhoorn may also provide reliable data concerning the tree growth at the start of the Roman Period. In this spectrum, *Alnus* is the dominating species, followed by *Corylus*, *Betula*, *Fraxinus* and *Quercus* (in declining order). When these data are considered as reliable, the conclusion must be that the upland trees on Voorne did not show an appreciable expansion on the Dunkirk I deposits on Voorne. It seems more likely that the oaks found in Nieuwenhoorn were obtained from the dune area or the levees. An origin on the Pleistocene sandy soils east of Voorne-Putten seems unlikely. The dendrochronological study revealed that the ring widths of all trees used in the different building phases showed such high correlations that they must have derived from the same area. The further the distance of this area to the site, the less likely that this area was persistently exploited for trees during several generations of inhabitation on the site of Nieuwenhoorn.

3.5   Conclusions

The identifications of wood have demonstrated the preference for certain species for roof support construction elements. The selection of tree species mainly focussed on elm, ash and sycamore during the Iron Age. Alder is very commonly applied in all parts of the construction. In the Roman Period, oak was selected more generally. This selection is consistent with the present-day standards of wood quality, which rates oak highest, followed by elm and sycamore. Pollen diagrams seem to indicate that the increased preference for oak during the Roman Period cannot be attributed to a more common occurrence of this tree. Furthermore, the palynological data do not indicate that oak trees were purposefully spared during the Iron Age, since their relative and absolute abundance decreases drastically at the beginning of the Iron Age habitation on Voorne-Putten. Transport of oak trees over water was probably problematic. An increase in the use of oak has also been observed in settlement sites in northern Germany and is apparent in the scarce data provided by other Dutch wetland sites as well.

Through dendrochronological research it has been made plausible that the oaks applied in the native Roman settlement near Nieuwenhoorn were obtained from mineral soils. Most probably, these trees were felled in the dunes of Voorne or on the levees along the Meuse north of Putten. An origin on Pleistocene sandy soils is less likely, as the trunks of all four building phases of the site show high mutual correlations in their ring width. This indicates that they most probably derived from the same area. It is not very likely that one single area was exploited consistently when it was not relatively close to the settlement.

4.1   Introduction

"Botanical macroremains" is a somewhat euphemistic
expression covering all botanical remains that can be detec-
ted by means of a stereo-microscope with moderate magni-
fications (up to ca. 25 ×). Since wood has been included in
the previous chapter, it is excluded here.

Botanical macroremains give information on a scale quite
different from pollen diagrams and wood. Where pollen
diagrams provide knowledge on a large area, without great
detail, the analysis of botanical macroremains in general
furnishes more detailed data about the vicinity of the sam-
pling sites. Wood remains present information on a scale
comparable to pollen diagrams, with the restriction that
wood spectra are strongly influenced by human selection
(see also *ch. 3*).

Since the sampling sites discussed here are all former
human settlements, especially the ruderal vegetations present
around the houses is encountered. Crops and refuse from
crop-processing, the so-called by-products, also play an
important role.

When dealt with in a general sense, botanical macro-
remains (seeds, fruits, stems, leaves, etc.) will hereafter be
referred to as "seeds". An archaeological presentation of the
sites discussed in the present study is included in paragraph
1.3.1. The location of the sites studied for botanical macro-
remains is indicated in figure 28.

4.1.1   METHODS

Usually botanical macroremains are sampled during the
archaeological excavation on a site. In the present study,
some alternative sampling strategies were applied. As no
Late Iron Age sites were excavated on Voorne-Putten until
October 1990 and the excavation of the Late Iron Age site
of Rockanje 08-52 could not be foreseen in the preceding
period, it was decided to sample some Late Iron Age sites in
a different way.

The sites concerned have become known through surveys
only. Pottery remains and other indications of former hab-
itation were discovered in the banks of ditches that cut
through the sites. Samples were obtained from banks in the
section near the water level. By sampling in the slopes of
ditches, archaeologically dated samples for macroremains
were obtained. Of course, these samples do not provide a

detailed knowledge of the archaeological contexts, which
would be available after excavation. Thus, the location of
the samples in relation to the building is unknown.

A related way of sampling was applied to one Middle
Iron Age site (Geervliet 17-55). Here, the samples from
banks did not provide satisfactory results. Sampling by
means of a corer for taking peat samples (Ø 6 cm) did yield
material which was too deep beneath the water level for
sampling along the ditch. However, only seven of these
unconventionally obtained samples are presented here,
against about one hundred samples from excavations.

On the excavated sites, the habitation layers were present
below the water table, the so-called "*Feuchtboden-Sied-
lungen*" *sensu* Willerding (1971, 1991). As a consequence, the
remains have been preserved in anaerobic, waterlogged
conditions. This allows excellent conservation of organic
material, such as seeds and wood. In contrast, on sites
situated above the water table (upland-sites; "*Trockenboden-
Siedlungen*"), only carbonized remains have stood up to the
ravages of time.

After sampling, and sometimes after years of storage in
plastic bags, the material was washed carefully with water
over a series of sieves with decreasing meshes down to
0.25 mm. The smallest recovered macroremains, held by a
sieve with a 0.25 mm mesh, are hardly visible to the naked
eye. Even with this size of mesh, seeds of some plant species
pass through the sieve. Using a still smaller size of mesh
would, however, soon cause blocking of the sieve. This
makes the use of these meshes extremely time-consuming. In
practice, with the smallest meshes of 0.25 mm the point of
diminishing returns seems to be reached. Because of the
waterlogged preservation of the botanical remains, flotation
techniques are less appropriate, as they mainly reveal
carbonized remains. Furthermore, flotation produces severe
bias, e.g. against grain chaff in comparison to kernels
(G.E.M. Jones 1986).

After sieving, a short inventory was drawn up to facilitate
subsequent selection of the samples to be further analysed.
From each sieve fraction, one teaspoonful of material was
examined under the microscope. The species present were
registered, together with a general impression of the preser-
vation condition of the material. The seeds on the coarsest
sieve could often be detected with the naked eye, so the
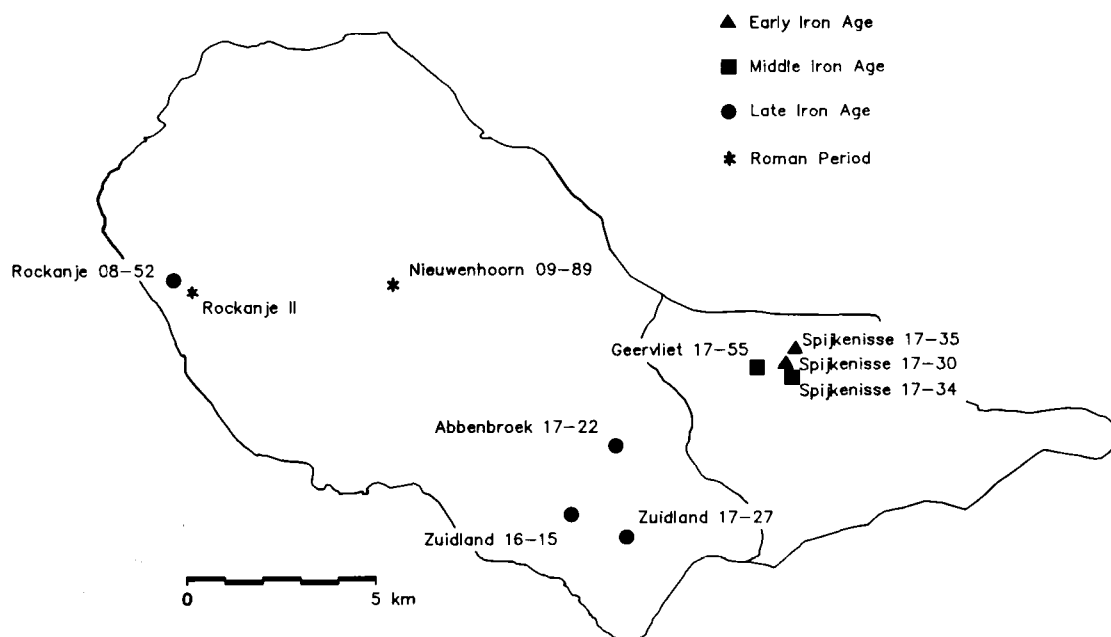
Fig. 28 Location of the sites studied for botanical macroremains on Voorne-Putten, scale 1:2000.

presence of grain kernels and other large seeds was often perceived. These observations enabled the final selection of samples to be analysed. Subsequently, the samples were stored in plastic bags, in water with some formaldehyde added. The samples were always kept wet to avoid damaging the fragile, waterlogged material.

In the final examination, the sample fractions were studied individually with a Wild M5 stereo microscope (magnification up to 50 ×). All remains which could potentially be identified were picked out and later identified, sorted and counted if possible. Large sample fractions were only partly examined. The numbers were then multiplied corresponding to the part analysed. Of the smallest fraction (0.25-0.5 mm), often only 1/16 or 1/64 was examined. Even a few teaspoonfuls sometimes contained hundreds of seeds, mainly of rushes (*Juncus* spec.).

The identification of macroremains was greatly facilitated by descriptions published earlier. These valuable sources of information are especially numerous in the German palaeoethnobotanical literature (see also the references in Appendix I). The reference collection of the botanical laboratory of the I.P.L. was also of great value. Grass- and rushseeds were mounted on microscope slides in gummisyrup to allow identification with a high-power light-transmitting microscope (Leitz Dialux, magnification 400-1600 ×).

After identification and counting, the mostly uncarbonized remains were stored in a mixture of water and glycerine (both 50 vol-%), with the addition of 5 mg phenol per litre.

Lists of taxa and quantities were stored in a computer to facilitate sorting and calculations.

4.2   Previous studies of botanical macroremains from Voorne-Putten

Analyses of botanical macroremains of Iron Age and Roman sites on Voorne-Putten have hardly been done before the present study. Bakels (1986) mentioned one impression of a cereal grain, gnawed at by a wood mouse (*Apodemus sylvaticus*), from the Early Iron Age site of Rotterdam-Hartelkanaal 10-69 (see *fig. 29*). This site yielded several other impressions. Eight of these belonged to *Hordeum vulgare*, other taxa could not be demonstrated. Seven of the grains were still enclosed by their chaff. The grain gnawed at by the mouse was also barley (Bakels *pers. comm.*).

4.3   The present study of botanical macroremains

In the framework of the present study, organically tempered pottery from Spijkenisse 17-34 (33 sherds) and Abbenbroek 17-22 (13 sherds) did not reveal identifiable plant remains. Some sherds from Geervliet 17-55 were presented to me by archaeologists of the B.O.O.R. They appeared to be abundantly tempered with the silicles of *Camelina sativa* (gold of pleasure; see *fig. 30*).

These scanty data on pottery impressions are supplemented substantially by the analysis of waterlogged and carbonized plant remains. They did not only produce a

Fig. 29 Barley grain from Rotterdam-Hartelkanaal 10-69, gnawed at by a wood mouse.
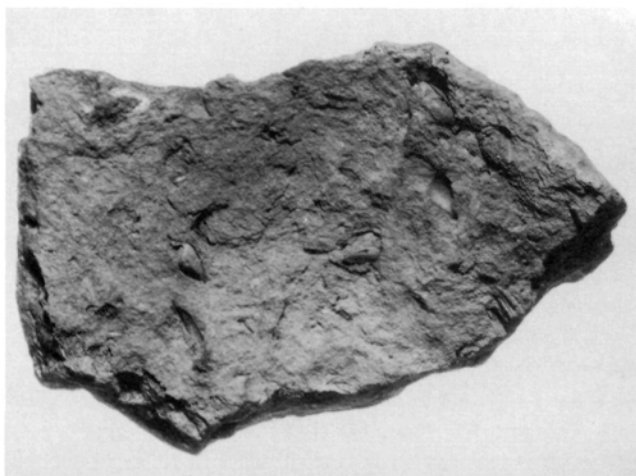
Fig. 30 Pottery from Geervliet 17-55 tempered with silicles of *Camelina sativa* (1.5 and 8x).

range of cultivated plants, but also attested to gathering of wild species for human consumption. Moreover, a range of other elements of the natural as well as the anthropogenically influenced vegetations surrounding the sites were found. The botanical macroremains of the following sites have been studied: Rotterdam-Hartelkanaal 10-69, Spijkenisse 17-30 and 17-35 (Early Iron Age); Spijkenisse 17-34, 17-35 and Geervliet 17-55 (Middle Iron Age); Abbenbroek 17-22, Zuidland 16-15 and 17-27 and Rockanje 08-52 (all Late Iron Age); and Nieuwenhoorn 09-89 and Rockanje II (Roman Period). The location of these sites is indicated in figure 28. It appears that all Early and Middle Iron Age sites studied are concentrated around the Bernisse on Putten, while the Roman sites are situated in the western part of Voorne. Only the Late Iron Age sites are both on Voorne and on Putten. It should be noted that one native Roman site along the Bernisse has also been excavated, viz. Simonshaven 17-24. Unfortunately, however, the conditions for preservation on this site were much worse than on all the other sites studied. Moreover, the site also produced medieval remains, which could not be separated stratigraphically with certainty from the Roman ones (Van Trierum *pers. comm.*). It was therefore decided not to analyse samples from this site.

Below, first the cultivated, then the gathered species will be discussed and finally the remaining plant remains. The raw data underlying the following paragraphs are presented in tables 17-24.

4.4 Cultivated plants

To facilitate comparisons, the material in this paragraph has been arranged per taxon and not per site. The corresponding tables have been arranged according to periods.
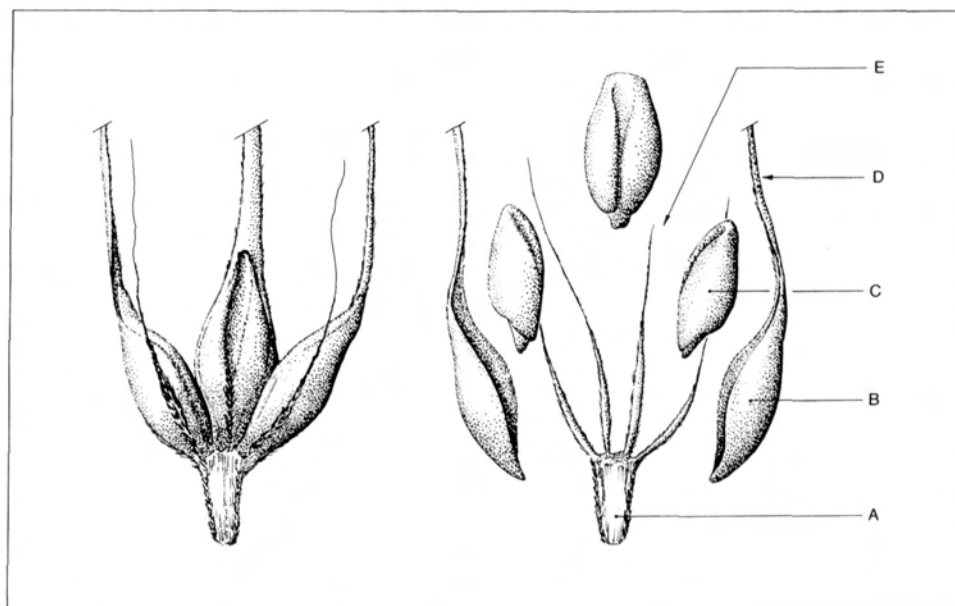
Fig. 31 Habitus of *Hordeum vulgare
vulgare*. A = rachis internode;
B = lemma; C = grain;
D = awn; E = glume.

4.4.1   HORDEUM VULGARE VULGARE (HULLED BARLEY)

In barley, several species, varieties and forms occur. Since only some of them can be cultivated in coastal areas (see *ch. 6*), the differentiation of these taxa is highly relevant. The following introduction, mainly based on Van Zeist's (1970) publication, may help the non-botanist (see also *fig. 31*).

In cereals, the ears are composed of a central rachis, which bears one spikelet on every rachis internode. In barley, each rachis internode bears three florets per spikelet. In two-row barley (*Hordeum distichum*), only the central florets are fertile, giving rise to symmetric kernels. In four- and six-row barley (*Hordeum vulgare*), the lateral florets are also fertile. Kernels developing in these lateral florets are asymmetric (lopsided, "*Krummschnäbel*"). In both species occur naked as well as hulled varieties. In the hulled varieties (var. *vulgare*), the glumes tightly envelop the grains. Consequently, the grains are angular in cross section, which is also apparent when the glumes have disappeared. In naked barley (var. *nudum*), the grains are not tightly hulled by the glumes and the cross section is more rounded. Naked barley grains also have a shrivelled skin (cf. Van Zeist 1970: 49-50). The erect, dense-eared six-row barley and the nodding, lax-eared four-row barley can be distinguished by the length of the rachis internodes and (to a lesser extent) by their grains. In uncarbonized material, six-row barley internodes are shorter than 2.5 mm, in four-row barley they are longer. As a result of carbonization, the internodes shorten (cf. Behre 1983: 16-19). The first few internodes of four-row barley that do not bear grains, are also shorter than 2.5 mm. Some short internodes in a sample where long ones predominate is thus no proof of an admixture with six-row barley.

Since the spikes are more condensed in the dense-eared six-row variety, the lateral grains are forced sideways, whereas in four-row barley, they are more twisted towards the central axis. Consequently, lopsided specimens of four-row barley are more asymmetric than six-row ones. Furthermore, the length/width ratio of the grains is smaller than 1.8 in six-row and larger in four-row barley (Knörzer 1970: 26).

All the barley grains and internodes found in the samples studied here can be attributed to hulled, four-row barley (*Hordeum vulgare* var. *vulgare* fo. *tetrastichum*). Barley is the most common cereal on nearly all sites. The most prominent exception is the Early Iron Age site of Spijkenisse 17-30, where barley is completely absent (see *table 10*). This table further shows distinctly higher quantities of barley remains during the Roman Period, and to a lesser extent in the Late Iron Age.

In almost all the excavated sites (where contexts are known), carbonized barley grains occur mainly in the hearths. Uncarbonized internodes on the other hand predominate in dung (Rockanje 08-52) or in floors (Rockanje II and Spijkenisse 17-34).

4.4.2   *TRITICUM* DIV. SPEC. (WHEAT)

The genus of wheats (*Triticum*) comprises several species. They can be subdivided into glume wheats, in which glumes tightly hull the kernels, and species with naked grains, which easily fall out of the glumes when ripe. Naked wheats are also referred to as free-threshing. The three glume wheat species of einkorn (*Triticum monococcum*), emmer (*T. dicoccum*) and spelt (*T. spelta*) are respectively diploid, tetraploid and hexaploid in their number of chromosomes. The most important naked wheats in western Europe are bread- and

Table 10. The occurrence of Hordeum vulgare. Quantities and, in brackets, frequencies per context per site.

		Carbonized			Uncarbonized	
		grain	internode	awn-fragm.	grain	internode
Early Iron Age:						
Sp. 17-30:	total (9)	—	—	—	—	—
Sp. 17-35:	total (5)	2 (2)	2 (1)	—	—	—
hearth (1)		—	—	—	—	—
	dung (3)	1 (1)	2 (1)	—	—	—
	refuse (1)	1 (1)	—	—	—	—
Middle Iron Age:						
Sp. 17-34:	total (19)	29 (6)	85 (8)	10 (4)	1 (1)	8 (3)
	hearth (3)	23 (2)	—	1 (1)	—	2 (1)
	floor (1)	1 (1)	—	4 (1)	1 (1)	5 (1)
	dung (6)	5 (3)	40 (4)	—	—	—
	ditch (9)	—	45 (4)	5 (2)	—	1 (1)
Sp. 17-35:	total (3)	4 (1)	18 (1)	—	—	3 (1)
	refuse (3)	4 (1)	18 (1)	—	—	3 (1)
Gv. 17-55:	total (3)	13 (3)	16 (3)	63 (3)	—	112 (3)
Late Iron Age:						
Ab. 17-22:	total (1)	—	—	—	—	—
Zl. 16-15:	total (1)	5 (1)	8 (1)	—	—	1 (1)
Zl. 17-27:	total (2)	59 (2)	203 (2)	50 (1)	62 (1)	124 (2)
Ro. 08-52:	total (11)	11 (4)	73 (3)	64 (1)	24 (3)	185 (3)
	hearth (4)	10 (3)	2 (1)	—	—	—
	dung (4)	—	—	—	7 (2)	113 (2)
	refuse (3)	1 (1)	71 (2)	64 (1)	17 (1)	72 (1)
Roman Period:						
Nh. 09-89:	total (26)	138 (8)	1477 (8)	302 (5)	23 (1)	6 (1)
	hearth (7)	136 (7)	1476 (7)	302 (5)	23 (1)	6 (1)
	dung (16)	2 (1)	1 (1)	—	—	—
Rock. II:	total (23)	126 (7)	237 (5)	12 (1)	1 (1)	184 (8)
	hearth (2)	18 (1)	3 (1)	—	—	—
	floor (19)	108 (6)	232 (3)	12 (1)	1 (1)	180 (7)
	pit (2)	—	2 (1)	—	4 (1)	—

club-wheat, which belong to the same, hexaploid species, *Triticum aestivum* s.l. The difference between glume and naked wheats also manifests itself in crop-processing (cf. Hillman 1981, 1984; G.E.M. Jones 1984). To dehusk glume wheats, parching is necessary to make the glumes brittle. This is usually done by roasting, the glumes can then easily be removed. In free-threshing or naked wheats, the grains can be separated from the glumes without roasting. This difference also has implications for the chances of carbonization of the different species (see *6.4*). The apparent advantage in threshing of naked wheats can turn into a disadvantage if harvesting is delayed too long. In that case, the naked wheat grains are easily spilled during harvesting. Besides, naked cereals in general are more susceptible to predation by birds and insects (Jacomet *et al.* 1989: 93).

In the present study, apart from a single grain of *Triticum* cf. *aestivum* s.l. in Rockanje II, all grains and chaff belonged to glume wheats. As in barley, the wheat chaff remains (spikelet forks and glume bases) outnumber the grains. The typical drop-shaped appearance of grains, which exclusively occurs in emmer (cf. Van Zeist 1970), can be observed in some specimens of the present material. Unmistakable grains of glume wheat species other than emmer have not been found. The carbonized chaff remains in most cases also show the characteristics of emmer-wheat. In contrast to einkorn, the spikelet forks are stouter and the two glumes of one spikelet fork are placed at an angle (more or less parallel in einkorn). The carbonized glumes of spelt have noticeable nerves on the dorsal side and have a larger width than those of emmer. The thickness of spelt glumes in contrast is smaller than in emmer (see also Jacomet *et al.* 1989: 325). Carbonized spelt glumes have not been found with certainty in the present material. Only Spijkenisse 17-34 and Zuidland 17-27 provided carbonized glumes of *Triticum* cf. *spelta*.

According to Körber-Grohne and Piening (1983: 65), uncarbonized glumes of spelt and emmer can, apart from their width, be identified by their epidermis cell patterns. Spelt has a zigzag epidermis cell pattern, while that of emmer is more wavy (see *fig. 32*). Material in our reference collection showed that emmer has much more irregular amplitudes in the meandering cell walls, while spelt is very
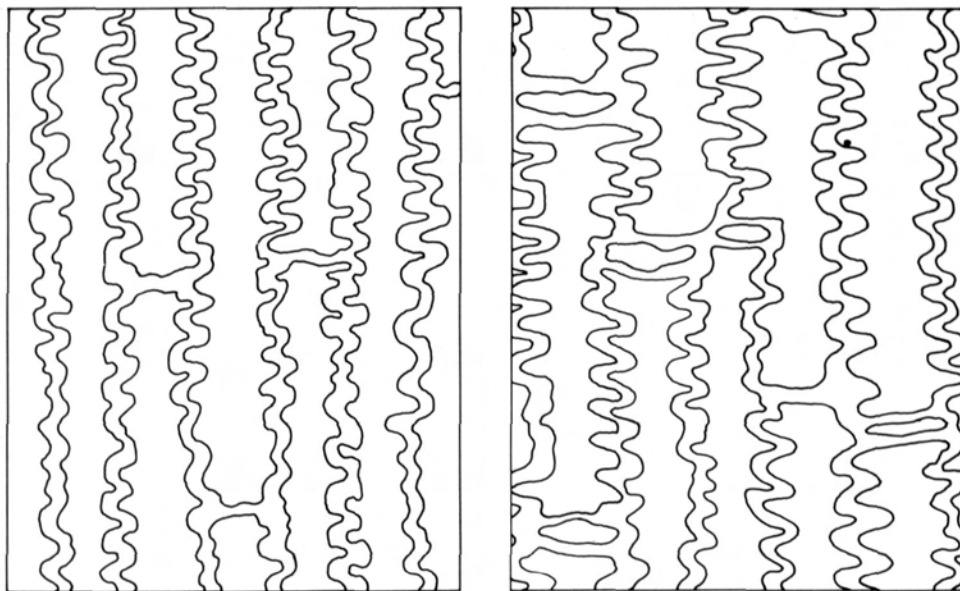
Fig. 32 Epidermis cell pattern of emmer (left) and spelt (right) according to Körber-Grohne/ Piening (1983: 65). Magnification ca. 600x.
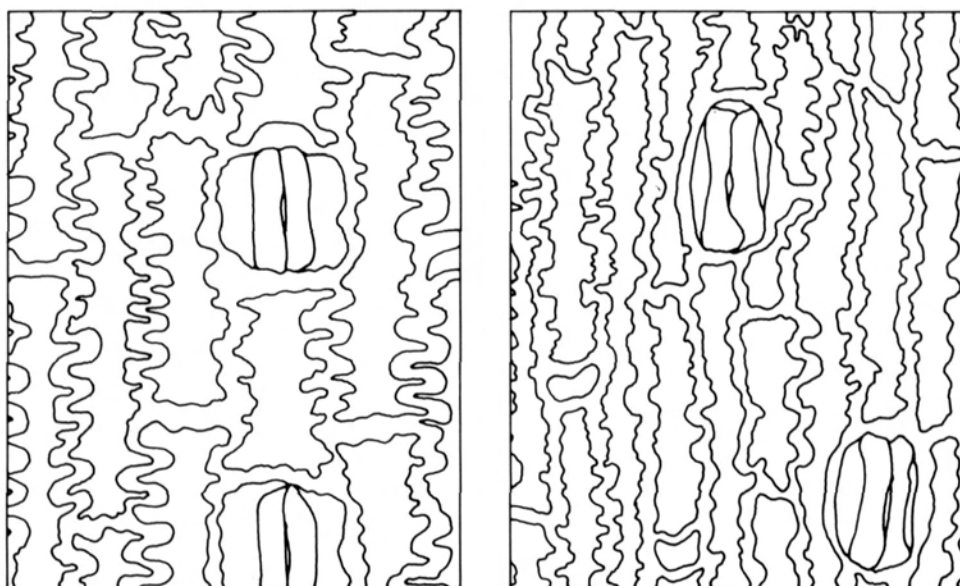
Fig. 33 Epidermis cell pattern of emmer (left) and spelt (right) according to the I.P.L. reference collection. Magnification ca. 600x.

regular (see *fig. 33*). The zigzag pattern observed by Körber-Grohne and Piening could not be found in our reference material, which included material from four different provenances.

The sites of Geervliet and Zuidland 17-27 yielded large numbers of waterlogged glumes. The widths of 380 glume bases from Geervliet have been measured. The distribution of the sizes is shown in figure 34a. Usually, the distinction between uncarbonized emmer and spelt is drawn at 1.3 mm (cf. Körber-Grohne/ Piening 1983). According to this criterion, about half of the glumes have the width of emmer. However, all the epidermes studied in emitted light showed the regularly wavy cell-wall pattern, according to our reference collection characteristic of spelt. The glume widths
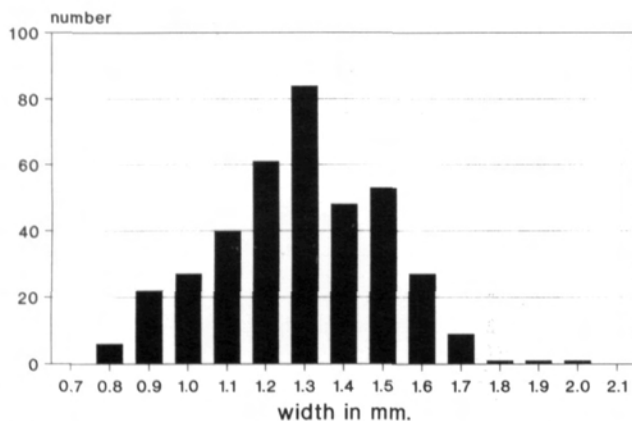
Fig. 34a Histogram showing the distribution of widths of glume bases of *Triticum* from Geervliet (n = 380)
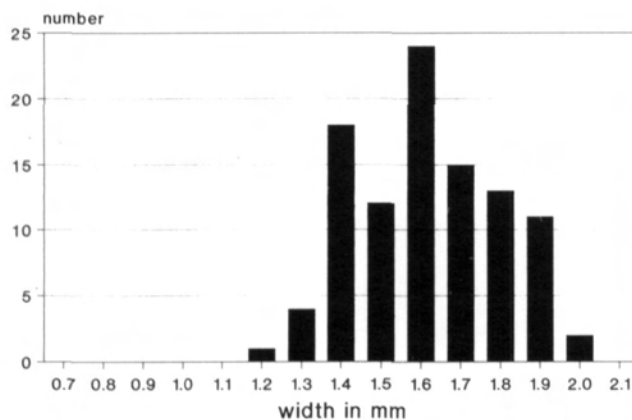
Fig. 34b Histogram showing the distribution of widths of glume bases of *Triticum* from Valkenburg (n = 100; material from Dr. J.P. Pals, I.P.P.).

yielded a unimodal curve. Both the unimodal width distribution and the uniform cell-wall pattern indicate that only one species is involved here. So far, spelt seems to be the most appealing candidate.

However, in the same samples from Geervliet, some carbonized glume bases are present. They are all relatively small, they lack the strong nervation which is characteristic of carbonized spelt glumes, and the margins do not show the right angles that characterize spelt either. They show all the characteristics of emmer glumes. The fact that all the grains found on Voorne-Putten were identified as emmer is also in contrast with the identification of the waterlogged glumes as spelt. Unfortunately, Geervliet did not yield carbonized *Triticum* grains that could be identified with certainty to give supplementary information.

In view of the confusion presented by all these data, further attention has been given to this subject.

For further exploration of the identification of these glumes, Dr. J.P. Pals kindly provided me with hundreds of waterlogged glumes from the Roman *castellum* near Valkenburg, which he had identified as spelt. The thickness of the glumes was remarkably small, corresponding to the criterion for spelt published by Jacomet *et al.* (1989: 325). This thickness was also much smaller than that found in the material from Geervliet. The width diagram of 100 of the glumes from Valkenburg is shown in figure 34b. The diagram shows high frequencies of values above 1.7 mm, in contrast to the diagram for Geervliet. The epidermis pattern of the glumes from Valkenburg could, owing to corrosion, be found in only one specimen. This epidermis was very much like those found on the glumes from Geervliet.

Thus, the epidermis cell pattern points to spelt, but the width of the material from Geervliet is clearly smaller than that of Valkenburg. It is possible that the wheat in Geervliet was grown under less appropriate conditions than that in Valkenburg, resulting in a smaller width. However, the fact that both the carbonized grains and the carbonized glumes from Geervliet are from emmer, strongly contradicts the identification as spelt.

Theoretically, a mixture of the two species is also possible. This would be supported by the presence of very small as well as very wide glumes. It would not be the first time that the presence of glumes of these two wheat species produce a unimodal width distribution (cf. Tomczyńska/ Wasylikowa 1988). This option is in contrast with the differences observed in thickness and size between the glumes of Geervliet and Valkenburg. If in Geervliet both species are represented, part of the material must resemble the glumes from Valkenburg.

In my opinion, two observations indicate that the glumes from Geervliet must be identified as emmer. Firstly, the larger width and smaller thickness of the spelt glumes from Valkenburg point to emmer for Geervliet. Secondly, spelt is completely absent among the carbonized material from Voorne-Putten.

This implies that the epidermis cell pattern cannot be used with confidence for the identification of subfossil material. The difference in present-day epidermis cells in emmer and spelt might be explained by a remark made by M. Jones (1981: 105). According to him, many crop species are inherently more likely than wild species to have undergone micro-evolutionary changes. The present difference in epidermis cells may not yet have existed during the Iron Age and the Roman Period. The epidermis cell pattern of the glumes deserve further attention, especially in the light of evolutionary changes.

Thus, all the glumes are considered to be emmer glumes.

Table 11. The occurrence of *Triticum dicoccum*. Quantities and, in brackets, frequencies per context per site.

		grain	Carbonized			Uncarbonized	
			spikelet fork	glume base	glume apex	spikelet fork	glume base
Early Iron Age:							
Sp. 17-30	total (9)	17 (1)	1? (1)	6? (3)	—	—	4? (1)
	hearth (5)	17 (1)	1? (1)	2? (2)	—	—	4? (1)
	dung (2)	—	—	4? (1)	—	—	—
Sp. 17-35	total (5)	—	—	—	—	—	—
Middle Iron Age:							
Sp. 17-34	total (19)	8? (3)	28 (4)	185 (12)	386 (3)	—	3 (1)
	hearth (3)	7? (2)	—	10 (2)	—	—	3 (1)
	floor (1)	1? (1)	2 (1)	5 (1)	1 (1)	—	—
	dung (6)	—	26 (3)	15 (5)	385 (2)	—	—
	ditch (9)	—	—	155 (4)	—	—	—
Sp. 17-35total (3)		11 (1)	21 (1)	—	6 (1)	15 (1)	
	refuse (3)	—	11 (1)	21 (1)	—	6 (1)	15 (1)
Gv. 17-55	total (3)	2? (1)	—	26 (2)	—	64 (3)	361 (3)
Late Iron Age:							
Ab. 17-22	total (1)	—	2 (1)	—	—	—	—
Zl. 16-15	total (1)	1? (1)	5 (1)	5 (1)	—	—	1 (1)
Zl. 17-27	total (2)	—	43 (2)	66 (2)	—	66 (2)	333 (2)
Ro. 08-52	total (11)	—	—	12 (1)	—	21 (3)	44 (4)
	hearth (4)	—	—	—	—	3 (1)	11 (2)
	dung (4)	—	—	—	—	9 (1)	15 (1)
	refuse (3)	—	—	12 (1)	—	9 (1)	18 (1)
Roman Period:							
Nh. 09-89	total (26)	—	—	—	—	—	—
Rock. II	total (23)	4? (1)	—	6 (1)	—	—	1 (1)
	hearth (2)	—	—	—	—	—	—
	floor (19)	4? (1)	—	6 (1)	—	—	1 (1)
	pit (2)	—	—	—	—	—	—

However, further research might prove this to be wrong. To meet this objection, all glumes wider than 1.3 mm are mentioned separately as *Triticum dicoccum/spelta* in the tables containing the raw data.

In conclusion, emmer is the most widespread wheat species, present on all Iron Age sites. The remarkable scarcity on the Roman sites will be discussed further in chapter 6.

Table 11 shows the occurrence of *Triticum dicoccum*. The total number of carbonized grains recovered amounts to 19 certain and 15 tentative identifications. Besides, 32 uncarbonized grains were found. In comparison to the number of carbonized barley grains, viz. 376, wheat is much scarcer. Chaff remains of wheats are much more common than grains. Carbonized *Triticum* grains mostly occur in hearth samples, whereas carbonized as well as uncarbonized chaff does not show such a restricted distribution.

4.4.3   *PANICUM MILIACEUM* (BROOMCORN MILLET)

Millet grains have been found in only one hearth sample in the Early Iron Age site of Spijkenisse 17-30. All were carbonized, remains of chaff did not occur. The grains

measure 1.80 (1.28-2.30) × 1.55 (1.15-1.98) × 1.24 (0.54-1.70) mm. These sizes are similar to other measurements on carbonized prehistoric material. Kroll (1987: 100) observed that the weeds that characterize millet crops when regular cultivation occurs, are absent on coastal sites as well as in samples from sites on Pleistocene sand. He concludes that millet has never been of considerable importance as a crop plant in northern Germany. This also seems to hold true for the present sites.

4.4.4   *LINUM USITATISSIMUM* (LINSEED OR FLAX)

Linum is a crop plant with two possible functions; as linseed where the seeds can be used for consumption or as flax where the stems are used for their fibres. Concentrations of seeds, as has been found in numerous palaeobotanical studies, have been seen as evidence for consumption. Behre (1977) mentioned that the *Linum* seeds in Jemgumkloster were mostly broken open lengthways, because oil had apparently been pressed out of them, which indicates consumption.

Direct evidence for the consumption of linseed has been

Table 12. The occurrence of Linum usitatissimum. Quantities and, in brackets, frequencies per context per site.

		Uncarbonized seed	Uncarbonized capsule segment	Carbonized seed	Carbonized capsule segment
Early Iron Age:					
Sp. 17-30	total (9)	—	—	—	—
Sp. 17-35	total (5)	15 (1)	1 (1)	—	—
	hearth (1)	—	—	—	—
	dung (3)	—	—	—	—
	refuse (1)	15 (1)	1 (1)	—	—
Middle Iron Age:					
Sp. 17-34	total (19)	29 (8)	2 (2)	21 (2)	5 (1)
	hearth (3)	8 (1)	—	21 (2)	5 (1)
	floor (1)	14 (1)	—	—	—
	dung (6)	2 (1)	1 (1)	—	—
	ditch (9)	5 (5)	1 (1)	—	—
Sp. 17-35	total (3)	232 (1)	71 (1)	—	—
	refuse (3)	232 (1)	71 (1)	—	—
Gv. 17-55	total (3)	96 (3)	180 (2)	—	—
Late Iron Age:					
Ab. 17-22	total (1)	1 (1)	3 (1)	—	—
Zl. 16-15	total (1)	1 (1)	8 (1)	1 (1)	—
Zl. 17-27	total (2)	158 (2)	547 (2)	—	4 (1)
Ro. 08-52	total (11)	73 (5)	75 (3)	1 (1)	—
	hearth (4)	3 (1)	—	1 (1)	—
	dung (4)	59 (3)	65 (1)	—	—
	refuse (3)	11 (1)	10 (2)	—	—
Roman Period:					
Nh. 09-89	total (26)	13 (2)	1 (1)	12 (2)	—
	hearth (7)	1 (1)	1 (1)	12 (2)	—
	dung (16)	12 (1)	—	—	—
Rock. II	total (23)	—	—	—	—

provided by Helbæk (1958), who demonstrated the occurrence of linseed in the intestines of the two men found at Tollund and Grauballe in Denmark.

Flax fibres are very difficult to demonstrate in subfossil material, because of their high susceptibility to corrosion (Behre 1972). Sometimes, however, flax fibres have been demonstrated in subfossil material (e.g. Körber-Grohne 1967, 1985). The use of flax was indirectly demonstrated by Körber-Grohne (1967), Van Zeist (1970: 129) and Behre (1976c). They found small heaps of the outer layers of the stems, which form the waste material from making Linum stems into fibres. Classical writers also report on the use of linen tissues in Germania (Plinius and Tacitus, cited in Körber-Grohne 1967). It can be concluded that in pre- and early historic times, Linum was used both for consumption and for its fibres. The seeds of present-day linseed grown for consumption and of flax for the production of fibers differ in size (cf. Zohary/ Hopf 1988: 114). Linseed cultivated for seeds have larger seeds than flax cultivated for its fibres. Large seeded specimens have not been demonstrated in palaeobotanical studies.

In the present material, linseed is far more common in an uncarbonized than in a carbonized state (see table 12). The seeds of Linum are enveloped in a capsule of ten segments. These capsules contain ten seeds at most. The seeds can be threshed out of the capsules mechanically. In contrast to glume wheats and hulled barley, roasting is not necessary. This explains the predominance of uncarbonized remains. Table 12 also reveals that Linum remains occur regularly distributed in all kinds of contexts. On some sites they occur far more frequently than on others. Especially on the Roman sites, Linum is much scarcer than on the Iron Age ones, while it is also lacking in Spijkenisse 17-30. On sites where the contexts are known, carbonized Linum remains appear to be restricted to hearths.

Table 13. Sizes of Linum usitatissimum seeds.

Site	sample	n	length (mm) average	length (mm) min.	length (mm) max.	width (mm) average	width (mm) min.	width (mm) max.
Sp. 17-34	279	2		3.55	3.94		2.27	2.43
Sp. 17-35	612	25	3.92	3.55	4.19	2.22	1.92	2.40
Gv. 17-55	2	11	3.64	3.35	3.94	1.91	1.60	2.11
Gv. 17-55	3	23	3.59	3.04	3.94	2.06	1.83	2.34
Zl. 17-27	8	10	3.74	3.49	4.09	2.09	1.92	2.37
Zl. 17-27	9	23	3.70	3.23	4.02	2.09	1.80	2.34

The sizes (see *table 13*) correspond to other prehistoric, uncarbonized linseed. As Behre (1983: 24) showed, medieval linseed is considerably larger. Its length measures on average 4.16 mm (in Elisenhof) and 4.20 mm (in Haithabu). Hellwig (1990) reported an average length of 4.18 mm for medieval material.

4.4.5   *CAMELINA SATIVA* (GOLD OF PLEASURE, FALSE FLAX)

Gold of pleasure is cultivated for its oil-rich seeds. These seeds are enclosed by two silicles, which have a very characteristic shape. In the Netherlands, it first appeared during the Iron Age, although Schultze-Motel (1979) mentioned some dubious Bronze Age finds in the Netherlands. Nowadays, it is cultivated in remote parts of Europe only. As in *Linum*, threshing is done mechanically. The fact that no roasting is needed, explains the predominance of uncarbonized remains. This is also the reason why *Camelina* and *Linum* are much more commonly found in *Feuchtboden-Siedlungen* (see Willerding 1971). *Camelina* is a secondary crop; during the Bronze Age it was probably a weed in *Linum* crops. However, it was a crop on its own right during the Early Iron Age, as Kučan (1986) demonstrated for northern Germany.

Seeds of *Camelina*, as well as silicles, which contain the seeds, have been found. They are very unevenly distributed over the sites investigated (compare *table 14*). Especially Geervliet 17-55 produced large numbers of silicles. This site has been sampled by means of a corer for taking peat samples after the discovery of *Camelina* silicles as tempering material in pottery on this site (see *fig. 30*). This use of gold of pleasure indicates that it was processed on the site of pottery production. In this way the large amounts of waste needed for tempering can be obtained (cf. Schultze-Motel 1979). If the pottery was produced locally, we could expect Geervliet to produce substantial quantities of gold of pleasure remains in samples for macroremains. The analyses showed this to be the case. One level of the cored sample showed almost nothing but *Camelina* capsules (see *fig. 35*). The presence of such large amounts of threshing waste of *Camelina* can only be expected on sites where this crop was grown by the inhabitants. The presence of threshing waste excludes importation, because that would be effected in the form of threshed seeds (see further *6.6.4*). These observations also strongly suggest that the pottery was indeed produced locally, in a domestic mode.

The fact that hundreds of *Camelina* remains occur in combination with only four *Linum* seeds in sample 1 from Geervliet indicates that *Camelina* was not a weed, but a crop on its own right on this site.

Table 14 clearly illustrates that *Camelina* predominates in the Middle Iron Age samples from Geervliet, and to a lesser extent in those from Spijkenisse 17-35 and in the Late Iron
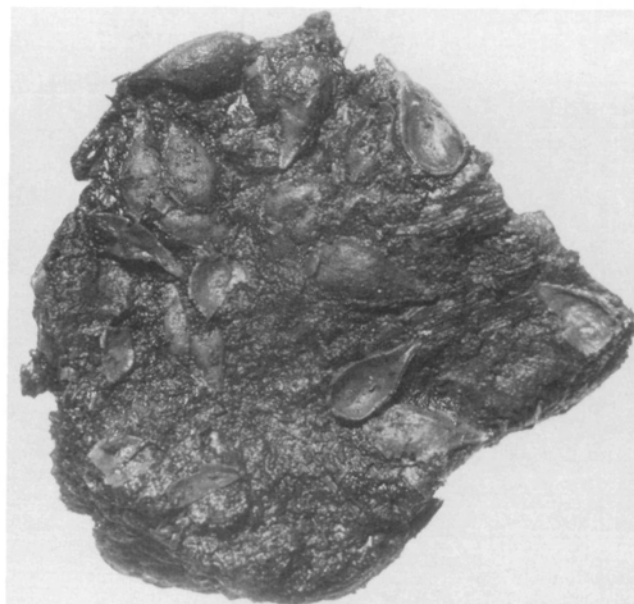
Fig. 35 Silicles of *Camelina sativa* in cored sample from Geervliet 17-55 (2x)

Age samples from Zuidland 17-27. All the other sites yielded just a few isolated seeds at best. The quantities on the excavated sites were too small to allow conclusions to be drawn about differences between contexts.

Table 14. The occurrence of *Camelina sativa*. Quantities and, in brackets, frequencies per context per site.

		Uncarbonized		Carbonized	
		seed	silicle	seed	silicle
Early Iron Age:					
Sp. 17-30	total (9)	—	—	—	—
Sp. 17-35	total (5)	1 (1)	—	—	—
	hearth (1)	—	—	—	—
	dung (3)	—	—	—	—
	refuse (1)	1 (1)	—	—	—
Middle Iron Age:					
Sp. 17-34	total (19)	1 (1)	—	—	—
	hearth (3)	1 (1)	—	—	—
Sp. 17-35	total (3)	20 (1)	18 (1)	—	—
	refuse (3)	20 (1)	18 (1)	—	—
Gv. 17-55	total (3)	85 (3)	366 (3)	8 (1)	20 (3)
Late Iron Age:					
Ab. 17-22	total (1)	—	—	—	—
Zl. 16-15	total (1)	—	—	1 (1)	—
Zl. 17-27	total (2)	3 (1)	31 (2)	—	—
Roman Period:					
Nh. 09-89	total (26)	5 (2)	—	1 (1)	—
	hearth (7)	4 (1)	—	1 (1)	—
	dung (16)	1 (1)	—	—	—
Rock. II	total (23)	—	—	—	—

4.4.6   *BRASSICA RAPA* (= *B. CAMPESTRIS*, TURNIP)

The identification of the different *Brassica* species is incorporated in the description of seeds (Appendix I). In our area it has been assumed that the recent *Brassica rapa* (= *B. campestris*) is not an indigenous species, but probably a remnant of earlier cultivation (cf. Van Zeist 1974; Schultze-Motel 1986; Jacomet *et al.* 1989). In palaeo-botanical literature, a debate is going on about the role of this species in prehistoric times. Some consider it a cultivated crop (cf. Van Zeist 1974; Schlichterle 1981), while others see it as an arable weed (cf. Behre 1983; Körber-Grohne 1987). Jacomet *et al.* (1989: 206) assume that *Brassica* seeds have been collected, in view of their high frequency but relatively low average concentrations. Murphy (1977 cited in Green 1981: 142) reported the find of a pot filled with *Brassica* seeds on the Iron Age site of Old Down Farm, which suggests a crop being stored for further cultivation or culinary use. Knörzer (1970: 67-68) found *Brassica* seeds together with pronounced garden plants (*Amaranthus*, *Lens*, *Vicia*, *Pisum*), a combination which he saw as storage of seeds of plants for consumption.

In the present study, turnip seeds occur in almost every sample of Spijkenisse 17-30 (see *table 15*). The greatest numbers have been found in hearth samples, in which several cereals were recorded. The other sites only revealed an incidental seed of this species. If *Brassica* occurred as a weed, a more even distribution among the sites would be expected. Furthermore, the greatest numbers occur in sam-

ples with other crop plants. This may also indicate that we are dealing with a cultivated species, or one gathered deliberately. Another indication that these seeds may have been used for consumption can be found in the scarcity of other oil-yielding plants in Spijkenisse 17-30. On all Iron Age sites, remains of oil-rich plants occur in substantial quantities, in the case of Spijkenisse 17-30 seemingly as turnips. Similar observations were made by Van Zeist (1974), who found *Brassica campestris* in Tzummarum with high frequency, while *Linum* and *Camelina* were both absent.

Brassica rapa is almost exclusively found uncarbonized. Silicles of this species have not been found, despite the extra attention given to finding them during the recovery of the larger numbers of seeds in Spijkenisse 17-30. Probably, these remains become unrecognizable when fragmented, in contrast to *Camelina* silicles and *Linum* capsule segments.

4.4.7   *VICIA FABA* (CELTIC BEAN)

In the range of edible Papilionaceae seeds, only Celtic bean has been found in the present study (see *fig. 36*). Lentil and pea, not unimportant in other material from the Iron Age and/or Roman Period, are conspicuous by their absence.

From a dietary point of view, legumes such as *Vicia faba* are important sources of vegetable proteins. Especially the amino acids isoleucine and lysine are important, since they complement the low levels of these amino acids in cereals. Besides, legumes are also important because of their role in crop rotation. In nodules on the roots, symbiosis occurs with bacteria that can fix nitrogen by oxidizing it into nitrate. This process fertilizes the soil for the following crop when the roots decay in the soil.

The potential recovery of Papilionaceae seeds is hampered by two facts. Firstly, uncarbonized seeds of this family decay very easily. Secondly, roasting is not necessary in crop-processing, so the chances of carbonization are small. Only uncarbonized bean straw can be preserved in quantities under favourable conditions, as is shown in Feddersen Wierde and Elisenhof. Even there only a few carbonized seeds have been found. In Neuß, where Knörzer (1970) analyzed the contents of burnt-down buildings, more than 50,000 Celtic beans were recovered, nearly as many as all *Triticum* grains together! This indicates that the consumption of these beans might very well have been considerably more important than the few seeds mostly found suggest.

The carbonized seeds found in Nieuwenhoorn all occur in four hearth samples. They are probably the result of accidents during food preparation.

4.5   Gathered wild plants.

In most cases, it is impossible to conclude deliberate gathering on the basis of archaeological plant remains. Many species, some of which occur abundantly on almost every west European site investigated, are potential food

Table 15. The occurrence of *Brassica rapa*. Quantities and, in brackets, frequencies per context per site.

		Uncarbonized seed	Carbonized seed
Early Iron Age:			
Sp. 17-30	total (9)	98 (8)	—
	hearth (5)	79 (4)	—
	floor (2)	5 (2)	—
	dung (2)	14 (2)	—
Sp. 17-35	total (5)	—	—
Middle Iron Age:			
Sp. 17-34	total (19)	5 (4)	—
	floor (1)	1 (1)	—
	ditch (9)	4 (3)	—
Sp. 17-35	total (3)	4 (2)	—
	refuse (3)	4 (2)	—
Gv. 17-55	total (3)	—	1? (1)
Late Iron Age:			
Ab. 17-22	total (1)	2 (1)	—
Zl. 16-15	total (1)	—	1 (1)
Zl. 17-27	total (2)	2 (1)	—
Ro. 08-52	total (11)	—	—
Roman Period:			
Nh. 09-89	total (26)	—	—
Rock. II	total (23)	—	—

Fig. 36 Seeds of *Vicia faba* from
Nieuwenhoorn (Roman Period)(6x).

plants. Very common are *Atriplex*, *Polygonum*, *Rumex* and
Chenopodium species. Consumption of the leaves of these
plants is highly probable, but virtually impossible to prove
(see also Hinz 1954; Knörzer 1971c). The seeds of these
species may also haven been eaten. Dembinska (1976) men-
tioned that seeds of Chenopodiaceae and Polygonaceae can
be ground into meal. Helbæk (1951) described an Iron Age
pot from Denmark which was filled with a mixture of barley
and considerable quantities of seeds of *Chenopodium album*,
Polygonum convolvulus and other weed seeds. In view of the
large quantities (ca. 30%), he concluded that these weed
seeds were gathered for their own sake.

Seeds of many of the above-mentioned species have also
been found in bog corpses. However, their presence may be
the result of crop impurities, apart from being remains of
vegetables. Besides, bog corpses may in some cases represent
sacrificial victims, whose last meal might also have had a
ritual, and thus not representative, character. The species
dealt with here give us (a little) more certainty about their
role in prehistoric food consumption on Voorne-Putten.

4.5.1   *RUBUS CAESIUS* AND *R. FRUTICOSUS* (BLACK-
BERRIES)
In Spijkenisse 17-35, blackberry seeds occur in one sample,
which dates from the Early Iron Age. It is highly improb-
able that these species grew in the vicinity of the site. *R.
caesius* occurs on calcareous soils, especially in dune areas
and in forests on levees (Fraxino-Ulmetum). Both black-
berry species do not occur on peaty soils (Weeda *et al.* 1987:
64). The native Roman site of Nieuwenhoorn also yielded
one seed of *Rubus fruticosus*. Collection of the fruits will
have taken place on a small scale only, in view of the
narrow distribution of the conspicuous seeds over the sites
investigated.

4.5.2   *PRUNUS SPINOSA* (SLOE)
Sloe stones are relatively large, and therefore conspicuous.
None the less, they occur only very occasionally in the Iron
Age samples, and on two sites only, viz. in three samples
from Spijkenisse 17-34 and in one sample from Spijkenisse
17-35. All these samples date from the Middle Iron Age.
According to Weeda *et al.* (1987: 104), sloe occurs on min-
eral soils that are not too clayey nor too acid. It grows in
shrubs along forest fringes and in hedges, in Fraxino-Ulme-
tum (levee) forests also in the forests themselves. The
absence on peaty soils renders the occurrence of sloe in the
close vicinity of the sites improbable. They must have been
collected from the levees or the dunes.

Fig. 37 Grains of *Glyceria fluitans* from Spijkenisse 17-34 (Middle Iron Age)(6x).

4.5.3   *ROSA* SPEC. (ROSE)

Wild roses especially occur along forest fringes and in hedges (Jacomet *et al*. 1989: 202). The present study demonstrated rose hips in Spijkenisse 17-34 (two samples), while the native Roman site near Rockanje yielded one tentative specimen. The very rare occurrence of rose hips indicates that the fruits were only seldom collected, as was also the case with blackberries and sloe.

4.5.4   *SAMBUCUS* CF. *NIGRA* (ELDERBERRY)

Elderberries are also edible. Elder occurs in forest clearings and fringes and in hedges but also in ruderal places. The single fruit found in Spijkenisse 17-35 may thus have come from an elder shrub near the site. Alternatively, it may have been gathered together with the blackberries, which occur in the same sample. As with the previous fruits, large scale collection was not practised on Voorne-Putten in the Iron Age or the Roman Period. This is all the more remarkable, because gathered fruits normally survive uncarbonized (cf. Jacomet *et al*. 1989: 193) and are thus mainly to be expected in waterlogged deposits, such as we find in the sites studied here.

4.5.5   *GLYCERIA FLUITANS* (FLOATING SWEETGRASS, MANNA-GRASS)

In a hearth at Spijkenisse 17-34 (samples 580 and 580a), as many as 416 carbonized grains of *Glyceria fluitans* were found (see *fig. 37*). In these samples, carbonized remains of several cultivated crops were also present (i.c. *Hordeum vulgare*, *Triticum* spec., *Linum usitatissimum* and *Camelina sativa*). A considerable portion of the *Glyceria* grains was unripe when carbonization took place.

A concentration of a species like this may have different causes. In the first place, if *Glyceria fluitans* was used for thatching, this might have resulted in a large number of grains on the site. However, because of its small leaves, this species is not particularly suited for this purpose, while *Glyceria maxima* is (cf. Aichele/ Schwegler 1983). A second alternative is collection of the fruits for human consumption. This consumption of manna-grass is well documented in historical data (e.g. Dembinska 1976).

Hegi (1906) described how the *Glyceria* grains were harvested by hitting the stems with a sieve. In this way the grains fell out of the ears into the sieve. The grains were dried at home. Kohl (1864) described harvesting *Glyceria* by boat. The blades were bent over the side into the boat and

with combs, resembling those for rippling flax, the seeds were threshed into a cloth. *Glyceria* is eaten when there is a shortage of cereals, for instance in times of war and crop failures. According to Hegi, the groats of manna-grass were also sold.

Körber-Grohne (1990) composed tables with all uncarbonized and carbonized grass seeds of sites in the Netherlands, Germany, Belgium, France and Switzerland. All the sites published until 1987 with more than one identified taxon of Gramineae were included. It appears that carbonized *Glyceria fluitans* has not been found in this area before. Uncarbonized specimens occur more frequently, sometimes even in large numbers. In Xanten (Knörzer 1981), it is the predominating grass species, in Bentumersiel (Behre 1977) only *Poa* and *Agrostis* are more abundant.

What is most remarkable is that A.G. Lange (1988: 66), in his numerical approach of the seeds of Roman Wijk bij Duurstede, observed an irregular distribution among his samples of *Glyceria fluitans*, and also of *Linum usitatissimum*, *Trifolium dubium* and *Sisymbrium officinale*. He assumed cultural causes for the extraordinarily high scores of *Linum* in some samples, but natural causes for the other species. Deliberate collecting of *Glyceria*, however, may also be a reasonable explanation for large numbers in some samples. Behre (1991a) found great numbers of waterlogged *Glyceria fluitans* grains in medieval cesspits in Bremen, a very direct evidence of consumption of this grass. According to Körber-Grohne (1987: 22), to get one gram of grains of *Glyceria fluitans*, 500 grains are required, while in cultivated barley 26 grains weigh one gram. The ease of threshing of *Glyceria*, however, is an advantage compared to hulled barley and emmer wheat.

As for Spijkenisse 17-34, *Glyceria fluitans* seems to have been consumed as early as the Iron Age. The unripe grains may be a result of the harvesting method, comparable to the method in which combs are used.

4.5.6   CONSPICUOUSLY ABSENT GATHERED PLANTS
Another very remarkable aspect regarding gathered wild plants should be discussed here. It is the complete absence of fruits and nutshells of *Quercus* (acorns) and *Corylus avellana* (hazelnuts). These two are often the predominating gathered taxa on pre- and early historic sites in western Europe. Despite the reconstructed presence of tidal forests along the Meuse, in which hazel was little affected by the inhabitants during the Early and Middle Iron Age habitation, its nutshells did not reach the settlements at some kilometres' distance in recoverable quantities.

4.6   Macroremains of other wild plants.
In the following section, the results of the analyses with respect to the wild taxa are discussed. After a general introduction, the results will first be discussed per site, followed

by a comparison between the sites. In the tables 10-20, the taxa have been arranged according to their present occurrence in plant communities. The syntaxonomical grouping *sensu* Westhoff and Den Held (1969) has here been used.

A drawback of this method is that the former ecological conditions sometimes were thus deviating from the present, that particular plants occurred in plant communities in which they are absent today. It is for this reason that A.G. Lange (1988) tried to group the taxa he had found in a Roman settlement by means of numerical methods. He concluded that the grouping corresponded closely to the present ecological grouping. This provides a basis for an *a priori* classification in ecological groups, although the method he used probably did not reveal all the details (see 4.7).

In the publication of Westhoff and Den Held (1969), the taxa have been arranged according to syntaxonomical approach of Braun-Blanquet. It was pointed out by Behre (1972), Willerding (1979), M. Jones (1988) and Behre and Jacomet (1991) that a detailed grouping of palaeobotanical data, in lower syntaxonomical units (orders, associations) is hampered by the possibility of taxa occurring in other plant communities than at present. It is less likely that considerable changes have taken place at class level. This class level has been used in the following.

Another problem arises from plant ecology itself. Most plant species are not restricted to only one single plant community. This is expressed in the fact that many species are not only character species (German: *Kennarten*) for a particular plant community, but also (or sometimes only) differential species (German: *Trennarten*) in others. For a more elaborate discussion of the concepts of the Braun-Blanquet method in the classification of vegetation, the reader is referred to the publication by Westhoff and Van der Maarel (1973).

In the present study, the primary subdivisions are founded on character species only. A very subjective grouping may otherwise be the result, as Behre (1977) pointed out. However, important alternative classes, of which particular species are differential species, have been listed in the tables concerned.

Some classes occur very regularly on the sites studied, and their ecology is of great use in the interpretation of the data. Some basal knowledge of these classes is relevant in the following description per site, so a short introduction is presented first.

4.6.1   ECOLOGICAL NOTES ON SOME ACTUAL PLANT
           COMMUNITIES
4.6.1.1   *Arable weeds.*
The arable weeds are subdivided into two different syntaxonomical classes. Class 12 (Chenopodietea) comprises species that occur in summer cereal and root crops (esp. order 12A)

and annual species from ruderal places like rubbish dumps, dung hills and the like (esp. order 12B). On the other hand, class 13 (Secalietea) consists of species occurring in winter cereal crops. The differences between species of summer- versus wintercrops become clear, when the associated methods for cultivation are inspected.

Ploughing is normally undertaken before sowing, thus in autumn for wintercrops, which are sown in September-November, and in early spring for summercrops (sown around April). Ideally, wintercrop weeds germinate in the autumn. In a wintercrop plot, they can develop together with the cereals, after ploughing. In that case they can produce ripe seeds in late summer when the cereals are also ripening.

Alternatively, the wintercrop weeds that have germinated in a plot that will carry a summercrop, will be ploughed under in early spring. The remaining time between sowing and harvesting is now too short for a wintercrop weed to produce ripe seeds.

Summercrop weeds have a much shorter growing cycle and can produce ripe seeds in summercrops. In wintercrops, any germinating summercrop weeds have to develop in an already dense growth of plants. Only in wintercrop fields with a lot of open space (owing to a badly growing crop) or along the edges, a considerably larger number of summer-crop weeds may well develop. Although this picture is somewhat idealized and actual data often show evidence of combined occurrences of summer- and wintercrop weeds, we usually find that in summercrops no wintercrop weeds can develop (see also Willerding 1980). The reverse occurs much more often. Thus, the presence of summercrop weeds is not too characteristic, but the presence or absence of wintercrop weeds is much more so (see also Bannink et al. 1974).

4.6.1.2   Plant communities of pastures and meadows.
Several classes contain elements of grasslands. Sandy, dry grasslands belong to class 20 (Koelerio-Corynephoretea), dry grasslands on calcareous soils to class 21 (Festuco-Bro-metea) and damp grasslands to class 25 (Molinio-Arrhena-theretea). Furthermore, in grazed heathlands on acid, poor soils another class occurs; class 30 (Nardo-Callunetea), while in salt environments class 24 (Asteretea tripolii) pro-vides good grazing territory. Very heavily grazed pastures are allocated to class 16 (Plantaginetea majoris), where resistance to treading is the key factor.

In the present study, class 20 and 21 are absent. Class 25 on the other hand is of considerable importance. This class is subdivided into two orders, in which the Arrhenathereta-lia include the mown meadows, which (at present) are heav-ily fertilized and the Molinietalia, which are essentially pastures, with less fertilization.

Körber-Grohne (1990: 25) has put forward that the spe-cies at present characterizing damp grasslands, and espe-cially mown ones, are dominated by *Arrhenatherum elatius*, which gave its name to the class and order. Subfossil seeds of this species, however, have been found only once, despite the potential capacity for good preservation in this species. Apparently, *Arrhenatherum* was very rare in prehistoric conditions, and thus it is improper to name former meadows after it. Körber-Grohne (1990: 98) proposed not to use

Table 16. Class numbers, syntaxonomical names and ecological descriptions after Westhoff & Den Held (1969) and class numbers after Ellenberg (1979).

Class number (Westhoff & Den Held)	Present class names	Ecological description	Class number (Ellenberg)
5	Potametea	Waterplants	1.3
8	Thero-Salicornietea	Therophytic saltmarsh pioneers	2.4
9	Cakiletea maritimae	Tide-mark plants	2.8
10	Isoeto-Nanojuncetea	Ephemeral plants	3.1
11	Bidentetea tripartiti	Therophytic nitrophilous pioneers	3.2
12	Chenopodietea	Summercrop weeds and annual ruderals	3.3
13	Secalietea	Wintercrop weeds	3.4
16	Plantaginetea majoris	Tread resistant plants	3.7
17	Artemisietea vulgaris	Perennial ruderals	3.5
19	Phragmitetea	Reedswamp plants	1.5
24	Asteretea tripolii	Saltmarsh plants	2.6
25	Molinio-Arrhenatheretea	Plants of damp grasslands	5.4
27-30	Parvocaricetea, Scheuchzerietea, Oxycocco-Sphagnetea, Nardo-Callunetea	Heathland and bog plants	1.7, 1.8, 5.1
32-34	Franguletea, Salicetea purpureae Rhamno-Pruneteae	Shrubs	8.1, 8.2 (p.p.) 8.4 (p.p)
35	Alnetea glutinosae	Alder carr plants	8.2
38	Querco-Fagetea	Forest plants of rich soils	8.4

present syntaxonomical names for prehistoric times, because of the absence of important character species. She prefers to use a name which indicates ecological factors, e.g. wet to damp grasslands instead of Molinietalia. This proposal will be followed here. Class numbers (*sensu* Westhoff/ Den Held 1969) will be used to avoid repeated use of these long descriptions. A drawback is that this numbering is not standardized, and deviates for instance from Ellenberg's (1979) numbering. In table 16, the class numbers, present syntaxonomical names, ecological descriptions and Ellenberg's class numbers are given for those classes which are of relevance here.

The occurrence of mown meadows during the Iron Age is especially relevant in the light of the common occurrence of byres with stalls in this period (see e.g. Waterbolk 1975; Haarnagel 1984). The housing of livestock will have necessitated some kind of winter feeding (see also Behre/ Jacomet 1991).

4.6.1.3   Plant communities of salt environments.
In salt marsh situations, the transition of sea to land passes through a characteristic series of plant communities. In the littoral zone, up to slightly below mean high water level (M.H.W.), the two *Zostera* species (eel grass) occur, which belong to class 2 (Zosteretea). In the tidal zone, in the range from slightly below M.H.W. to springtide level, the vegetation is dominated by *Salicornia europaea* s.l., arranged in class 8 (the present Thero-Salicornietea). *Suaeda maritima*, *Aster tripolium* and *Spartina X townsendii* may occur as accompanying species. This vegetation of annual pioneers is followed by perennial plants allocated to class 14 (Spartinetea), a still open type of vegetation in which at present the neophyte *Spartina* X *townsendii* strongly predominates. In the supralittoral zone of a salt marsh, perennial plants form a closed plant cover, arranged in class 24 (Asteretea tripolii). This type of vegetation provides excellent pastures. On the tide-marks that are deposited at high tide levels in salt marshes, a characteristic vegetation is present, often with *Atriplex littoralis* or *Suaeda maritima*, they are included in class 9 (Cakiletea maritimae).

According to Westhoff *et al.* (1971), plant species that are characteristic of the contact zone between salt and fresh water are a.o. *Odontites verna*, *Carex cuprina*, *Trifolium fragiferum*, *Triglochin palustris*, *Ranunculus sardous*, *Oenanthe lachenalii* and *Aster tripolium*.

4.6.1.4   Waterside vegetation types.
The vegetation of reed and other large grasses and sedges which grow "with their feet submerged" for the greater part of the year, is included in class 19 (Phragmitetea). According to Westhoff *et al.* (1971), three possible succession series can be observed in reed communities, viz. the tendency to form an alder carr vegetation, to acidification with oligotrophic

bog formation, and to ruderalisation. Several tall herbs characterize ruderal situations in reed vegetations, e.g. *Lysimachia vulgaris*, *Stachys palustris*, *Lythrum salicaria*, *Eupatorium cannabinum*, *Valeriana officinalis*, *Thalictrum flavum* and *Epilobium hirsutum*. According to these authors, the fringes of reed along shores in more brackish situations are replaced by vegetations with *Scirpus maritimus* and *S. lacustris* ssp. *tabernaemontani*, locally with *Althaea officinalis* and *Oenanthe lachenalii*.

In places which periodically fall dry, a vegetation of annual plants develops, belonging to class 11 (Bidentetea tripartiti).

4.6.1.5   Vegetation types of environments disturbed by man.
The first plant community to be mentioned here is class 16 (Plantaginetea majoris), consisting of tread resistant plants on all kinds of soils. In more neglected places around human settlements, the tall perennial weeds of class 17 (Artemisietea vulgaris) dominate the vegetation.

4.6.2   THE MACROREMAINS OF ROTTERDAM-HARTELKANAAL 10-69
This Early Iron Age site yielded only two samples for botanical macroremains, which have been studied by W.J. Kuijper (see *table 17*). These samples apparently did not contain any carbonized plant remains. Crop plants are not represented, neither are crop weeds or plants that are indicative of anthropogenic influence. Unfortunately, the samples may

Table 17. Botanical macroremains of Rotterdam-Hartelkanaal 10-69. Counted numbers. (Contexts unknown).

Sample number	28	54	Alternative
Volume (l)	0.25	0.5	classes
Therophytic nitrophilous pioneers (cl.11)			
Polygonum hydropiper	1	—	12,13,19,33
Tread resistant plants (cl.16)			
Potentilla anserina	—	2	10,24
Ranunculus repens-type	—	4	10,12,13,25
Reedswamp plants (cl.19)			
Eleocharis palustris	2	—	10,16,24
Lycopus europaeus	—	1	35
Plants of damp grasslands (cl.25)			
Hypericum quadrangulum	—	3	
Stachys palustris	—	2	12,13,33
Heathland and bog plants (cl.27-30)			
Hydrocotyle vulgaris	—	1	10,16,19,33
Alder carr plants (cl.35)			
Carex cf. elongata	5	6	
Various:			
Euphorbia palustris	—	1	25
Mentha aquatica/arvensis	2	—	12,13,16,19
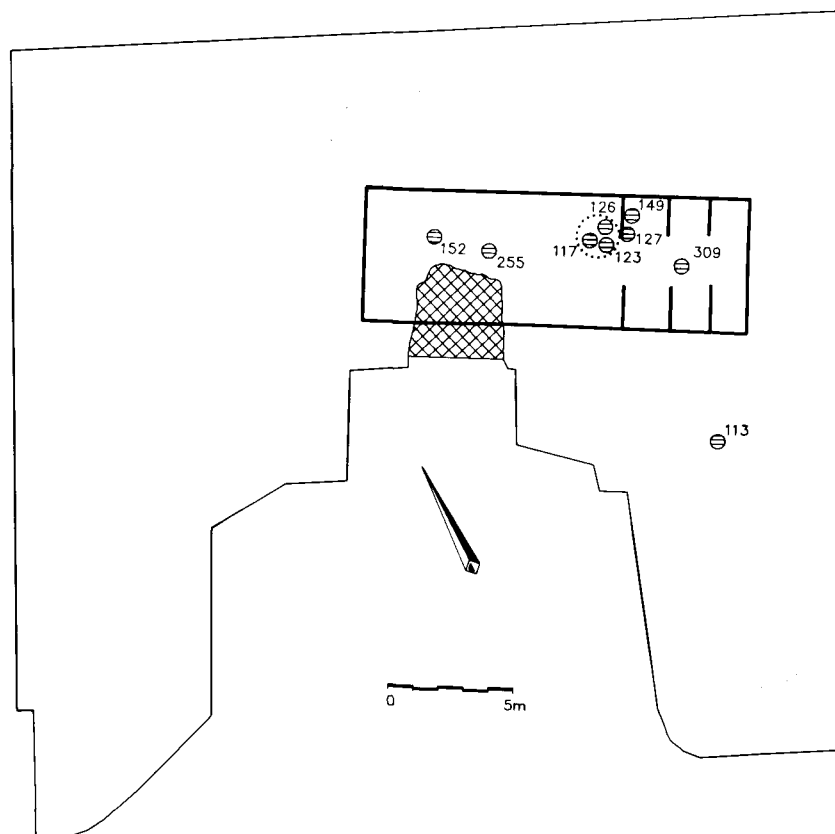
Fig. 38 Location of samples for botanical
macroremains in and around the houseplan
of Spijkenisse 17-30, scale 1:300.
Dotted line = hearth.

have been composed of the peaty subsoil of the site (see Van
Trierum *in press*). If so, crop plants or other anthropogenic
indicators could not be expected. All species, albeit char-
acter species of various syntaxonomical classes, may have
derived from natural vegetation types.

4.6.3   THE MACROREMAINS OF SPIJKENISSE 17-30
On this Early Iron Age site, several hearths (samples 113,
117, 126, 127 and 309), floor layers (sample 149 and 152)
and dung layers (sample 123 and 255) were sampled (see *fig.
38*).

One hearth, represented by sample 113, was situated out-
side the building. It was considered possible that this hearth
served a special purpose (roasting of grain or the like), but
botanical evidence for such a function could not be found
(compare *table 18*). The only carbonized remains belonged
to *Alnus glutinosa* and clearly came from the firewood.
Apart from this very poor sample (with respect to number
of taxa and absolute number of macroremains), the samples
are dominated by seeds of waterside plants (class 19 and
class 11).

Taxa occurring in damp meadows and pastures (class 25)
are considerably more important than arable weeds. These
arable weeds are without exception characteristic of class 12.

As explained before, this class comprises both summercrop
weeds (the present order of Polygono-Chenopodietalia) and
annual ruderal vegetations of dung hills, refuse heaps and
the like (the present Sisymbrietalia). Of the four species
occurring here, two (*Capsella bursa-pastoris* and *Polygonum
aviculare*) are character species of the annual ruderals, the
other two (*Solanum nigrum* and *Stellaria media*) typify both
orders. Consequently, they were not necessarily derived from
cultivated fields either. The absence of ecologically more
restricted, stenoecious crop weed species and the remarkably
small amount of cereal chaff found on this site will be
discussed further in chapter 6.

In the samples, indicators of salt habitats are present in
very small numbers of seeds, the only species concerned is
Salicornia europaea.

4.6.4   THE MACROREMAINS OF SPIJKENISSE 17-35
The two Iron Age phases occurring on this site (see *1.3.1.1*)
both yielded samples for macroremains. Unfortunately, only
a few samples proved worth analysing.

Sample 614 concerns a hearth in the Early Iron Age
building, no. 506 represents dung from the byre area and
sample 604 is from the central aisle in the byre. The samples
598 and 600 can also be dated to the Early Iron Age, but

Table 18. Botanical macroremains of Spijkenisse 17-30. Counted numbers. * = carbonized.

Sample number Context Volume (l)	113 hearth 0.3	117 hearth 2	123 dung 2	126 hearth 3	127 hearth 1.5	149 floor 0.25	152 floor 0.1	255 dung 0.5	309 hearth 0.5	Alternative classes
Crop plants:										
Brassica rapa	—	1	13	74	3	1	4	1	1	
Cerealia indet.	—	—	1*	1*	—	—	—	—	—	
cf. Triticum dicoccum fr.	—	—	—	28*	—	—	—	—	—	
Panicum miliaceum	—	—	—	38*	—	—	—	—	—	
Triticum cf. dicoccum gl.b.	—	1*	4,4*	1*	—	—	—	—	—	
Triticum cf. dicoccum sp.f.	—	—	—	1*	—	—	—	—	—	
Triticum dicoccum	—	—	—	17*	—	—	—	—	—	
Triticum spec. awn fr.	—	—	—	1*	—	—	—	—	—	
Therophytic saltmarsh pioneers (cl.8):										
Salicornia europaea	—	—	—	—	—	—	—	1	35	24
Ephemeral plants (cl.10):										
Juncus bufonius	—	368	128	96	32	2	1	16	—	12,13,16,24
Therophytic nitrophilous pioneers (cl.11):										
Chenopodium rubrum	—	48	—	—	9	—	—	3	2?	12
Ranunculus sceleratus	1	30	415	1211	12,3*	5	19	6	21	
Rorippa palustris	—	8	—	—	—	—	3	—	—	
Rumex maritimus	1	1,1*	—	—	3	2	4	—	—	
Stellaria aquatica	—	—	2	—	—	—	—	—	—	
Summercrop weeds (cl.12):										
Capsella bursa-pastoris	—	—	—	—	—	—	—	1	—	11,16
Polygonum aviculare	—	—	2	1?	—	—	2	—	—	
Solanum nigrum	—	1	—	—	—	—	—	—	—	11
Stellaria media	—	—	2	2	—	—	2	—	—	
Tread resistant plants (cl.16):										
Carex cuprina-type	—	7,4*	37	127	3,1*	1	1	4	—	25
Carex hirta	—	—	—	—	—	—	—	—	1	25
Juncus effusus-type	—	—	64	—	32	—	—	—	—	25
Plantago major	—	—	—	—	3	1	—	—	—	10,12,13,24
Poa trivialis-type	—	—	—	48	32	1	13	89	16	17,33
Potentilla anserina	—	1	—	—	3*	—	—	—	—	10,24
Ranunculus repens-type	—	1	—	2	—	—	—	—	—	10,12,13,25
Triglochin palustris	—	—	—	—	—	—	—	2	—	24,27
Perennial ruderals (cl.17):										
Galium aparine	—	—	—	2*	—	—	—	—	—	12,33,38
Urtica dioica	—	4	63	375	3	—	—	1	—	33,38
Reedswamp plants (cl.19):										
Berula erecta	—	3	1	2	2	3	4	3	89	25,33,35
Carex paniculata-type	—	2	—	—	—	—	—	—	3	35
cf. Oenanthe aquatica	—	2	—	—	—	—	—	—	—	
Cladium mariscus	—	32,1*	23	15,3*	7	4	12	6	201,1*	
Eleocharis palustris	—	26,238*	80	6,54*	49,83*	1*	—	116	6,1*	10,16,24
Galium palustre	—	61	—	—	43	—	1	1	—	10,16
Iris pseudacorus	—	—	—	—	3	—	—	—	—	33,35
Lycopus europaeus	2	48	10	—	22	9	17	15	143	35
Phragmites australis	—	—	—	48	148	—	13	79	38	17,24,27
Phragmites australis stem	—	10-s*	—	7*	10,10*	—	—	—	—	17,24,27
Rumex hydrolapathum	—	—	—	—	1?	—	—	—	3	33
Scirpus lacustris tabernaemontani	2	17,71*	52	109,7*	26,8*	8	5	5	12	
Scutellaria galericulata	—	—	4	—	1	—	—	—	2	35
Typha spec.	—	—	—	—	3	—	—	1	—	25
Saltmarsh plants (cl.24):										
Juncus gerardi	—	128	480	144	96	27	2	512	40	10,16,25

Sample number	113	117	123	126	127	149	152	255	309	
Context	hearth	hearth	dung	hearth	hearth	floor	floor	dung	hearth	Alternative
Volume (l)	0.3	2	2	3	1.5	0.25	0.1	0.5	0.5	classes
Plants of damp grasslands (cl.25):										
Carex cf. panicea	—	—	—	—	—	—	—	—	1	29
cf. Cirsium palustre	—	—	—	—	—	—	—	—	1	35
Hypericum quadrangulum	—	20	—	—	—	32	—	—	190	
Lychnis flos-cuculi	—	36	—	—	1	1	—	5	268	
Lythrum salicaria	—	16	—	1	35,16*	96	2	25	157	19,35
Stachys palustris	8	11	—	2	3	1	—	1	54	12,13,33
Thalictrum flavum	—	1	—	1	—	1	—	—	2	33
Heathland and bog plants (cl.27-30):										
Hydrocotyle vulgaris	—	3	—	—	4	1	6	—	168	10,16,19,33
Juncus squarrosus	—	—	32	—	—	—	—	1	—	
Juncus subnodulosus	—	16	32	—	—	27	6	112	448	19,25
Sagina nodosa-type	—	—	—	—	—	16	—	—	22	
Stellaria palustris	—	—	—	—	—	—	—	6	14	
Alder carr plants (cl.35):										
Alnus glutinosa	1*	—	—	—	—	—	—	—	—	
Alnus glutinosa catkin axis	—	—	—	—	2*	—	—	—	—	
Alnus glutinosa bud	4*	19,1*	—	—	2,18*	—	—	—	—	
Forest plants of rich soils (cl.38):										
Moehringia trinervia	—	—	—	2	—	—	—	—	—	33
Various:										
Agrostis spec.	—	32	32*	101*	54	2	24	488	48,8*	16,24,25
Atriplex patula/prostrata	—	2,88*	17	12,2*	70	10	24	16	91	11,12,16,17,24
Bromus mollis/secalinus	—	—	—	7*	—	—	—	—	—	
Carex spec. bicarpellate	—	—	—	—	—	—	3	—	—	
Eupatorium cannabinum	—	1	—	1	—	3	—	35	19	17,25
Euphrasia/Odontites spec.	—	—	—	—	—	—	—	2	1	
Euphorbia palustris	—	—	—	—	2	—	—	—	—	25
Gramineae indet.	—	8*	2*	—	6*	—	27	—	—	
Gramineae/Sclerotium	—	1*	—	—	—	—	—	—	—	
Juncus articulatus-type	—	96	128	—	80	—	1	144	24	10,16,25
Juncus spec.	—	16	320	—	—	—	—	112	32	
Juncus spec. non bufonius	—	32*	—	—	32*	—	13*	—	—	
Mentha aquatica/arvensis	1	50	8	51	8	3	4	7	165	12,13,16,19
Molinia-type stem	—	—	—	—	1	—	—	—	—	
Papilionaceae indet.	—	4*	—	—	—	—	—	—	—	
Phalaris arundinacea	—	—	—	—	—	—	—	1	—	16,19,25,33
Rumex spec.	—	1,1*	6	2	—	—	—	—	3	
Salix spec. bud scale	—	—	—	—	9,1*	—	—	—	—	
Anagallis minima/Samolus valerandi	—	—	—	—	—	—	—	—	8	6,10
Trifolium repens/fragiferum	—	7*	—	—	7*	—	—	—	—	
Umbelliferae non Oenanthe	—	—	—	—	1	1	—	—	—	

they were probably redeposited and not *in situ* (Van Trierum *in press*). Samples 612, 615 and 616 are (*in situ*) from Middle Iron Age contexts (see *table 19*). Figure 39 illustrates the location of the samples on this site.

As in Spijkenisse 17-30, the samples, both from Early and Middle Iron Age contexts, are dominated by waterside plants (classes 19 and 11). The Middle Iron Age sample 612 shows extraordinarily large numbers of *Galium aparine* and *Urtica dioica*, both perennials belonging to class 17, characteristic of neglected ruderal places, fallow land, etc. *Galium aparine* can also be a serious pest in wintercrops in traditional agricultural conditions (cf. Reynolds 1981b). In view

of the absence of other wintercrop weeds, it seems, however, unlikely that the present cleaver seeds derive from arable fields. Taxa of class 12 (summercrops or dung hills etc.) are more common. In contrast to Spijkenisse 17-30, the site of 17-35 also produced some ecologically restricted (stenoecious) summercrop weeds. They are more or less limited in their occurrence to summer cereal- and root crops. Here we are dealing with *Echinochloa crus-galli*, *Erysimum cheiranthoides* and *Polygonum persicaria*. Plants from meadows (cl. 25) also occur regularly, species from salt environments are very rare again.

A remarkable occurrence is the characteristic fruit of *Xan-*

Table 19. Botanical macroremains of Spijkenisse 17-35. Counted numbers, * = carbonized.

Sample number	506	598	600	604	614	612	615	616	
Volume (l)	1	3.5	2.5	2.5	0.5	3	0.5	1.5	
Context	dung	refuse	dung	dung	hearth	refuse	refuse	refuse	Alternative
Period	EIA	EIA	EIA	EIA	EIA	MIA	MIA	MIA	classes
Crop plants:									
Brassica cf. rapa	—	—	—	—	—	3	1	—	
Camelina sativa	—	1	—	—	—	20	—	—	
Camelina sativa silicle fr.	—	—	—	—	—	18	—	—	
cf. Hordeum vulgare	—	—	—	—	—	2*	—	—	
Hordeum vulgare internode	—	—	2*	—	—	3,18*	—	—	
Hordeum vulgare	—	1*	1*	—	—	4*	—	—	
Hordeum cf. vulgare	—	—	—	—	—	6	—	—	
Hordeum/Triticum internode	—	—	—	—	—	15*	—	—	
Linum usitatissimum	—	15	—	—	—	232	—	—	
Linum usitatissimum capsule fr.	—	1	—	—	—	71	—	—	
Triticum dicoccum glume base	—	—	—	—	—	15,21*	—	—	
Triticum dicoccum spikelet fork	—	—	—	—	—	6,11*	—	—	
Waterplants (cl.3-5):									
Potamogeton spec.	—	4	—	—	—	—	—	—	
Zannichellia palustris	—	3	—	—	—	—	—	—	
Therophytic saltmarsh pioneers (cl.8):									
Salicornia europaea	—	—	—	—	—	—	1	1	24
Tide-mark plants (cl.9):									
Atriplex littoralis-type	—	—	—	—	—	5	—	—	
Ephemeral plants (cl.10):									
Juncus bufonius	32	176	4800	—	—	1120	1920	896	12,13,16,24
Therophytic nitrophilous pioneers (cl.11):									
Bidens cernua	—	1	4	—	—	6	1	—	19
Bidens tripartita	—	15	6	—	—	35	—	5	12,19
Chenopodium rubrum	—	4	20	—	—	1150	2	2	12
Polygonum hydropiper	—	17	13	—	—	14	—	—	12,13,19,33
Polygonum minus	—	88	101	—	—	—	—	6	19
Ranunculus sceleratus	—	241	178	450	—	245	1000-s	420	
Rorippa palustris	—	2	—	—	—	15	110-s	127	
Rumex maritimus	—	22	111	—	—	67,3*	100	25	
Stellaria aquatica	2	22	6	—	—	1997	—	—	
Summercrop weeds (cl.12):									
Capsella bursa-pastoris	—	—	—	—	—	15	—	—	11,16
Chenopodium ficifolium	—	74	19	—	—	1442	—	—	
Echinochloa crus-galli	—	3	—	—	—	73	—	—	
Erysimum cheiranthoides	—	—	2	—	—	—	—	—	
Polygonum aviculare	—	3	—	—	—	4	—	—	24
Polygonum lapathifolium	—	50	—	—	—	389	—	62	11
Polygonum persicaria	—	—	—	—	—	98,1*	173	—	19
Sisymbrium officinale	—	—	—	—	—	184	—	—	
Solanum nigrum	—	3	—	—	—	38	—	—	11
Sonchus arvensis	—	2	—	—	—	—	—	—	
Sonchus asper	—	3	—	—	—	33	—	—	
Sonchus oleraceus	—	—	—	—	—	18	—	—	
Stellaria media	—	5	2	—	—	1670	—	—	
Urtica urens	—	—	—	—	—	34	—	—	
Tread resistant plants (cl.16):									
Carex cf. hirta	—	—	—	—	—	2	—	—	25
Carex cuprina-type	—	6	2	—	—	3	—	—	25
Juncus effusus-type	—	—	480	—	—	362	—	—	25
Plantago major	1	53	5	—	—	283	—	—	10,12,13,25
Poa annua	—	—	—	—	—	18	—	—	10,11,12

Sample number	506	598	600	604	614	612	615	616	
Volume (l)	1	3.5	2.5	2.5	0.5	3	0.5	1.5	
Context	dung	refuse	dung	dung	hearth	refuse	refuse	refuse	Alternative
Period	EIA	EIA	EIA	EIA	EIA	MIA	MIA	MIA	classes
Poa trivialis-type	34	332	502	96	—	2451	228	187	17,33
Potentilla anserina	—	15,3*	5	—	—	2	—	—	10,24
Ranunculus repens-type	—	67	36	—	—	11	—	—	10,12,13,25
Ranunculus sardous	—	1	—	—	—	—	—	—	10,25
Perennial ruderals (cl.17):									
Galium aparine	—	—	—	—	—	107,3*	—	—	12,33,38
Solanum dulcamara	—	—	3	—	1	—	1	—	19,33,35
Urtica dioica	—	164	106	8	—	9974	—	—	33,38
Reedswamp plants (cl.19):									
Alisma plantago-aquatica	—	17	6	—	—	142	—	—	33
Alisma spec. embryo	—	23	6	—	—	196	—	—	33
Berula erecta	2	66	20	29	13	26	4	14	25,33,35
Carex acuta-type	—	172	59	—	—	3	—	—	
Carex acutiformis	—	10	7?	—	—	—	—	—	
Carex paniculata-type	—	23*	4	—	—	11	—	—	35
Carex pseudocyperus	2	2	—	—	—	2	—	—	
Carex riparia	—	13	1	—	1	—	—	—	35
Cladium mariscus	3	35	4	6	63	—	—	3	
Eleocharis palustris	2	783	365	—	—	921	2	—	24
Galium palustre	—	16,5*	10,2*	15	4	66,1*	2	10	10,16,24
Glyceria fluitans	—	21	2	—	—	53	—	—	
Glyceria maxima	1	4	2	—	—	45	—	—	33
Iris pseudacorus	—	15,2*	15	—	1	—	—	1	33,35
Lycopus europaeus	15	46	148	679	166	361	10	119	35
Oenanthe aquatica	—	1	—	—	—	1?	—	—	
Oenanthe fistulosa	—	74,6*	46	—	—	66	—	—	
Phragmites australis	99	4	—	—	—	11	—	—	17,24,27
Phragmites australis stem	10	—	—	—	—	10-s	10-s,3*	—	17,24,27
Rumex hydrolapathum	—	58	6	—	—	81	—	—	33
Sagittaria sagittifolia	—	1	—	—	—	—	—	—	
Scirpus lacustris tabernaemontani	28	2686,3*	1787	1510	200	62	19	516	
Scutellaria galericulata	—	—	—	20	13	10	—	13	35
Sparganium erectum	—	145,5*	9	—	—	1	—	—	33
Typha spec.	216	112	160	—	4	48	—	1	25
Veronica beccabunga-type	16	—	—	—	—	—	—	—	
Saltmarsh plants (cl.24):									
Aster tripolium	—	—	—	—	—	—	—	1	17
Juncus gerardi	—	32	—	—	—	—	16	—	10,16,25
Scirpus maritimus	—	—	—	—	—	—	1	—	
Plants of damp grasslands (cl.25):									
Angelica sylvestris	—	—	—	—	—	4	—	—	33
Caltha palustris	—	1	—	—	—	—	—	—	19,27,33
Carex disticha	—	999,9*	286	—	—	208	1	—	16
Cirsium palustre	—	14?	—	3	—	—	—	—	35
Filipendula ulmaria	—	1	—	—	—	216	—	—	
Hypericum quadrangulum	—	808	960	1048	59	192	17	266	
Lychnis flos-cuculi	—	163	124	—	—	194	2	25	
Lythrum salicaria	716	140	94	3248	66	390	2	182	19,35
Molinia caerulea	—	—	—	—	—	5	—	—	29,30,32,35
Prunella vulgaris	—	—	—	—	—	3	—	—	10,33
Senecio aquatica	—	19	—	—	—	50	—	—	
Stachys palustris	3	2	5	59	11	4	—	6	12,13,33
Thalictrum flavum	—	3	2	—	—	1	—	—	33
Valeriana officinalis	—	—	—	—	—	10	—	—	19,33
Heathland and bog plants (cl.27-30):									
Calluna vulgaris	—	—	—	—	—	48	—	—	

Sample number	506	598	600	604	614	612	615	616	
Volume (l)	1	3.5	2.5	2.5	0.5	3	0.5	1.5	
Context	dung	refuse	dung	dung	hearth	refuse	refuse	refuse	Alternative
Period	EIA	EIA	EIA	EIA	EIA	MIA	MIA	MIA	classes
Calluna vulgaris flower	—	—	—	—	—	4	—	—	
Calluna vulgaris twig	—	—	1	—	—	—	—	—	
Epilobium palustre	—	15	—	—	2	133	—	2	19
Erica tetralix leaf	—	—	2	—	—	10	—	—	25,32
Galium cf. saxatile	—	—	—	—	—	86	—	—	
Hydrocotyle vulgaris	—	15	10	8	—	12	1	4	10,16,19,33
Juncus subnodulosus	—	336	560	—	—	398	48	—	19,25
Pedicularis palustris	—	12	1	—	—	6	—	—	
Potentilla erecta-type	—	15	21	—	—	88	—	—	
Stellaria palustris	—	7	—	—	—	—	—	—	
Shrubs (cl.32-34):									
Myrica gale leaf fr.	—	—	—	—	—	2	—	—	
Myrica gale bud scale	—	—	—	—	—	10-s	—	—	
Prunus spinosa	—	—	—	—	—	5	—	—	
Sambucus cf. nigra	—	1	—	—	—	—	—	—	38
Alder carr plants (cl.35):									
Alnus glutinosa	—	9	5	—	—	23	—	—	
Thelypteris palustris leaf fr.	—	—	—	—	—	6	—	—	19
Forest plants of rich soils (cl.36-38):									
Moehringia trinervia	—	231	150	—	—	—	—	—	
Various:									
Agrostis spec.	756	20	2	80	—	1269	88	103	16,24,25
Alopecurus spec.	—	—	—	—	—	6	—	—	
Atriplex patula/prostrata	6	82	60	33	134	2489	100	15	11,12,16,17,24
Betula cf. pubescens	—	—	—	—	—	11	—	—	
Betula cf. pubescens scale	—	—	—	—	—	1	—	—	
Bromus spec.	—	—	—	—	—	19	—	—	
Carex cf. remota	—	1	—	—	—	—	—	—	
Carex oederi s.l.	—	—	—	—	—	5	—	—	
Cerastium spec.	—	44	42	—	—	261	—	—	
cf. Claviceps sclerotium	—	1	—	—	—	—	—	—	
Epilobium hirsutum-type	—	203	16	—	2	238	—	—	25
Eupatorium cannabinum	3	—	1	42	6	1	—	64	17,25
Euphrasia/Odontites spec.	—	—	4	—	—	12	—	—	
Galeopsis bifida-type	—	—	—	—	—	11	—	—	
Gramineae indet.	32	—	—	—	—	6	—	1	
Juncus articulatus-type	64	752	15680	—	—	1663	32	48	10,16,25
Juncus spec.	—	16	480	—	—	72	48	16	
Mentha aquatica/arvensis	—	1008,12*	283	448	115	211	—	94	12,13,16,19
Myosotis spec.	—	69	4	—	—	134	—	—	
Peucedanum palustre	—	1	—	—	—	—	—	—	19,27,35
Phalaris arundinacea	—	1	—	—	—	19	—	—	16,19,25,33
Rhinanthus spec.	—	7	—	—	—	3	—	—	
Rubiaceae non Galium palustre	—	3	—	—	—	—	—	—	
Rubus caesius	—	9	—	—	—	—	—	—	17,33
Rubus fruticosus s.l.	—	4	—	—	—	—	—	—	
Rumex conglomeratus	—	176,3*	—	—	—	—	—	—	16
Rumex spec.	—	18,5*	43	—	5	320	1	15	
Sagina apetala/procumbens	—	907	1648	—	4	336	32	16	10,16
Trifolium repens flower	—	—	1?	—	—	4	—	—	10,16
Trifolium spec. pod fr.	—	—	—	—	—	1	—	—	
Veronica spec.	—	—	—	—	—	108	—	—	
Viola palustris-type	—	1	—	—	—	7	—	—	
Xanthium strumarium	—	—	—	—	—	1	—	—	
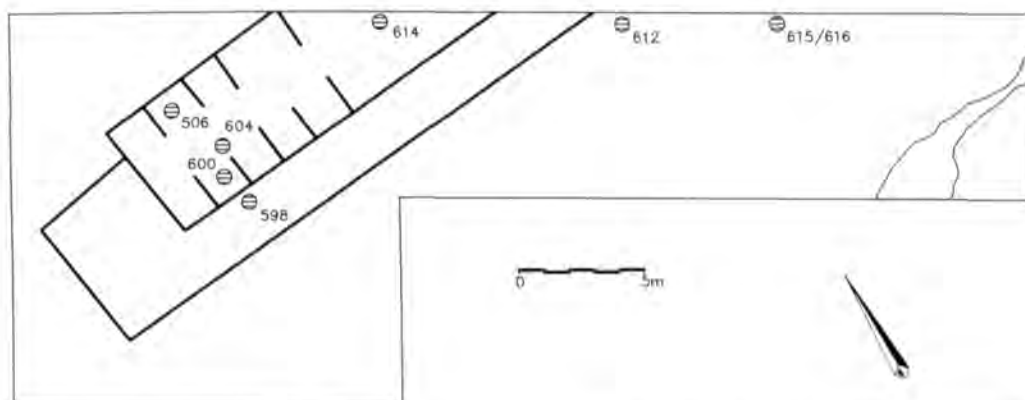
Fig. 39 Location of samples for botanical macroremains in and around the houseplan of Spijkenisse 17-35, scale 1:300.
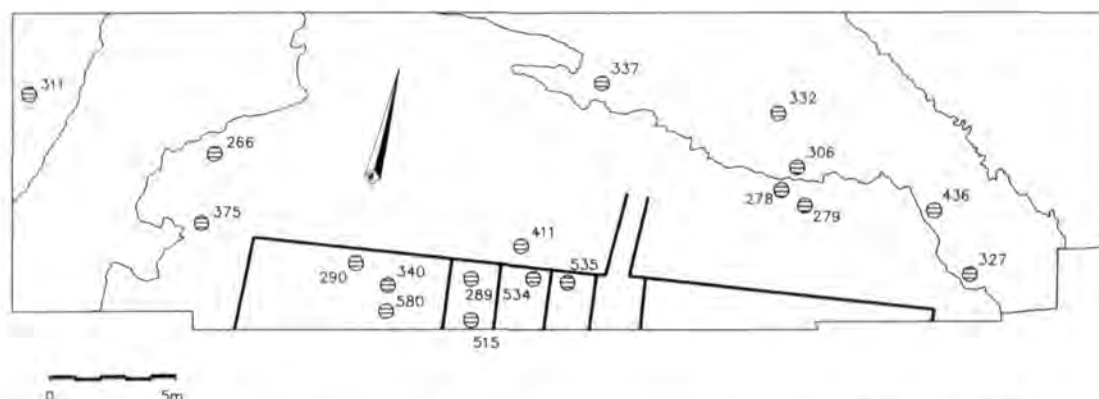
Fig. 40 Location of samples for botanical macroremains in and around the houseplan of Spijkenisse 17-34, scale 1:300.

thium strumarium, which is also found on several other Iron Age sites on Voorne-Putten. This occurrence in Iron Age contexts, and the fact that all west European sites that yielded fruits of this species are situated near rivers, have led Brinkkemper and Kuijper (*in press*) to conclude that the cocklebur was spread by natural agents, and not by man, as was previously assumed (cf. Opravil 1983).

As in Spijkenisse 17-30, salt plants are rather rare, *Salicornia europaea* and *Juncus gerardi* occur in two samples. *Aster tripolium* and *Atriplex littoralis*-type in one. Both Early and Middle Iron Age contexts contain some salt plants.

The eight samples contained on average ca. 50 taxa, but some poor and some very rich samples occurred. The richest sample (expressed in number of taxa), sample 612, revealed 104 taxa (belonging to at least 102 different species), the largest number of all samples analysed in the present study.

4.6.5 THE MACROREMAINS OF SPIJKENISSE 17-34
Of this Middle Iron Age settlement, 19 samples for botanical macroremains have been analysed. They came from

hearths (samples 340, 580 and 580a), from dung layers (samples 289, 290, 411, 515, 534 and 535), from a ditch, contemporary with habitation (samples 266, 278, 306, 311, 327, 332, 337, 375 and 436) and from a floor layer (sample 279). The location of the samples is indicated in figure 40. The results of the analyses are given in table 20.

The presence of the ditch is clearly demonstrated in the large numbers of waterplants (class 5), especially *Callitriche* spec. and *Chara* spec. Furthermore, this is the only site that yielded *Najas marina* fruits. *Najas marina* is typical of fresh or slightly brackish water (Van der Meijden 1990: 471). In this respect, it is interesting to note that as in Spijkenisse 17-30 and 17-34, salt marsh plants (cl. 8, 9 and 24) are present in only very small quantities and few species. The ditch concerned cannot have dried out yearly, since *Chara* and *Najas* indicate the presence of permanently open water.

Waterside plants (cl. 19 and 11) are very markedly present, as may be expected along a ditch. Species of pastures (cl. 25) are much more common than arable weeds (cl. 12), both in terms of numbers of taxa and of seeds.

One weed has been listed as a wintercrop weed (cl. 13:

Table 20. Botanical macroremains of Spijkenisse 17-34. Counted numbers. * = carbonized.

Sample number	266	278	279	289	290	306	311	327	332	337	340	375	411	436	515	534	535	580	580a	Alternative
Context	ditch	ditch	floor	dung	dung	ditch	ditch	ditch	ditch	ditch	hearth	ditch	dung	ditch	dung	dung	dung	hearth	hearth	classes
Volume (l)	1	1	2	1.5	0.6	2	1.5	1	1	1	0.5	1	1.5	2	0.5	3	3	3	3	
Crop plants:																				
Brassica rapa	—	—	1	—	—	—	—	1	1	—	—	—	—	2	—	—	—	—	—	
Camelina sativa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	
Cerealia indet. fr.	—	—	1*	1*	1*	1*	—	1*	1*	—	—	—	2*	1*	—	4*	35*	—	12	
Hordeum awn fr.	1*	—	4*	—	—	—	—	—	—	—	—	4*	—	—	—	—	—	1*	—	
Hordeum vulgare internode	3*	—	5*	—	2*	4*	—	2*	—	—	—	1	1*	36*	—	9*	28*	2	—	
Hordeum vulgare	—	—	1*	1*	—	—	—	—	—	—	—	—	1*	—	—	—	3*	1,19*	4*	
Linum usitatissimum capsule fr.	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	5*	—	
Linum usitatissimum	1	—	14	—	—	—	1	1	—	1	—	—	—	1	2	—	—	8,14*	7*	
Triticum cf. dicoccum	—	—	1*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3*	4*	
Triticum cf. spelta glume base	—	—	—	—	2*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Triticum dicoccum glume base	—	—	5*	1*	—	—	—	1*	2*	1*	—	—	7*	9*	—	64*	83*	3,1*	9*	
Triticum dicoccum spikelet fork	—	—	2*	—	—	—	—	—	—	—	—	—	3*	—	—	13*	10*	—	—	
Triticum dicoccum glume apex	—	—	1*	—	—	—	—	—	—	—	—	—	—	—	—	96*	289*	—	—	
Triticum spec. awn fr.	—	—	—	—	—	—	—	—	—	—	—	—	—	24*	—	1000*	400*	—	—	
Triticum spec. internode	—	—	8*	—	—	4*	—	—	—	—	—	—	—	—	—	8*	—	1*	—	
Waterplants (cl.3-5):																				
Callitriche spec.	1671	35	4	—	—	155	19	45	74	106	—	376	—	—	—	—	—	61,16*	—	
Ceratophyllum demersum	3	—	—	—	—	—	1?	1	2	—	—	—	—	—	—	—	—	—	—	
Ceratophyllum spec.	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—	—	—	—	—	
Ceratophyllum submersum	2	—	2	—	—	2	—	—	1	—	—	—	—	—	—	—	—	—	—	
Chara spec. oospores	14	850	—	—	—	2152	216	448	512	3041	—	104	—	72	—	48	—	—	—	
Najas marina	4	6	17	—	—	31	—	4	10	53	—	11	—	—	—	—	—	—	—	
Potamogeton spec.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	
Ranunculus sg. Batrachium	—	—	—	—	—	—	10	—	—	—	—	—	—	—	—	—	—	3	—	
Zannichellia palustris	30	134	5	—	—	62	2	5	32	96	—	86	—	—	—	—	—	—	4	—	
Therophytic saltmarsh pioneers (cl.8):																				
Salicornia europaea	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	24
Tide-mark plants (cl.9):																				
Atriplex littoralis-type	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	
Matricaria maritima	—	—	1	—	—	—	9	—	—	—	—	—	—	—	—	—	—	—	—	
Ephemeral plants (cl.10):																				
Juncus bufonius	464	624	14400	5424	—	3456	1400	672	1536	480	16	288	1488	1680	64	720	2500	16	—	12,13,16,24
Therophytic nitrophilous pioneers (cl.11):																				
Bidens cernua	—	—	16	—	—	2	—	1	1	2	—	1	—	22	—	—	—	2	—	19
Bidens spec	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Bidens tripartita	—	—	9	—	—	2	18	5	—	—	—	—	—	20	9	—	—	1,3*	—	12,19
Chenopodium rubrum	—	38	5	4	1	65	1	42	110	8	1	4	—	60	—	—	—	4	1	12
Polygonum hydropiper	—	—	—	—	—	—	—	11	6	1	—	6	—	6	—	—	—	—	—	12,13,19,33
Polygonum minus	37	1	13	2	—	17	—	16	2	5	—	4	—	17	—	—	—	—	—	19
Ranunculus sceleratus	184	50	22	83	2	114	84	108	7	42	—	130	2	24	—	4	13	101, 22*	12,3*	

Sample number	266	278	279	289	290	306	311	327	332	337	340	375	411	436	515	534	535	580	580a	Alternative
Context	ditch	ditch	floor	dung	dung	ditch	ditch	ditch	ditch	ditch	hearth	ditch	dung	ditch	dung	dung	dung	hearth	hearth	classes
Volume (l)	1	1	2	1.5	0.6	2	1.5	1	1	1	0.5	1	1.5	2	0.5	3	3	3	3	
Rorippa palustris	1	—	—	—	—	—	32	1	—	—	—	—	—	4	—	—	—	3	—	
Rumex maritimus	3	3	—	1	—	1	24	2	—	—	—	8	—	—	—	—	—	2	—	
Stellaria aquatica	44	2	48	162	—	73	69	41	26	6,1*	—	10	—	336	—	—	—	4,3*	3	
Summercrop weeds (cl.12):																				
Chenopodium ficifolium	5	—	63	8	—	64	22	11	4	9	—	—	—	106	—	12,9*	12	4,2	1	
Chenopodium polyspermum	—	—	—	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Echinochloa crus-galli	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1*	1*	—	—	
Hyoscyamus niger	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	
Polygonum aviculare	1	—	4	—	—	—	—	1	4	—	—	1	—	1	—	—	—	—	—	24
Polygonum lapathifolium	13	10	48,1*	87	—	49	53	15	20	1	—	5	2	119	3	—	2	6,5*	1	11
Polygonum persicaria	—	—	62	—	—	—	45	10	—	7	—	—	—	—	—	—	—	—	—	19
P.lapathifolium/persicaria	—	—	—	—	—	—	19	—	—	—	—	—	—	—	—	—	—	—	—	
Solanum nigrum	—	1	—	—	—	1	—	—	2	—	—	—	—	4	—	—	—	—	—	11
Sonchus arvensis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	
Sonchus asper	1	1	3	—	—	4	22	—	—	—	—	—	—	5	—	—	—	3	—	
Stellaria media	9	2	132,1*	2	—	8,8*	—	14	2	—	1	2	—	196	—	—	3?	1,1*	—	
Urtica urens	—	—	—	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—	
Wintercrop weeds (cl.13):																				
Cuscuta epilinum	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	
Tread resistant plants (cl.16):																				
Alopecurus geniculatus	—	3	—	—	—	—	175	—	—	—	—	—	—	—	—	—	—	—	—	
Carex hirta	—	—	—	—	—	4	—	—	—	—	—	—	—	—	—	—	1?	—	—	25
Juncus effusus-type	32	128	—	96	—	192	900	32	368	224	16	512	432	48	—	—	1750	—	—	25
Juncus cf. effusus capsule	—	—	—	—	—	—	—	—	—	—	—	—	—	1*	—	—	—	—	—	25
Leontodon autumnalis	—	—	—	—	—	—	8	—	—	—	—	—	—	—	—	—	—	—	—	10,24,25
Plantago major	4	8	14	—	21	32	315	3	4	—	1	16	4	8	—	2	32	27,1*	—	10,12,13,24
Poa trivialis-type	54	22	141	56	464	113	5	12	101	33	—	36	54	78	3	1	112	2	—	17,33
Potentilla anserina	—	—	1	—	—	2	73	1	3	2,2*	—	2	—	4	—	—	—	1	—	10,24
Ranunculus repens-type	11	10	5	—	—	32	74	9	9	21	—	35	—	3	—	—	2	1	—	10,12,13,25
Ranunculus sardous	—	—	—	—	—	—	4	—	—	—	—	—	—	—	—	—	—	1	—	10,25
Perennial ruderals (cl.17):																				
Artemisia cf. vulgaris	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	12
Galium aparine	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	12,33,38
Solanum dulcamara	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	19,33,35
Urtica dioica	20	17	19	24	16	110	8	28	29	8	5	30	25	190	1	14	64	9	—	33,38
Reedswamp plants (cl.19):																				
Alisma plantago-aquatica	13	10	—	—	—	100	—	112	44	114	—	108,4*	—	—	—	—	30	16,2*	7,3*	33
Alisma spec. embryo	8	13	4	—	13	32	6	15	4	36	—	4	4	—	—	2	—	6,3*	—	33
Berula erecta	1	13	7	4	—	166	1	47	16	44,1*	1	10	—	8	—	—	2	1	7,1*	25,33,35
Carex acuta-type	8	1	—	—	—	20	—	5	12	4	—	36	—	—	—	—	—	—	—	
Carex cf. acutiformis	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	
Carex cuprina-type	—	—	—	—	—	—	—	—	—	—	—	4	—	—	—	—	—	—	—	25
Carex elata	—	—	1	—	—	—	—	—	—	8?	—	—	—	—	—	—	—	—	—	
Carex paniculata-type	—	—	2	—	—	—	—	—	—	4,2*	—	—	—	4	—	1	—	3	1	35
Carex pseudocyperus	—	—	4	—	—	—	—	1	—	1	—	—	8	4	—	—	—	—	—	

Sample number	266	278	279	289	290	306	311	327	332	337	340	375	411	436	515	534	535	580	580a	Alternative
Context	ditch	ditch	floor	dung	dung	ditch	ditch	ditch	ditch	ditch	hearth	ditch	dung	ditch	dung	dung	dung	hearth	hearth	classes
Volume (l)	1	1	2	1.5	0.6	2	1.5	1	1	1	0.5	1	1.5	2	0.5	3	3	3	3	
Carex riparia	—	—	1	—	—	—	2	—	—	—	—	—	—	4?	—	—	—	—	—	35
Cicuta virosa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	
Cladium mariscus	37	1	52,1*	7	—	110,8*	5	97,3*	104	32	—	25	1	—	—	—	3,1*	6	7	
Eleocharis palustris	54	55	137,1*	28	369,2*	323	67	74	48,2*	60	2	59	37,1*	164,4*	9	87,6*	752,4*	94,43*	4	10,16,24
Galium palustre	—	2*	—	—	—	24	—	2	—	5	—	13	—	4	—	—	—	2	—	10,16
Glyceria fluitans	15	7	9	—	—	9	170	1	2	1	—	8	5	18	—	1	1	50, 113*	8, 309*	
Glyceria cf. fluitans	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	216, 22*	35*	87*	
Glyceria maxima	2	20	1	—	—	20	4	—	10	4	—	8	8	—	—	8	118	3,47*	1,61*	33
Hippuris vulgaris	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1*	—	
Iris pseudacorus	—	—	—	—	—	2	—	—	—	4	—	2*	—	—	—	—	—	—	—	33,35
Lycopus europaeus	—	5	19	30	3,1*	40	1	7	6	42,1*	1	14	60	44	3	—	72,1*	4	—	35
Lysimachia thyrsiflora	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	
Oenanthe aquatica	—	—	—	—	—	—	1	5?	—	—	—	—	—	—	—	—	—	—	—	
Oenanthe fistulosa	—	8	20	5	—	18	—	13	12	15	—	26	—	5	—	—	—	—	—	
Phragmites australis	—	—	3	—	—	—	—	35	18	104	—	—	—	—	3	—	24	—	—	17,24,27
Phragmites australis stem[1]	—	—	—	—	—	—	—	—	—	10-s	—	—	—	—	1	—	—	—	—	17,24,27
Rumex hydrolapathum	10	18	—	—	—	53	—	14	32	79	—	110	—	7	—	—	—	—	—	33
Scirpus lacustris tabernaemontani	86	737	48,45*	19	27	469	15	319	272	265	1	87	8	291	—	33	105	9,12*	16	
Scutellaria galericulata	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	2	—	—	35
Sium latifolium	—	1	—	—	—	—	—	1	—	4	—	23	—	—	—	—	—	—	—	33
Sparganium erectum	—	1	—	—	—	1	2	1	2	5	—	—	—	—	—	1	—	2,4*	1	33
Typha spec.	50	128	6	240	16	456	24	32	—	64	16	32	300	120	—	96	48	34	—	25
Veronica beccabunga-type	592	304	320	48	—	192	—	65	—	64	—	32	—	—	—	—	—	17	—	

Perennial saltmarsh plants (cl.24):

	266	278	279	289	290	306	311	327	332	337	340	375	411	436	515	534	535	580	580a	
Glaux maritima	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	10,27
Juncus gerardi	32	—	136	48	—	128	900	32	32	—	—	—	—	—	—	—	—	16	—	10,16,25
Scirpus maritimus	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	17,19,24
Spergularia maritima/salina	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	16
Triglochin maritima	—	—	—	—	—	—	6	—	—	—	—	—	—	—	—	—	—	—	—	

Plants of damp grasslands (cl.25):

	266	278	279	289	290	306	311	327	332	337	340	375	411	436	515	534	535	580	580a	
Alopecurus pratensis	—	—	—	—	—	—	120	—	—	—	—	—	—	—	—	—	—	—	—	
Angelica sylvestris	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	33
Caltha palustris	—	1	—	—	—	13	—	3	2	15	—	4	—	—	—	—	—	—	—	19,27,33
Carex disticha	3	10	39	19	33	54	20	28	30,2*	210, 40*	—	58	6	45	1	—	74	2	3	16
Carex cf. panicea	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	29
Cirsium palustre	—	—	1?	2	—	—	—	1?	—	—	—	—	—	—	—	—	—	—	—	35
Daucus carota	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Filipendula ulmaria	—	1	2	—	—	—	—	2	2	2	—	—	—	1	1	—	—	2	—	
Hypericum quadrangulum	50	8	5	16	18	8	—	—	—	—	—	—	96	24	—	—	6	—	—	
Lychnis flos-cuculi	2	1	39	—	1	48	7	25	16	32	—	4	—	40	—	1	18	5	—	
Lythrum salicaria	404	713	208	—	—	788	24	151	116	41	—	509	192	44	—	96	50	10	3	19,35
Molinia caerulea	2	1	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	29,30,32,35
Prunella vulgaris	—	—	1	—	—	—	—	—	1	—	—	—	—	1	—	—	—	3	—	10,33
cf. Scirpus sylvaticus	35	—	—	—	—	—	2	32	—	2	—	—	—	—	—	—	—	—	—	

Sample number	266	278	279	289	290	306	311	327	332	337	340	375	411	436	515	534	535	580	580a	Alternative
Context	ditch	ditch	floor	dung	dung	ditch	ditch	ditch	ditch	ditch	hearth	ditch	dung	ditch	dung	dung	dung	hearth	hearth	classes
Volume (l)	1	1	2	1.5	0.6	2	1.5	1	1	1	0.5	1	1.5	2	0.5	3	3	3	3	
Senecio aquaticus	8	2	—	—	—	—	27	4	4	2	—	12	—	—	—	—	—	—	—	—
Stachys palustris	1	—	3	1	—	4	—	2	—	3	—	1	2	—	—	—	—	—	—	12,13,33
Thalictrum flavum	—	—	2	—	—	4	—	—	—	—	—	—	—	4	—	—	—	—	—	33
Trifolium dubium	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	—	
Valeriana officinalis	—	—	2	—	1	—	—	—	—	1	—	4	3	—	—	—	5	—	—	19,33
Heathland and bog plants (cl.27-30):																				
Calluna vulgaris	—	—	—	—	—	—	—	—	—	—	—	—	—	24	—	—	—	—	—	
Epilobium palustre	—	1	25	—	—	—	—	1	2	—	—	—	—	8	—	—	—	—	—	19
Erica tetralix	—	—	—	—	—	—	—	—	—	—	16	—	—	—	—	—	—	—	—	25,32
Erica tetralix leaf	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	25,32
Hydrocotyle vulgaris	17	11	36	17	—	59	6	16	24	6	—	16	2	57	—	—	2	2	2	10,16,19,33
Juncus subnodulosus	64	176	543	912	—	1920	—	256	384	96	112	96	768	96	16	—	—	32	—	19,25
Pedicularis palustris	—	—	—	—	—	—	—	—	—	4,1*	—	—	—	—	—	—	—	—	—	
Potentilla erecta-type	—	—	—	—	—	—	—	1	—	—	—	—	—	8	—	—	—	2	—	
Schoenus nigricans	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	
Stellaria palustris	—	—	1	—	—	8	—	3	4	2	—	—	—	1	—	—	—	—	—	
Shrubs (cl.32-34):																				
Myrica gale	—	—	—	4	—	—	5	—	—	—	—	—	—	—	1	—	—	—	—	
Myrica gale bud	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	50	—	—	—	
Myrica gale bud scale	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	100	—	—	—	
Prunus spinosa	—	—	3	—	—	3	—	—	1	—	—	—	—	2	—	—	—	—	—	
Alder carr plants (cl.35):																				
Alnus glutinosa	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	15,6*	8,1*	
Alnus spec. catkin axis	—	—	—	—	—	—	—	—	—	—	1*	—	—	—	—	—	—	3	1	
Alnus spec. bud scale	—	—	—	—	2*	—	—	—	—	—	26*	—	—	—	—	—	—	1	—	
Thelypteris palustris leaf fr.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	10	—	—	—	19
Plants of forests on rich soils (cl.36-38):																				
Crataegus laevigata	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	
Various:																				
Agrostis spec.	64	3	—	—	64	320	1	3	55	65	—	—	—	24	—	1	—	—	—	16,24,25
Atriplex patula/prostrata	12	5	106	18	56	115	204	80,1*	124	18	2,1*	20	51	417	1	27	18	12,3*	2	11,12,16,17,24
Avena spec.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Avena-type awn fr.	—	—	2*	—	1*	—	—	—	—	—	—	—	—	24*	—	98*	9*	—	—	
cf. Avena lemma-base	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2*	—	1*	—	
cf. Campanulaceae	—	—	—	—	—	—	24	—	—	—	—	—	—	—	—	—	—	—	—	
Carex oederi s.l.	—	—	—	1	—	8	—	—	—	—	—	—	—	5	—	—	—	—	—	
Carex spec. bicarpellate	—	—	—	—	—	—	3	—	—	1	—	—	—	—	—	1	—	1	—	
Carex spec. tricarpellate	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	1	—	
Cerastium spec.	—	2	20	—	—	—	1	6	4	2	—	4	—	32	—	—	—	—	—	
Cirsium arvense	—	—	1	—	—	—	—	—	—	1?	—	—	—	—	—	—	—	—	—	13,17,25
cf. Crepis spec.	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Elymus spec.	—	—	—	—	2	—	—	—	1	—	—	—	—	—	—	—	—	—	—	
Epilobium hirsutum-type	—	—	—	—	—	1	—	1	—	1	—	—	—	—	—	—	—	—	—	25
Eupatorium cannabinum	—	2	1	1	—	—	2	3	4	2	2	—	7	6	—	6	78	—	—	17,25
Euphrasia/Odontites spec.	—	—	1	—	—	—	69	—	2	1	—	—	—	—	—	—	—	—	—	

Sample number	266	278	279	289	290	306	311	327	332	337	340	375	411	436	515	534	535	580	580a	
Context	ditch	ditch	floor	dung	dung	ditch	ditch	ditch	ditch	ditch	hearth	ditch	dung	ditch	dung	dung	dung	hearth	hearth	Alternative
Volume (l)	1	1	2	1.5	0.6	2	1.5	1	1	1	0.5	1	1.5	2	0.5	3	3	3	3	classes
Galeopsis bifida-type	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Galium cf. spurium	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	
Gramineae indet.	18	3	1*	—	96	1?	1	—	4	33	—	—	—	—	1	—	72	16	—	
Juncus articulatus-type	448	448	3800	240	—	4224	900	960	1296	992	—	480	2784	840	16	3744	7000	112	—	10,16,25
Juncus spec.	144	112	—	48	—	192	100	128	48	64	—	64	48	—	—	5332	400	—	—	
Luzula cf. multiflora	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	
Mentha aquatica/arvensis	80	102	108	11	25	321	63	154	118	84,1*	—	190	38	64	—	31	90	15,3*	2,2*	12,13,16,19
Myosotis spec.	2	4	4,1*	—	—	60	—	15	8	21	—	4	—	—	—	—	—	—	—	
Phalaris arundinacea	—	—	—	—	—	—	—	3	—	4	—	12	—	8	—	—	—	—	—	16,19,25,33
Potentilla spec.	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Rhinanthus spec.	—	—	—	—	—	—	—	—	—	—	—	—	2	—	3	3	2	—	—	
Rosa spec.	—	—	1	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	
cf. Rosaceae indet.	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	
Rubus fruticosus s.l.	—	—	—	—	—	—	—	1	—	—	—	—	1	—	—	—	—	—	—	
Rubus spec.	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Rumex acetosella	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1*	12,13
Rumex conglomeratus	—	2	—	—	—	—	—	6	—	—	—	—	—	—	—	—	—	—	—	16
Rumex spec.	17	33	16	—	—	56	—	33	18	14,2*	—	95	—	—	1	—	—	9,4*	7	7
Sagina apetala/procumbens	16	16	705	—	—	1024	—	96	64	160	—	—	—	384	—	—	—	—	—	10,16
Sagina nodosa-type	—	—	—	—	—	64	—	—	—	—	—	—	—	—	17	—	—	—	—	
Salix spec. bud scale	—	—	—	—	—	—	—	—	—	—	1	12	—	—	—	—	—	—	—	
cf. Samolus valerandi	—	—	—	—	—	—	—	32	2	64	—	—	—	—	—	—	—	—	—	6,10
cf. Scirpus stem fr.	—	—	—	—	2*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Silene dioica/vulgaris	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Solanum spec.	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Umbelliferae cf. Oenanthe	—	—	9	—	—	—	—	—	—	15	—	—	—	—	—	5	55	1	—	
Umbelliferae indet.	4	8	—	—	—	24	—	—	6	—	—	26	1	—	—	—	2	—	—	
Xanthium strumarium spine	—	—	—	—	—	—	4	—	—	—	—	—	—	—	—	—	—	—	—	

¹ The presence of Phragmites stems has not been registrated consistently.

Table 21. Botanical macroremains of Geervliet 17-55. Counted numbers. * = carbonized. (Contexts unknown).

Sample number	1	2	3	Alternative
Volume (l)	0.5	0.5	0.5	classes
Cultivated plants:				
Brassica cf. rapa	—	1*	—	
Camelina sativa	49,8*	5	31	
Camelina sativa silicle fr.	250,12*	78,7*	38,1*	
Camelina sativa silicle fork	3	1	—	
Hordeum vulgare awn fr.	18*	43*	2*	
Hordeum vulgare internode	46,8*	25,2*	41,6*	
Hordeum vulgare	3,1*	1*	4,11*	
Hordeum/Triticum internode	1*	—	—	
Hordeum/Triticum spec.	—	1*	—	
Linum usitatissimum	4	21	71	
Linum usitatissimum caps. fr.	—	42	138	
Triticum dicoccum gl. b.	64,1*	99	95,24*	
Triticum dicoccum intern. + sp.f.	1	—	—	
Triticum dicoccum sp. f.	5	14	36	
Triticum dicoccum/spelta gl. b.	17	84	2	
Triticum dicoccum/spelta sp. f.	—	9	—	
Triticum spec.	—	—	2*	
Triticum spec. internode	12	—	5,9*	
Triticum spec. awn fr.	32*	—	240*	
Waterplants (cl.3-5):				
Callitriche spec.	—	—	1	
Ephemeral plants (cl.10):				
Juncus bufonius	144	416	800	12,13,16,24
Therophytic nitrophilous plants (cl.11):				
Bidens cernua	8	4	—	19
Bidens tripartita	3	4	2	12,19
Chenopodium rubrum	1,1*	—	—	12
Polygonum hydropiper	1*	3	2	12,13,19,33
Polygonum minus	1	4	—	19
Ranunculus sceleratus	1	4	—	
Rorippa palustris	—	—	16	
Stellaria aquatica	—	4	14	
Summercrop weeds (cl.12):				
Anagallis arvensis	—	—	2	
Chenopodium ficifolium	7,7*	19	15	
Echinochloa crus-galli	15	11	6,2*	
Erysimum cheiranthoides	1	—	—	
Polygonum aviculare	1	2	—	24
Polygonum lapathifolium	1	12	6	11
Solanum nigrum	—	—	1	11
Sonchus asper	—	2	8	
Sonchus oleraceus	—	—	1	
Stellaria media	1	3	1	
Tread resistant plants (cl.16):				
Carex hirta	—	—	1	25
Juncus effusus-type	—	304	80	25
Plantago major	—	10	25	10,12,13,24
Poa annua	—	—	1	10,11,12
Poa trivialis-type	40	20	236	17,33
Potentilla anserina	—	1	—	10,24
Ranunculus repens-type	1	4	3	10,12,13,25
Rumex crispus	—	2	3	

Sample number	1	2	3	Alternative
Volume (l)	0.5	0.5	0.5	classes
Perennial ruderals (cl.17):				
Urtica dioica	—	—	3	33,38
Reedswamp plants (cl.19):				
Carex paniculata-type	—	2	—	35
Cicuta virosa	—	1	—	
Eleocharis palustris	15	67,1*	41,6*	10,16,24
Galium palustre	—	1*	1,1*	10,16
Glyceria fluitans	1	—	—	
Glyceria maxima	—	—	2	33
Lycopus europaeus	3	4	20	35
Oenanthe fistulosa	2	10	5	
Phragmites australis	19	32	—	17,24,27
Phragmites australis stem	4	11,1*	6	17,24,27
Scirpus lacustris tabernae-montani	3	12	2	
Typha spec.	—	1	—	25
Saltmarsh plants (cl.24):				
Juncus gerardi	—	—	64	10,16,25
Spergularia maritima/salina	—	—	16,16*	16
Plants of damp grasslands (cl.25):				
Carex disticha	6	12	18,2*	16
Filipendula ulmaria	1	2	2	
Hypericum cf. quadrangulum	—	2	—	
Lychnis flos-cuculi	5	15	13	
Lythrum salicaria	16	—	34	19,35
Prunella vulgaris	—	9	11	10,33
Trifolium pratense flower	3	—	—	
Trifolium pratense calyx	2	—	—	
Trifolium pratense pod	1	2	—	
Valeriana officinalis	—	1	1	19,33
Vicia cf. cracca	—	2	—	
Heathland and bog plants (cl.27-30):				
Calluna vulgaris leaf	—	4	—	
Epilobium palustre	3	4	3	19
Erica tetralix leaf	—	—	2*	25,32
Hydrocotyle vulgaris	—	3	—	10,16,19,33
Juncus subnodulosus	—	64	80	19,25
Potentilla erecta-type	—	1	—	
Sagina nodosa-type	—	16	—	
Stellaria palustris	—	1	1	
Shrubs (cl.32-34):	—	—	—	
Myrica gale bud scale	—	100-s	8	
Alder carr plants (cl.35):				
Thelypteris palustris leaf fr.	17	6	+	19
Various:				
Agrostis spec.	70	80	410	16,24,25
Atriplex patula/prostrata	2	12	6,2*	11,12,16,17,24
Avena spec.	—	—	1*	
Avena spec. glume	1*	—	1?*	
Avena spec. awn fr.	2*	—	3*	
Bromus spec.	—	11	14	
Carex spec. tricarpellate	—	—	1	
Cerastium spec.	10	10	2	
Epilobium hirsutum-type	—	—	1	
Eupatorium cannabinum	1	—	—	17,25

Sample number	1	2	3	Alternative classes
Volume (l)	0.5	0.5	0.5	
cf. Eupatorium cannabinum pappus	2	4	—	17,25
Euphrasia/Odontites spec.	1	—	7	
Gramineae indet.	19	26	132	
Hordeum spec.	—	2	4	
Juncus articulatus-type	160	464	1008	10,16,25
Juncus spec.	16	—	16	
Juncus spec. capsule	—	—	1*	
Mentha aquatica/arvensis	7,2*	8	2	12,13,16,19
Myosotis spec.	1*	2	2	
Rhinanthus spec.	—	3	4	
Rumex conglomeratus	1*	12	4	16
Rumex spec.	5	46	13,1*	
Sagina apetala/procumbens	2	66	80	10,16
cf. Senecio spec.	—	1	—	
Sphagnum spec. leaf	—	—	1	
Stellaria neglecta	1	—	—	
Trifolium spec. flower	1	6	1	
Trifolium spec. calyx	1	—	—	
Umbelliferae indet.	—	—	2	

Secalinetea). This is *Cuscuta epilinum* (flax bindweed), which is a parasitic weed in flax fields and does not have wild host plants. It is, however, not at all an indication of autumn-sowing of flax, since it occurs in spring-sown flax as well. Behre (1983) observed that in the flax fields in medieval Haithabu there were also some Secalietea species. He pointed out that this was still the case in recent times, and the reason why the weeds of summercrop flax are looked upon as wintercrop weeds. The total absence of other wintercrop weeds strongly points to spring sowing of flax in Iron Age Spijkenisse.

The summercrop weeds found are dominated by euryoecious species, which are not very informative. On the other hand, some species with more restricted ecological demands have also been found. They are mainly characteristic of cultivated fields (*Echinochloa*, *Sonchus* and *Polygonum*). It is remarkable that the more specific weeds all belong to relatively tall species. This information will be further elaborated on in chapter 6.

The 19 samples yielded on average 51 taxa, with a maximum of at least 78 different species.

4.6.6   The Macroremains of Geervliet 17-55

This Middle Iron Age site has not been excavated. During a survey carried out by employees of the B.O.O.R., some pottery fragments with coarse organic tempering material were discovered. Archaeologists assumed that it was grain and I was in the position to confirm this identification. It appeared that the silicles of *Camelina sativa* (gold of pleasure) were used for tempering (see also *4.4.5*). If the pottery was manufactured locally, we may expect *Camelina* remains to be common in the botanical macroremains of the site.

This was clearly confirmed in the samples that were obtained by sampling with a corer (see *table 21*). Some levels consisted of virtually nothing but *Camelina* silicles. Remarkably enough, crop weeds are rather scarce in the same samples. As usual, all are summercrop weeds. This is the only site on which a low-growing, stenoecious summer-crop weed (i.c. *Anagallis arvensis*) has been found. It is probably connected with the crop concerned. *Camelina* is mostly harvested by uprooting, as was convincingly demonstrated by Körber-Grohne (1967; see also *6.4.3*). With such a harvesting method, low growing weeds will also reach the site.

The waterside vegetations are of considerable importance, as on all other Iron Age sites studied. Tread resistant plants are also well represented. Meadow species are not abundant, but they outnumber the crop weeds. Remarkable is the occurrence of numerous bud remains of *Myrica gale*.

This site has a large number of taxa per sample, on average 67. This is especially large in view of the small volumes of the samples analysed. The taxa found in sample 2 belong to at least 62 different species.

4.6.7   The Macroremains of the Late Iron Age Sites near Abbenbroek and Zuidland

At the start of the present research, no Late Iron Age sites on Voorne-Putten had been excavated. For this reason it was decided to obtain samples from this period in an alternative way. At the time (1987), six Late Iron Age sites were known from surveys. Three of these were situated so low in relation to the water table that they seemed the most promising with respect to the preservation of waterlogged organic remains. These three were sampled in the banks of ditches, as explained in paragraph 4.1.1.

Table 22 shows that the sample from the site of Abbenbroek 17-22 yielded a few linseed remains as well as two spikelet forks of emmer wheat and two turnip seeds (see *4.4*), which is very meagre for three litres of processed soil. Since the context of the sample is unknown, no conclusions can be drawn from the scarcity of crop plant remains. The great majority of seeds of this site come from waterside vegetations. As in all Iron Age sites around the Bernisse, plants of salt marsh vegetations are very rare. In Abbenbroek, only *Aster tripolium* belongs to this category.

The site of Zuidland 16-15 also yielded one sample. Here, some barley, wheat, linseed and gold of pleasure have been found. The wild plants are dominated by the nitrophilous species *Ranunculus sceleratus* and *Urtica dioica*. Crop weeds, pasture plants and tread resistant species are all rare.

From Zuidland 17-27, two samples have been analysed. Sample number 8 consists of dung and number 9 concerns a dark, hearth-like layer. Both samples contain much grain, both barley and emmer wheat. Linseed is also abundantly present, and there are some gold of pleasure and turnip

Table 22. Botanical macro-remains of Abbenbroek 17-22, Zuidland 16-15 and Zuidland 17-27. Counted numbers. * = carbonized. (Contexts unknown).

	Ab. 17-22	Zl.16-15	Zl.17-27	Zl.17-27	
sample nr.	1	1	8	9	Alternative
volume (l)	3	3	5	4.5	classes
Crop plants:					
Brassica rapa	2	—	5	2	
Camelina sativa silicle fr.	—	—	33	12	
Camelina sativa	1*	—	2?	3	
Cerealia indet.	—	2*	—	16*	
Hordeum vulgare	—	5*	12*	62,47*	
Hordeum vulgare awn fr.	—	—	20*	50*	
Hordeum vulgare internodes	—	1,8*	9,44*	123,175*	
Hordeum vulgare lemma	—	—	—	21*	
Linum usitatissimum	1	1,1*	51	117	
Linum usitatissimum capsule fr.	3	8	462,2*	141,4*	
Triticum dicoccum glume base	—	1,5*	—	—	
Triticum dicoccum spikelet fork	2*	5*	—	—	
Triticum dicoccum/spelta glume base	—	—	185,42*	148,24*	
Triticum dicoccum/spelta spikelet fork	—	—	27,27*	39,16*	
Triticum spec.	8	1*?	—	26	
Waterplants (cl.3-5):					
Callitriche spec.	4	—	—	—	
Chara spec. oospores	192	—	—	—	
Therophytic saltmarsh pioneers (cl.8):					
Salicornia europaea	—	—	16	—	24
Tide-mark plants (cl.9):					
Atriplex littoralis-type	—	—	—	1	
Ephemeral plants (cl.10):					
Centaurium spec.	—	—	—	16	16,24
Juncus bufonius	5184	—	8150,64*	4100,288*	12,13,16,24
Therophytic, nitrophilous pioneers (cl.11):					
Bidens cernua	14	—	1	10	19
Bidens tripartita	—	1	258	138	12,19
Chenopodium glaucum/rubrum	—	3	—	—	12
Chenopodium rubrum	61	25	—	10	12
Polygonum hydropiper	4	—	—	—	12,13,19,33
Polygonum minus	—	—	8	—	
Ranunculus sceleratus	132	100-s	133	62	
Rorippa palustris	4	—	—	—	
Rumex maritimus	23	—	516	5	
Stellaria aquatica	10	39,1*	81	15	
Summercrop weeds (cl.12):					
Capsella bursa-pastoris	—	1	4	4	11,16
Chenopodium ficifolium	16	30,2*	—	68	
Echinochloa crus-galli	—	—	225,17*	83,1*	
Polygonum aviculare	—	—	8	2	24
Polygonum lapathifolium	6	8	250	115,6*	11
Solanum nigrum	5	—	26	—	11
Sonchus asper	3	2	216	59	
Sonchus oleraceus	—	—	25	4	
Stellaria media	14	1	4	—	
Sisymbrium officinale	—	—	—	2	
Urtica urens	5	—	—	—	
Tread resistant plants (cl.16):					
Alopecurus geniculatus	—	—	4	—	
Carex cuprina-type	—	—	8	2	25
Juncus effusus-type	—	—	215	144	25
Plantago major	5	26	628	113	10,12,13,24
Poa trivialis-type	—	13	461	48	17,33
Potentilla anserina	2	4	8	3	10,24

	Ab. 17-22	Zl.16-15	Zl.17-27	Zl.17-27	
sample nr.	1	1	8	9	Alternative
volume (l)	3	3	5	4.5	classes
Ranunculus repens-type	—	—	—	9	10,12,13,25
Ranunculus sardous	1	—	8	4	10,25
Triglochin palustris	—	—	162	44	24,27
Perennial ruderals (cl.17):					
Artemisia cf. vulgaris	—	—	—	6	12
Conium maculatum	—	11	—	3	
Solanum dulcamara	2	—	—	—	19,33,35
Urtica dioica	17	100-s	8	—	33,38
Reedswamp plants (cl.19):					
Alisma plantago-aquatica	11	—	40	4	33
Alisma spec. embryo	8	7	16	—	33
Berula erecta	2	—	4	4	25,33,35
Carex acuta-type	—	—	1	2	
Carex paniculata-type	4	—	9	5	35
Carex pseudocyperus	2	—	—	—	
Cicuta virosa	—	—	20	2	
Cladium mariscus	1	1*	8	6,2*	
Cladium mariscus leaf fr.	—	—	—	2,25*	
Eleocharis palustris	27,2*	73,3*	941,4*	245,14*	10,16,24
Galium palustre	—	—	8	15,4*	10,16
Glyceria fluitans	—	—	9	20	
Glyceria maxima	45	1	12	3	33
Iris pseudacorus	—	—	2	—	33,35
Lycopus europaeus	28	7,2*	590	137	35
Oenanthe fistulosa	2	—	29	6	
Phragmites australis	—	—	81	24	17,24,27
Phragmites australis stem	—	—	—	10-s	17,24,27
Rumex hydrolapathum	2	—	—	8	33
Sagittaria sagittifolia	2	—	—	—	
Scirpus lacustris tabernaemontani	72	100-s,4*	735,72*	1030,39*	
Sium latifolium	—	—	62	8	33
Typha spec.	196	1	12	—	25
Veronica beccabunga-type	4	—	—	—	
Saltmarsh plants (cl.24):					
Aster tripolium	11	—	38	34	17
Scirpus maritimus	25	—	1260,18*	—	17,19
Spergularia cf. marginata	—	—	32	4	16
Plants of damp grasslands (cl.25):					
Carex cf. panicea	—	—	—	2	29
Carex disticha	14	16	58	26	16
Hypericum quadrangulum	—	2	4	—	
Lychnis flos-cuculi	5	1	8	8	
Lythrum salicaria	—	8	81	12	19,35
Molinia caerulea	—	1	16	17	29,30,32,35
Prunella vulgaris	—	—	45	21	10,33
Stachys palustris	—	1	—	2	12,13,33
Thalictrum flavum	—	—	8	—	
Heather and bog plants (cl.27-30):					
Andromeda polifolia	6	—	—	—	
Calluna vulgaris	—	—	—	216	
Calluna vulgaris flower	6	—	—	2	
Calluna vulgaris leaf	588*	—	—	44	
Carex cf. flava	—	—	1	—	
Carex cf. nigra	6	—	—	—	
Erica tetralix	384	—	—	—	25,32
Erica tetralix leaf	29,23*	—	9,4*	36,8*	25,32
Hydrocotyle vulgaris	13	18	—	7	10,16,19,33

sample nr.	Ab. 17-22	Zl.16-15	Zl.17-27	Zl.17-27	
	1	1	8	9	Alternative
volume (l)	3	3	5	4.5	classes
Juncus subnodulosus	—	—	215	—	19,25
Sphagnum spec. leaf	1000-s	—	—	100-s	
Shrubs (cl.32-34):					
Myrica gale	6	—	4	—	
Alder carr plants (cl.35):					
Thelypteris palustris leaf fr.	—	—	—	17	19
Forest plants of rich soils (cl.36-38):					
Moehringia trinervia	—	—	—	4	33
Various:					
Agrostis spec.	4	—	1105,8*	594,32*	16,24,25
Atriplex patula/prostrata	38	46,2*	1090	258	11,12,16,17,24
Avena spec.	—	—	1?*	1*	
Avena spec. awn fr.	—	2*	16*	14*	
Carex oederi s.l.	1	1	—	—	
Carex riparia/hirta	—	—	—	2	
Cerastium spec.	—	—	—	8	
cf. Galium spec.	—	1*	—	—	
cf. Lolium perenne	—	—	—	2	
Cruciferae indet.	—	—	—	4	
Eupatorium cannabinum	—	1,5	—	2	17,25
Euphrasia/Odontites spec.	1	16	225	99,12*	
Galium cf. saxatile	—	—	4	—	
Gramineae indet	195	1	16,16*	6	
Hordeum spec.	—	—	1	4	
Juncus articulatus-type	768	—	2466	1152	10,16,25
Juncus spec.	—	—	430	—	
Mentha aquatica/arvensis	14	128	—	20	12,13,16,19
Myosotis spec.	4	—	—	—	
Peucedanum palustre	—	—	18?	4	19,27,35
Phalaris arundinacea	—	—	—	2	16,19,25,33
Poa spec.	—	4*	—	4*	
Rhinanthus spec.	—	1	—	—	
Rumex acetosella	—	—	8	—	
Rumex conglomeratus	—	—	—	2	16
Rumex spec.	9	1*	9	6,4*	
Sagina apetala/procumbens	192	—	—	144	10,16
cf. Sinapis arvensis	—	1	—	—	
Umbelliferae indet.	4	2	46	—	
Vaccinium spec.	—	—	—	2	
Xanthium strumarium	—	—	21	2	

seeds as well. The share of cultivated plants is among the highest of all the sites investigated on Voorne-Putten (see also *4.8.1*).

Sonchus asper and *Echinochloa crus-galli*, both stenoecious summercrop weeds, are present in considerable numbers. Remarkably enough, *Sonchus* is indicative of rich soils, whereas *Echinochloa* occurs on poor, sandy soils (Westhoff/Den Held 1969). This may be attributed to the two different crop types present in the samples, cereals and linseed, which were probably cultivated on different soils. However, more detailed information requires more detailed sampling, which is only possible in excavations.

Regarding the wild plants, apart from the always numerous waterside vegetations, plants from pastures are also of considerable importance, especially if the representatives of class 16 are also seen as indicators of grazing.

The numerous seeds of *Triglochin palustris* are highly remarkable, since they hardly ever occurred in the other sites studied. This site also yielded fruits of *Xanthium strumarium*, a species already discussed in paragraph 4.6.4.

4.6.8   THE MACROREMAINS OF ROCKANJE 08-52
This site was excavated in October 1990, during the final part of the present investigations. Since it was the first Late
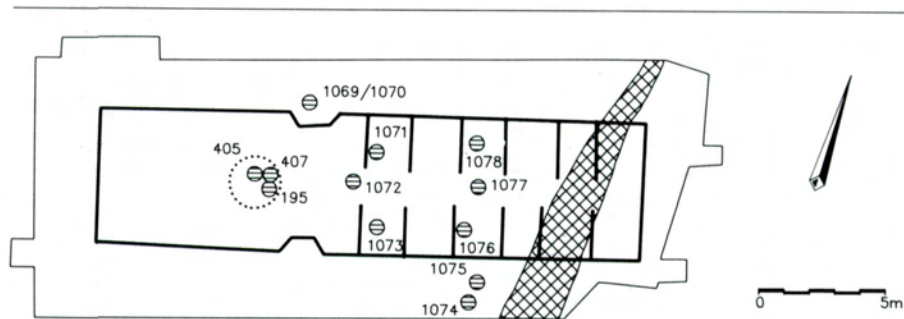
Fig. 41 Location of samples for botanical macroremains in and around the houseplan of Rockanje 08-52, scale 1:300. ..... = hearth.

Iron Age site excavated on Voorne-Putten, and since it was the link between the other Iron Age sites excavated around the Bernisse on the one hand and the Roman sites on Voorne on the other, it has been included in the analyses. This was above all possible thanks to W.J. Kuijper, who undertook the time consuming sortings and identifications of the samples. Twelve samples have been analyzed, the location of these samples is indicated in figure 41. Samples 1073, 1076, 1077 and 1078 are derived from dung in the byre area, samples 230, 282, 405 and 407 contain mainly carbonized remains from hearths. Sample 1070 represents the natural subsoil and samples 1069, 1074 and 1075 are from refuse layers, situated outside the house.

The sample of the natural subsoil is dominated by *Sphagnum*, *Myrica gale* and *Juncus bufonius* (compare *table 23*). *Sphagnum* and *Myrica* belong to raised bog vegetations, where *Myrica* points to strong decomposition, owing to desiccation. Such a terrain apparently served as the basis for settlement.

Of the cultivated plants, *Hordeum*, *Triticum*, *Linum* and *Camelina* have all been found regularly. The crop weeds are represented by several stenoecious summercrop weeds, which reach large numbers in some samples.

The remains from the dung layers in the part of the house with stalls for livestock are strongly dominated by salt marsh plants. Most likely, this biotope has been exploited for livestock grazing territory and/or for hay-making.

Remarkable is the very rare occurrence of reed swamp species, despite the fact that reed stems are abundantly present. In view of this, Westhoff and Den Held (1969) made a significant remark. In the more saline parts of an estuary, the species-rich reed vegetations from the freshwater tidal area show a considerable reduction in numbers of species, without addition of many new ones. Thus the few species associated with the reed stems are additional evidence of the salinity of the environment around Rockanje during the Late Iron Age.

Grasses occur numerously, especially *Poa* and *Agrostis*,

but also the rare species of *Parapholis strigosa* has been found.

The small samples yielded a moderate number of taxa, the number of seeds is very large though, especially when the small volumes are considered.

4.6.9   THE MACROREMAINS OF NIEUWENHOORN 09-89
The native Roman settlement found on this site consisted of four building phases, one above the other. It dates from between 57 AD and the first half of the second century AD, as dendrochronological datings have revealed (see *3.1.6*). Samples have been taken from a section of habitation layers about 1 m thick. The data provided by the analysis of the section carried out by W.J. Kuijper, will be discussed first. The individual samples each covered ca. 5 cm of the height of the section. Apart from the section, some other samples from other contexts have been analysed (see *table 24*). The location of the samples is indicated in figure 42.

The main results of the analyses of the section have been presented in a seed diagram (see *fig. 43*). The lower three samples, 3048, 3046 and 3044, consist of different heather species and *Sphagnum* remains. They belong to the natural subsoil on which the settlement had been founded. It was evidently a raised bog.

The following seven samples (3043-3037) consist of dung. Here, these same heathland species occur, but now substantially supplemented with waterside plants, in which *Scirpus maritimus* is the dominant element. *Myrica gale* also occurs regularly in these samples. The samples concerned show a splendid horizontal layering, which must be due to the deliberate spreading out of bundles of plant material, in which *Scirpus maritimus* predominated. These may have been obtained in the close vicinity of the site. The delicate layering is unlikely to have remained intact if livestock was trampling on it in a shed. The spreading out of the material in a very short time may explain the small extent of homogenization and fragmentation. In Feddersen Wierde, a native Roman settlement in northern Germany, Körber-

Table 23. The botanical macroremains of Rockanje 08-52. Counted numbers, * = carbonized.

Sample number Context Volume (l.)	DI-clay 0.15	230 hearth 0.5	282 hearth 0.5	405 hearth 1	407 hearth 0.1	1069 refuse 0.5	1070 subsoil 0.5	1073 dung 0.5	1074 refuse 0.5	1075 refuse 0.25	1076 dung 0.5	1077 dung 0.5	1078 dung 0.5	Alternative classes
Crop plants														
Camelina sativa	—	—	—	—	1*	—	—	—	—	—	—	—	—	
Camelina sativa silicle fr.	—	—	—	—	—	3	—	—	200	—	—	—	—	
Hordeum vulgare awn fr.	—	—	—	—	—	64*	—	—	—	—	—	—	—	
Hordeum vulgare	—	—	3*	3*	4*	17,1*	—	6	—	1	—	—	—	
Hordeum vulgare internode	—	—	—	2*	—	72,69*	—	17	—	2*	96	—	—	
Hordeum/Triticum spec.	—	—	—	—	—	4*	—	—	—	—	—	—	—	
Linum usitatissimum capsule fr.	—	—	—	—	—	9	—	—	—	1	65	—	—	
Linum usitatissimum	—	—	—	3,1*	—	11	—	54	—	—	1	4	—	
Triticum dicoccum glume base	—	—	2	9	12*	18	—	15	—	—	—	—	—	
Triticum dicoccum sp.f.	—	—	—	3	—	9	—	9	—	—	—	—	—	
Triticum spec.	—	—	—	—	—	1	—	—	—	—	1	—	—	
Waterplants (cl.5):														
Potamogeton spec.	—	—	—	3*	—	—	—	—	—	—	—	—	—	
cf. Potamogeton spec. leaf apex	—	—	—	1*	—	—	—	—	—	—	—	—	—	
Therophytic saltmarsh pioneers (cl.8):														
Salicornia europaea	—	—	—	1	—	580	—	104	—	—	576	176	2048	24
Tide-mark plants (cl.9):														
Atriplex littoralis-type	2	—	—	—	—	1	—	—	—	—	67	—	—	
Matricaria maritima	—	—	—	—	—	152	—	28	—	—	1024	—	16	
Suaeda maritima	4	—	—	3	—	260	—	170	—	—	1185	18	116	
Ephemeral plants (cl.10):														
Centaurium spec.	—	—	1	—	—	—	—	32	—	—	—	—	—	16,24
Juncus bufonius	—	—	10	—	10-s	20480	1024	21248	7000	4608	65000	3968	30000	12,13,16,24
Therophytic nitrophilous pioneers (cl.11):														
Chenopodium glaucum/rubrum	—	—	4	1	—	—	32	—	96	64	—	1024	12	
Summercrop weeds (cl.12):														
Polygonum aviculare	—	—	—	3*	—	12	—	5	—	—	197	1	12	24
Polygonum lapathifolium	—	—	—	11*	2*	20	—	47	3	14	435	—	47	11
Sonchus asper	—	—	—	—	—	52	—	12	—	4	996	—	20	
Sonchus cf. oleraceus	—	—	—	—	—	—	—	8	—	—	1	—	4	
Stellaria media	—	—	—	1	1,1*	212	—	216	3	4	2112	—	1118	
Tread resistant plants (cl.16):														
Alopecurus geniculatus	—	—	—	—	—	—	—	64	—	—	32	—	—	
Carex cf. hirta	—	—	—	—	—	—	—	4	—	—	—	—	—	25
Plantago major	—	—	—	24*	2,1*	1424	—	1288	—	32	2176	—	6196	10,12,13,24
Plantago major capsule fr.	—	—	—	—	1	8	—	—	—	—	—	—	—	10,12,13,24
Poa trivialis-type	—	—	—	—	11,72?*	2412	—	1472	6	32	3488	32	—	17,33
Potentilla anserina	—	—	—	—	—	8	—	—	—	4	—	—	—	10,24
Ranunculus repens-type	—	—	—	—	—	—	—	—	—	—	1	—	—	10,12,13,25
Ranunculus sardous	—	—	—	16*	4,19*	134	—	99	3	6	448	—	33	25
Triglochin palustris	—	—	—	—	—	—	—	81	—	—	66	—	—	24,27

Sample number	DI-clay	230	282	405	407	1069	1070	1073	1074	1075	1076	1077	1078	
Context		hearth	hearth	hearth	hearth	refuse	subsoil	dung	refuse	refuse	dung	dung	dung	Alternative
Volume (l.)	0.15	0.5	0.5	1	0.1	0.5	0.5	0.5	0.5	0.25	0.5	0.5	0.5	classes
Perennial ruderals (cl.17):														
Apium graveolens	—	—	—	—	4*	92,1*	—	604	—	—	448	16	1044	
Artemisia cf. vulgaris	—	—	—	—	—	—	—	64	—	—	—	—	—	12
Calystegia sepium	—	—	—	1*	—	—	—	1	—	—	3	—	1	12
Oenanthe cf. lachenalii	—	—	—	—	—	—	—	—	—	—	192	—	—	
cf. Solanum dulcamara buds	—	—	—	—	—	2	—	—	—	—	—	—	—	19,33,35
Urtica dioica	—	—	—	—	—	192	—	64	—	32	2624	—	3072	33,38
Reedswamp plants (cl.19):														
Carex paniculata-type	—	—	—	—	—	—	—	4	—	—	—	—	—	35
Carex pseudocyperus	—	—	—	—	—	—	—	—	—	—	32	2	—	
Cladium mariscus	—	1*	3*	11*	—	—	—	—	—	—	—	—	—	
Eleocharis palustris	—	—	—	4	—	—	—	—	—	—	—	—	—	10,16,24
Galium palustre	—	—	—	6*	—	20	—	24	—	—	195	—	—	10,16
Glyceria maxima	—	—	—	—	—	—	—	—	—	—	—	2	—	33
Iris pseudacorus	—	—	—	1,1*	—	1	—	—	—	—	—	—	—	33,35
Lycopus europaeus	—	—	—	4*	—	—	—	—	—	—	256	—	4	35
Phragmites australis	—	—	—	—	—	4	—	—	—	—	—	—	—	17,24,27
Phragmites australis stem	—	—	10*	100	—	1000	—	1000	—	2	—	10	1000	17,24,27
Rumex hydrolapathum	—	—	—	1?*	—	—	—	2	—	—	—	—	—	33
Scirpus lacustris tabernaemontani	—	—	—	4*	—	8	—	5	—	—	—	—	5	
Scutellaria galericulata	—	—	—	—	—	4	—	—	—	—	129	—	—	35
Saltmarsh plants (cl.24):														
Aster tripolium	2	—	—	—	—	—	—	—	—	—	—	—	—	17
Glaux maritima	—	—	—	8*	—	28	—	120	—	34	391	—	9	10,27
Glaux maritima capsule-fragm.	—	—	—	—	—	308	—	42	—	—	41	—	3078	10,27
Juncus gerardi	—	—	—	—	—	33280	—	28672	9000	21760	90000	3456	90000	10,16,25
Juncus gerardi capsule	—	—	—	—	—	1	—	3	—	—	1500	1	10	10,16,25
Limonium vulgare calyx	—	—	—	—	—	7	—	—	—	—	37	—	1	
Parapholis strigosa	—	—	—	—	—	—	—	1	—	—	—	—	—	
Plantago maritima	—	—	—	6*	—	42	—	107	—	—	157	—	42	12
Plantago maritima capsule fr.	—	—	—	—	—	62	—	139	—	—	900	—	17	12
Puccinellia cf. maritima	—	—	—	—	—	4	—	—	—	—	—	—	—	
Puccinellia distans	—	—	—	—	—	4	—	—	—	—	288	—	—	16
Scirpus maritimus	6	—	—	2*	1*	14	—	49	3	—	1	—	4	17,19
Spergularia maritima-type	—	—	—	76*	—	256	—	324	—	1	384	—	5132	16
Spergularia salina	—	—	—	—	—	—	—	—	—	—	4032	848	—	16
Triglochin maritima	—	—	—	—	—	20	—	125	—	—	205	—	—	14
Plants of damp grasslands (cl.25):														
cf. Angelica sylvestris	—	—	—	—	—	—	—	4	—	—	—	—	—	33
Cirsium palustre	4	—	—	—	—	—	—	—	—	—	—	—	—	35
Festuca pratensis	—	—	—	—	—	—	—	19	—	—	—	—	—	
Lychnis flos-cuculi	—	—	—	8	—	—	—	72	—	32	896	—	2052	
Lysimachia vulgaris	—	—	—	—	—	68	—	4	—	—	96	—	—	19
Lythrum salicaria	—	—	—	—	—	192	—	544	—	—	1280	—	2048	19,35
Molinia caerulea	—	—	—	119*	4*	140	—	30	6	—	—	—	8	29,30,32,35
Stachys palustris	—	—	—	1*	—	—	—	—	—	—	—	—	—	12,13,33

Sample number Context Volume (l.)	DI-clay 0.15	230 hearth 0.5	282 hearth 0.5	405 hearth 1	407 hearth 0.1	1069 refuse 0.5	1070 subsoil 0.5	1073 dung 0.5	1074 refuse 0.5	1075 refuse 0.25	1076 dung 0.5	1077 dung 0.5	1078 dung 0.5	Alternative classes
Heathland and bog plants (cl.27-30):														
Andromeda polifolia	—	—	—	24*	—	—	—	—	—	—	—	—	—	
Calluna vulgaris	—	—	—	—	—	—	768	—	—	—	—	—	—	
Calluna vulgaris flower	—	—	—	—	—	—	88	—	—	—	—	—	—	
Calluna vulgaris leaf	—	—	—	—	—	—	16*	—	—	32*	—	—	—	
Calluna vulgaris twig	—	—	—	1	—	—	—	—	—	—	—	—	—	
Epilobium palustre	—	—	—	—	—	64	—	—	—	32	2496	—	1024	19
Erica tetralix	—	—	—	—	—	256	5120	512	—	256	—	640	—	25,32
Erica tetralix leaf	—	—	—	—	—	—	100,100*	—	—	4	—	—	4	25,32
Eriophorum vaginatum spindle	—	—	1*	10*	—	—	—	—	—	—	—	—	—	
Galium saxatile	—	—	—	—	—	—	—	32	—	—	64	—	—	
Hydrocotyle vulgaris	—	—	—	—	—	80	—	24	6	—	416	10	32	10,16,19,33
Menyanthes trifoliata	—	—	1*	8*	—	—	—	—	—	—	—	—	—	19
Ranunculus flammula	—	—	—	—	—	—	—	4	—	—	—	—	—	10,16
Shrubs (cl.32-34):														
Myrica gale	—	—	—	—	4*	20	143	16	200	108	1	46	—	
Myrica gale bud	—	—	—	—	—	12	200	5	2	—	—	1	30	
Myrica gale leaf	—	—	—	—	—	2	2	10	2	2	10	2	20	
Alder carr plants (cl.35-37):														
Thelypteris palustris leaf fr.	—	—	—	—	—	3	—	18	—	—	100	2	2	19
Betula spec.	—	—	—	—	—	—	—	4	—	—	—	—	—	
Plants of rich soils (cl.38):														
Moehringia trinervia	—	—	—	12	—	64	—	—	—	—	544	—	—	33
Various:														
Agrostis spec.	—	—	—	—	—	7262	64	23712	—	2304	35392	9024	30000	16,24,25
Atriplex patula/prostrata	40	1*	6*	192*	2,2*	1684	—	755	45,3*	540	12234	198	26692	11,12,16,17,24
Bromus cf. mollis	—	—	—	—	1,2*	21	—	26	—	—	272	—	5	
Carex distans/extensa	—	—	—	2*	—	—	—	—	—	—	—	—	—	16,24
Carex spec.	—	—	—	—	—	4	—	—	—	2	—	2	4	
Cirsium cf. arvense	—	—	—	—	—	—	—	—	—	—	1	—	—	13,17,25
Cochlearia officinalis	—	—	—	—	—	—	—	—	—	—	32	—	—	
Elymus spec.	—	—	—	—	—	—	1	—	—	—	—	—	—	
Eupatorium cannabinum	—	—	—	—	—	—	—	70	—	—	32	—	—	17,25
Euphrasia/Odontites spec.	—	—	—	—	—	4	—	36	—	—	64	—	—	
Festuca cf. rubra	—	—	—	—	—	24	—	—	—	—	19	1	5	
cf. Festuca rubra	—	—	1*	4*	27*	—	—	—	—	—	—	—	—	
Hippophae rhamnoides stellate hair	—	—	—	—	—	—	32	—	—	—	—	—	—	
Juncus articulatus-type	—	—	—	—	—	—	256	—	—	—	—	—	—	10,16,25
Juncus maritimus	—	—	—	—	—	—	—	—	—	—	1536	3328	6000	16
Juncus maritimus capsule	—	—	—	—	—	—	—	—	—	—	200	—	—	16
Juncus spec. capsule	—	—	—	1*	—	—	—	—	—	—	—	—	—	
Lotus/Trifolium spec.	—	—	—	1*	—	—	—	—	—	—	—	—	—	
Mentha aquatica/arvensis	—	—	—	3,28*	—	—	—	—	—	—	64	—	4	12,13,16,19
Menyanthes trifoliata	—	—	—	—	—	—	1	—	—	—	—	—	—	19
Molinia caerulea	—	—	—	—	4?*	140	—	30	6	—	—	—	8	

Sample number	DI-clay	230	282	405	407	1069	1070	1073	1074	1075	1076	1077	1078	Alternative classes
Context		hearth	hearth	hearth	hearth	refuse	subsoil	dung	refuse	refuse	dung	dung	dung	classes
Volume (l.)	0.15	0.5	0.5	1	0.1	0.5	0.5	0.5	0.5	0.25	0.5	0.5	0.5	
cf. Oenanthe spec.	–	–	–	–	–	4	–	108	–	2	–	–	–	
Papilionaceae pod fr.	–	–	–	–	–	–	–	–	–	–	2	–	6	
cf. Poa spec.	–	–	1*	16*	–	–	–	–	–	–	–	–	–	
cf. Rorippa palustris	–	–	–	–	–	–	–	–	–	–	64	–	–	
Sagina apetala/procumbens	–	–	–	–	–	1280	–	512	–	–	2048	–	–	10,16
Samolus valerandi	816	–	–	–	–	–	–	–	–	–	–	–	–	6,10
Samolus valerandi/Anagallis minima	–	–	–	–	–	–	72	544	1	–	4288	–	2000	6,10
Sphagnum spec. capsule lid	–	–	–	10-s	10-s	10000	100	1	100	1000	100	20	100	
Sphagnum spec. leaf	–	–	–	5*	–	–	–	100	–	–	–	–	–	
Stellaria cf. palustris	–	–	–	–	–	–	–	–	–	–	–	–	–	
Trifolium cf. repens	–	–	–	–	11*	–	–	–	–	–	–	–	–	10,16
Trifolium repens flower	–	–	–	–	10	200	–	93	–	–	34	–	6	10,16
Vicia cf. cracca	–	–	–	–	–	9	–	–	–	–	–	–	–	
Vicia spec.	–	–	1*	–	4*	–	–	–	–	–	–	–	–	

Grohne (1967) observed that in the drainage that served to let the dung flow out, reed and bulrush stems were preserved in their entire length. Fragmentation was much greater in the pure dung layers. However, this cannot be the case in Nieuwenhoorn, as the central part of the stall is sampled.

In the next nine samples (3036-3029), which all have a dung matrix, huge numbers of *Juncus gerardi* seeds occur, while the heathland species vanish. *Aster tripolium* shows maximum numbers in sample 3036. *Plantago major* and *Atriplex patula/prostrata* increase strongly. It is remarkable that in comparison with Rockanje II (see *4.6.10*), typical salt marsh plants are of limited importance in these samples, whereas freshwater species like *Lycopus* and *Lythrum* reach large quantities. *Juncus bufonius* reaches its highest densities in the uppermost two dung samples.

In the four uppermost samples, crop plants, mainly *Hordeum vulgare* (barley) and *Triticum* spec. (wheat), furthermore some *Vicia faba* (Celtic bean) and *Linum usitatissimum* (linseed, flax) begin to appear, apart from the occurrence of *Linum* in sample 3039 and some *Hordeum* in 3036 and 3031. These four samples were taken from hearths. The rarity of crop plants in samples 3043-3029, the delicate layering and the uniform composition of species is another indication that this deposit was formed in a short time. In another part of the same section, there is a hearth present below this uniform deposit. Therefore, the site was already inhabited before this deposit was formed. This indicates that the uniform layers were deposited after the building of the first house on the site. It cannot have served to allow for habitation of the raised bog prior to the first habitation phase. Possibly, it was added relatively rapidly in the course of habitation. At the moment, the reason can only be guessed at. The terrain could for instance have become wetter due to compaction or erosion of the underlying peat.

Such deliberate deposition of material to raise the settlement area reminds us of the practice in the northern part of the Netherlands and Germany. There, such raises resulted in the formation of dwelling mounds (*Terpen, Wierden*) during the first centuries AD or even already during the Iron Age. Apparently, the aquatic conditions were more favourable on Voorne-Putten, since high mounds were not formed there, despite the fact that habitation did occur in the second and third centuries AD.

The four uppermost samples of the section are from an ashy deposit, the hearth of the second building phase. Thus, sediments that belong to the third and fourth building phases are no longer extant.

The other samples studied come from different contexts. Highly remarkable was the discovery of excrements of goats/sheep inside the house of the first phase (sample 2002). Apparently, the lack of well-defined stalls, which are so characteristic of Iron Age farms on Voorne-Putten, does not mean that no domesticates were housed at all. Analysis of

Table 24. Botanical macroremains of Nieuwenhoorn 09-89. Counted numbers, * = carbonized.

Sample number	2002	3001	3009	3049	3056	3048	3046	3044	3043	3042	3041	3040	3039	3038	3037	3036	3035	3034	3033	3032	3031	3030	3029	3026	3027	3026	3025	Alternative
Context	goat? dung	hearth	hearth	hearth	hearth	subsoil	subsoil	subsoil	dung	dung	dung	dung	dung	dung	dung	dung	dung	dung	dung	dung	dung	dung	dung	hearth	hearth	hearth	hearth	classes
Volume (l)	0.01	1.5	0.5	2.5	2	1.5	0.5	0.75	0.5	1.5	1	0.75	1	0.5	0.5	1.5	0.75	0.5	0.5	0.5	0.5	0.5	1	1.5	1	1	1.5	
Crop plants:																												
Brassica rapa	-	8*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Camelina sativa	-	5*	4,1*	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Cerealia indet.	-	-	-	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6*	2*	2*	-	
Cerealia indet. rachis base	-	-	1*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Hordeum vulgare	-	36*	23,18*	25*	1*	-	-	-	-	-	-	-	-	-	-	2*	-	-	-	-	-	-	-	23*	57*	4*	8*	
Hordeum vulgare internode	-	497	6,83*	167*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1*	-	-	-	306*	362*	2*	39*	
Hordeum vulgare awn fr.	-	-	146*	42*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100-s	10-s	-	4*	
Hordeum vulgare lemma	-	-	6*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Linum usitatissimum	-	1	1	-	-	-	-	-	-	-	-	-	12	-	-	-	-	-	-	-	-	-	-	10*	2*	-	-	
Linum usitatissimum capsule fr.	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Triticum dicoccum	-	1*	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1*	-	-	
Triticum dicoccum gl.b.	-	17*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9*	5*	1*	-	
Triticum dicoccum sp.f.	-	-	-	16*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2*	-	1*	1	-	
Vicia faba	-	-	-	7*	1*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6*	3	-	-	
Therophytic saltmarsh pioneers (cl.8):																												
Salicornia europaea	-	592	8	-	-	-	-	8	-	-	-	-	-	-	-	128	32	-	-	-	-	-	-	-	-	72,16*		24
Tide-mark plants (cl.9):																												
Atriplex littoralis-type	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	19	42	-	1	-	-	-	-	-	-	-	-	
Matricaria maritima	-	40,32*	-	-	-	-	-	-	-	-	-	-	-	-	-	200	-	-	-	-	-	-	16*	-	-	-	-	
Suaeda maritima	-	40	-	-	-	-	-	-	-	-	-	1	-	-	-	264	16	-	-	4	-	-	-	-	-	-	-	
Ephemeral plants (cl.10):																												
Anagallis minima	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	256	-	-	-	-	-	-	-	-	-	-	-	16,24
Centaurium spec.	-	-	16	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Juncus bufonius	-	25344	208	520	-	-	-	768	720	3600	896	608	320	96	3072	1152	2560	145	544	3200	1344	6912	13312	960	-	-	192	12,13,16,24
Therophytic nitrophilous pioneers (cl.11):																												
Bidens tripartita	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	1	1	-	1	-	-	-	-	12,19
Chenopodium glaucum	-	-	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	4	-	1	-	-	-	-	-	-	-	
Chenopodium rubrum	-	5088,896*	-	-	32	-	-	-	4	10	-	-	12	-	56	8912	2320	28	-	50	7	28	-	5	-	-	8	12
Ranunculus sceleratus	-	72	2	6	-	-	-	-	12	10	-	24	20	8	4	648	200	-	50	32	11	44	-	-	8,8*	-	-	
Rumex maritimus	-	-	-	-	-	-	-	-	5	-	-	-	6	11	21	187	42	10	2	-	1	-	-	-	-	-	-	
Summercrop weeds (cl.12):																												
Chenopodium ficifolium	-	-	5	11*	-	-	-	-	-	20	-	4	4	-	-	-	-	-	-	-	-	-	-	9,4*	562	292	1123	24
Polygonum aviculare	-	-	-	16*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1*	1	1	3	24
Polygonum lapathifolium	-	40	-	1,1*	-	-	-	-	-	-	-	-	-	-	-	-	8	1	-	-	-	-	-	-	1,1*	-	-	11
Polygonum persicaria	-	-	-	2*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	19
Solanum nigrum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	97	328	-	-	-	-	-	-	-	-	-	-	11
Sonchus asper	-	16	14	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	
Sonchus cf. oleraceus	-	-	4	-	-	-	-	-	-	-	-	1	-	-	-	9	-	-	-	-	-	-	-	-	-	-	-	
Stellaria media	-	-	-	3*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4*	-	-	-	
Wintercrop weeds (cl.13):																												
Avena fatua flowerbase	-	1?*	1*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12
Cuscuta epilinum	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Tread resistant plants (cl.16):																												
Alopecurus geniculatus	-	-	-	-	-	-	-	60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2*	-	-	-	
Plantago major	-	1704,72*	5	58,127*	64	-	-	-	-	-	-	8	4	-	4	1224	616	22	4	130	134	10	32,8*	150,74*	48*	36*	-	10,12,13,24
Poa trivialis-type	-	2144	19	-	-	-	-	-	-	-	-	8	-	-	-	-	8	-	-	-	1?	-	2560	-	-	-	-	17,33
Potentilla anserina	-	16	-	21,3*	-	-	-	-	-	-	-	-	-	-	-	-	8	-	1	1	1	4	-	1,1*	1	1*	1,2*	10,24
Ranunculus sardous	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10,25
Triglochin palustris	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24,27

Perennial ruderals (cl.17):

Sample number	2002	3001	3009	3049	3056	3048	3046	3044	3043	3042	3041	3040	3039	3038	3037	3036	3035	3034	3033	3032	3031	3030	3029	3028	3027	3026	3025	Alternative classes
Context	goat? dung	hearth	hearth	hearth	hearth	subsoil	subsoil	subsoil	dung	dung	dung	dung	dung	dung	dung	dung	dung	dung	dung	dung	dung	dung	dung	hearth	hearth	hearth	hearth	
Volume (l)	0.01	1.5	0.5	2.5	2	1.5	0.5	0.75	0.5	1.5	1	0.75	1	0.5	0.5	1.5	0.75	0.5	0.5	0.5	0.5	0.5	1	1.5	1	1	1.5	
Apium graveolens	-	112	-	19,3*	-	-	-	-	-	-	-	-	-	-	-	192	32	-	-	-	-	-	-	-	8	-	-	-
Artemisia vulgaris	-	-	-	1*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12
Calystegia sepium	-	1*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12
Oenanthe cf. lachenalii	-	752,24*	-	-	-	-	-	-	-	-	-	-	-	-	56	-	-	-	-	-	-	-	-	-	-	-	-	-
Solanum dulcamara	-	16	-	-	-	-	-	-	1	-	-	-	1	-	-	-	16	6	-	-	-	-	-	-	-	-	-	19,33,35
Urtica dioica	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33,38
Reedswamp plants (cl.19):																												
Berula erecta	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25,33,35
Carex acuta-type	-	-	4	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Carex pseudocyperus	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Cladium mariscus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1*	-	-	
Eleocharis palustris	-	664,104*	5	1645,2*	2984,704*	-	-	-	3	8	16	12	59	60	326	1234	192	40	73	119	81,2*	210	6380,32*	1139,506*	65,119*	84	13,110*	10,16,24
Galium palustre	-	72,8*	18,1*	-	-	-	-	-	-	4	-	-	5	5	8	-	-	1	-	-	-	-	-	-	-	-	-	10,16
Glyceria maxima	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33
Iris pseudacorus	-	-	-	-	-	-	-	-	27,1*	7	-	-	1	-	-	-	-	-	-	-	-	-	-	1*	-	-	-	33,35
Lycopus europaeus	-	640,32*	49,12*	28,33*	-	-	-	-	19	30	16	8	5	8	32	876	112	12	35	28	7	62	-	4*	16,8*	-	8,12*	35
cf. Oenanthe fistulosa	-	-	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Phragmites australis	-	32	9	-	-	-	-	-	-	-	-	-	57	-	-	8*	32	38	93	-	-	-	-	-	-	-	-	17,24,27
Phragmites australis stem	-	-	10,10*	-	-	-	-	-	-	-	-	-	-	-	10-s,10*	-	-	-	-	-	-	-	-	-	10-s	-	-	17,24,27
Rumex hydrolapathum	-	-	1	-	-	-	-	-	1	25	2	3	5	2	4	-	-	-	-	-	-	1?	-	-	-	-	-	33
Scirpus lacustris tabernaemontani	-	3,2*	2	-	-	-	-	-	6	29	-	-	4	-	139	168	-	-	-	-	-	-	-	-	-	-	42	42
Typha spec.	-	-	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25
Veronica beccabunga-type	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Saltmarsh plants (cl.24):																												
Aster tripolium	-	552,216*	-	3	-	-	-	-	-	-	-	-	4	38	625	90	-	7	1	3	1	-	-	3*	-	-	-	17
cf. Puccinellia distans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3*	-	-	-	
Glaux maritima	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	-	-	-	-	-	10,27
Juncus gerardi	-	84480	560	10040	-	-	-	-	48	480	-	-	96	752	22400	55936	200192	110	2368	6272	7296	33280	61440	17280	2048	-	7744	10,16,25
Juncus cf. gerardi	-	-	48	1610	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10,16,25
Puccinellia distans	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16
Scirpus maritimus	-	960,247*	264,7*	165,608*	-	-	-	-	40	540	1496,8*	425	532	383,2*	5688	9988	1109	66,1*	89	102	111	143	644,24*	184,280*	1,14*	20*	-	17,19
Spergularia maritima/salina	-	96	-	42,14*	-	-	-	-	-	-	-	-	4	-	-	-	2	-	-	-	-	-	-	-	-	-	-	16
Triglochin maritima	-	1	1	21	-	-	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	3	18	2	-	-	4	4
Plants of damp grasslands (cl.25):																												
Carex disticha	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	-	4*	16
Cirsium cf. palustre	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	8	2	-	-	-	-	-	-	-	-	-	-	35
Filipendula ulmaria	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Hypericum quadrangulum	-	768	16	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Hypericum cf. quadrangulum	-	-	16	14*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Lychnis flos-cuculi	-	48	-	2,9*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1*	-	-	-	
Lysimachia vulgaris	-	40	64	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19
Lythrum salicaria	-12768,1536*	-	36*	70,33*	-	-	-	-	4	30	128	16	272	16	36	840	128	12	8	128	1	1844	24	-	192*	-	128	19,35
Lythrum salicaria capsule	-	-	8*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5*	-	-	19,35
Molinia caerulea	-	24	19	1*	-	-	-	-	-	-	-	-	-	-	12	-	-	-	-	1	2	-	-	-	-	-	-	29,30,32,35
Prunella vulgaris	-	-	-	3*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	10,33
Trifolium cf. arvense	-	-	-	21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8*	-	-	-	
Valeriana officinalis	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19,33
Heathland and bog plants (cl.27-30):																												
Andromeda polifolia	-	-	1	-	-	4	-	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Andromeda polifolia leaf	-	-	-	-	-	1,2*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Calluna vulgaris	2	-	80	-	-	1920	-	-	48	480	512	64	32	36	-	10-s	-	-	-	1	-	-	-	-	-	-	-	
Calluna vulgaris flower	-	-	22	-	-	240	-	-	7	52	40	-	1	3	256*	-	-	-	-	-	-	-	-	-	-	-	-	
Calluna vulgaris leaf	-	-	20	14*	-	1000-s	-	-	100-s	100-s	100-s	10-s	100-s	100-s	16,4*	-	-	-	-	10-s*	10-s*	-	-	-	-	-	-	
Calluna vulgaris twig	-	-	1	-	-	-	-	-	-	2	16	-	3	-	-	-	-	-	-	10-s	-	-	-	-	-	-	1	
Erica tetralix	-	-	48	-	-	2432	1792	4096	272	120	128	64	-	64	-	-	-	-	-	-	-	-	-	-	-	-	-	25,32
Erica tetralix leaf	9*	-	128,9*	-	-	1677	6	32,852*	100-s	100-s	10-s	10-s	10-s	10-s	8	-	-	-	-	10-s	10-s	-	-	102*	3*	-	1*	25,32
Erica tetralix twig	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25,32
Eriophorum vaginatum spindle	-	-	-	-	-	1	100-s	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Hydrocotyle vulgaris	-	48	-	3	-	-	-	20	1	-	-	-	-	-	4	24	-	-	-	-	-	-	-	-	8	-	-	10,16,19,33
Juncus subnodulosus	-	-	32	-	-	-	-	-	336	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19,25
Rhynchospora alba	-	-	-	-	-	-	38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

| Sample number | 2002 | 3001 | 3009 | 3049 | 3056 | 3048 | 3046 | 3044 | 3043 | 3042 | 3041 | 3040 | 3039 | 3038 | 3037 | 3036 | 3035 | 3034 | 3033 | 3032 | 3031 | 3030 | 3029 | 3028 | 3027 | 3026 | 3025 | Alternative |
| Context | goat? dung | hearth | hearth | hearth | hearth | subsoil | subsoil | subsoil | dung | dung | dung | dung | dung | dung | dung | dung | dung | dung | dung | dung | dung | dung | dung | hearth | hearth | hearth | hearth | classes |
Volume (l)	0.01	1.5	0.5	2.5	2	1.5	0.5	0.75	0.5	1.5	1	0.75	1	0.5	0.5	1.5	0.75	0.5	0.5	0.5	0.5	0.5	1	1.5	1	1	1.5	
Sphagnum spec. capsule	·	·	·	·	·	8	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	
Sphagnum spec. capsule lid	·	·	·	·	·	176	22	32	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	
Sphagnum spec. leaf	·	32	·	·	·	10000-s	1000-s	·	·	10-s	·	10-s	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	
Shrubs (cl.32-34):																												
Myrica gale	·	8	590,3*	·	·	·	·	·	2	5	·	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	
Myrica gale catkin axis	·	·	5	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	
Myrica gale bud	10	·	17	·	·	·	·	·	9	28	8	10-s	2	2	8	·	·	10-s	1	6	10-s	4	·	·	·	·	·	
Myrica gale leaf fr.	·	·	12	·	·	·	·	·	10-s	10-s	·	1	10-s	·	·	·	·	1	3	10-s	·	10-s	·	·	·	·	·	
Alder carr plants (cl.35):																												
Carex cf. elongata	·	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	
Various:																												
Agrostis spec.	·	4032	779	·	·	·	·	·	24	360	·	·	·	52	584	672	5248	31	26	33	89	788	256?	·	·	·	·	16,24,25
cf. Agrostis spec.	·	·	8	51*	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	68	·	·	·	·	·	·	16,24,25
Althaea officinalis	·	·	16	·	·	·	·	·	·	·	·	·	·	·	·	·	·	4	·	·	·	·	·	·	·	·	·	17
Arenaria serpyllifolia macrocarpa	·	·	·	·	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	12,20,21
Atriplex patula/prostrata	·	368,64*	246,80*	171,68*	·	·	·	·	93	72	24	13	33	16	85	1504	467	4	4	2	3	16	8	23,49*	85,61*	28	85,201*	11,12,16,17,24
Avena spec. awn fr.	·	·	·	23*	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	164	83	·	·	
Betula spec.	·	·	·	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	
Bromus mollis/arvensis	·	3*	8*	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	
Bromus spec.	·	·	3,10*	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	5*	4*	·	·	
Carex spec. bicarpellate	·	8	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2*	·	·	·	
Carex cf. rostrata	·	·	·	·	·	·	·	·	·	·	·	·	·	·	8	·	·	·	·	·	·	·	·	·	·	·	·	
Carex spec. tricarpellate	·	·	·	6	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	4*	·	·	·	19,28
Cerastium spec.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	4	·	1	·	·	·	·	·	·	
Elymus spec.	·	·	·	2*	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	
Eupatorium cannabinum	·	120	7	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	17,25
Euphrasia/Odontites spec.	·	392,64*	15	18,42*	·	·	·	·	·	·	·	·	·	·	4	256	24	·	9	8	1	12	·	29,46*	8,32*	8*	44*	
Festuca rubra/ovina	·	7,3*	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·	·	·	
Gramineae indet.	·	·	10	1*	·	·	·	·	·	·	1	·	·	·	1	·	·	·	8	·	·	·	·	63*	1*	12*	8*	
Hordeum spec.	·	·	7	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	
Juncus articulatus-type	·	768	·	·	·	·	·	·	16	·	·	96	64	64	256	128	·	10	96	·	64	768	1280	160	·	·	·	10,16,25
Juncus maritimus	·	·	16	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	16
Juncus spec.	·	·	16	3	1000-s	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	320	-4,128*	·	·	
Juncus spec. capsule	·	·	·	·	·	·	·	·	·	·	·	·	·	4	·	·	·	·	·	·	·	·	·	·	·	·	·	
cf. Lolium spec.	·	·	·	·	·	·	·	·	·	·	·	·	·	4	·	·	·	·	·	·	·	·	·	·	·	·	·	
Lotus spec.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1*	·	·	·	
Luzula multiflora	·	·	1	·	·	·	·	4	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	
Lysimachia spec.	·	·	·	·	·	·	·	·	·	20	·	·	·	·	·	·	·	5	1	·	·	·	·	·	·	·	·	
Malvaceae indet.	·	·	·	3*	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	
Malva/Althaea spec.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·	
Medicago/Melilotus spec.	·	8*	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	
Mentha aquatica/arvensis	·	1488	138,24*	15,3*	32	·	·	·	16	10	·	8	24	8	96	1536	120	20	27	8	7	4	8	12*	16*	·	·	12,13,16,19
cf. Oenanthe spec.	·	·	·	·	·	·	·	·	·	4	·	·	·	·	·	97	88	3	15	8	4	10	32	1,7*	28,1*	·	12	
Papilionaceae indet.	·	·	·	1*	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	
Papilionaceae pod fr.	·	·	·	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	
Peucedanum palustre	·	·	9	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	19,27,35
Poa spec.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	16*	·	·	
Potentilla spec.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	8*	
Rhinanthus spec.	·	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	·	·	1	·	·	·	
Rubus fructicosus s.l.	·	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	
Rumex crispus/obtusifolius	·	·	·	2,1*	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	
Rumex spec.	·	8	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2	1	·	·	·	8	4	·	·	·	
Sagina apetala/procumbens	·	768	·	·	·	·	·	·	·	·	128	·	32	·	128	·	·	·	·	·	·	·	·	·	·	·	·	10,16
Salix spec. bud	·	·	·	·	·	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	
Anagallis minima/Samolus valerandi	·	·	96,16*	·	·	·	·	·	16	·	·	·	·	·	768	·	512	·	·	·	128	·	·	·	·	·	·	
Trifolium spec. flower fr.	·	·	·	·	·	·	·	·	·	·	·	·	1	·	·	·	·	2	·	·	·	2	·	·	·	·	·	
Umbelliferae indet.	·	·	90,43*	64	·	·	·	·	·	8	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·	·	

Table 25. Botanical macrore-
mains of Rockanje II, trench
1. Counted numbers.

Sample depth (cm ÷ NAP)	131-133	140-145	145-150	153-158	163-168	Alternative classes
Context	heightening material for all samples					
Volume (l)	0.25	0.75	0.75	0.75	0.5	
Crop plants:						
Hordeum vulgare	1	—	—	5	—	
cf. Hordeum vulgare	—	—	—	35	—	
Hordeum vulgare internode	—	—	5	130	—	
Triticum dicoccum glume base	—	—	—	1	—	
Waterplants (cl.3-5):						
Chara spec. oospores	16	—	64	32	3	
Potamogeton spec.	—	—	—	1	—	
Zannichellia palustris	2	—	—	2	2	
Therophytic saltmarsh pioneers (cl.8):						
Salicornia europaea	1	—	—	4	—	24
Tide-mark plants (cl.9):						
Atriplex littoralis-type	—	—	—	3	—	
Matricaria maritima	—	5	8	259	5	
Suaeda maritima	—	7	2	—	—	
Ephemeral plants (cl.10):						
Centaurium spec.	16	—	—	16	—	16,24
Juncus bufonius	1175	432	528	320	14	12,13,16,24
Therophytic nitrophilous pioneers (cl.11):						
Alopecurus aequalis	—	—	—	32	—	
Chenopodium glaucum	—	92	—	4	—	
Chenopodium rubrum	1	138	11	157	9	12
Ranunculus sceleratus	16	—	13	4	9	
Rumex maritimus	—	—	—	5	—	
Summercrop weeds (cl.12):						
Capsella bursa-pastoris	—	13	1	7	—	11,16
Chenopodium ficifolium	8	477	50	657	13	
Erysimum cheiranthoides	—	110	52	—	—	
Euphorbia helioscopia	—	1	—	—	—	
Lepidium ruderale	—	—	1	2	—	
Polygonum aviculare	7	56	28	559	1	24
Polygonum lapathifolium	4	2000	54	93	—	11
Sisymbrium officinale	—	—	—	11	—	
Solanum nigrum	—	—	—	4	—	11
Sonchus asper	1	49	7	670	4	
Sonchus cf. arvensis	—	—	—	50	—	
Sonchus oleraceus	—	35	9	491	2	
Stellaria media	1	256	20	103	1	
Tread resistant plants (cl.16):						
Carex cuprina-type	—	1	2	4	—	25
Leontodon autumnalis	—	—	4	29	—	10,24,25
Plantago major	25	7000	33	1100	17	10,12,13,24
Poa annua	—	—	—	11	—	10,11,12
Poa trivialis-type	39	12	35	264	19	17,33
Potentilla anserina	14	6	20	251	2	10,24
Ranunculus repens-type	—	—	—	1	—	10,12,13,25
Perennial ruderals (cl.17):						
Apium graveolens	—	—	—	3	1	
Artemisia cf. vulgaris	—	—	—	2	—	12
Oenanthe lachenalii	—	—	—	2	—	
Reedswamp plants (cl.19):						
Berula erecta	—	2	5	11	—	25,33,35
Carex acuta-type	—	—	—	3	—	
Eleocharis palustris	4	1	5	40	2	10,16,24
Glyceria maxima	—	—	1	—	—	33

| Sample depth (cm ÷ NAP) | 131-133 | 140-145 | 145-150 | 153-158 | 163-168 | |
| Context | | heightening material for all samples | | | | Alternative |
Volume (l)	0.25	0.75	0.75	0.75	0.5	classes
Phragmites australis	6	80	33	25	6	17,24,27
Phragmites australis stem	—	100-s	100-s	—	—	17,24,27
Poa cf. palustris	—	—	—	4	—	16
Scirpus lacustris tabernaemontani	24	8	27	277	1	
Typha spec.	16	17	—	32	10	25
Saltmarsh plants (cl.24):						
Aster tripolium	—	—	2	54	—	17
Glaux maritima	3	—	1	12	—	10,27
cf. Glaux maritima capsule	—	—	—	1	—	10,27
Juncus gerardi	3310	1088	35000	30000	110	10,16,25
Plantago cf. maritima	—	—	1	—	—	
Puccinellia distans	—	4	1	70	—	16
Scirpus maritimus	5	36	4	22	—	17,19
Spergularia maritima/salina	95	144	139	1000	21	16
Triglochin maritima	6	3	—	45	—	
Plants of damp grasslands (cl.25):						
Daucus carota	—	—	—	1	—	
Lythrum salicaria	—	—	—	2	—	19,35
Scirpus sylvaticus	—	—	—	—	2	
Heathland and bog plants (cl.27-30):						
Menyanthes trifoliata	—	—	—	1	—	19
Potentilla erecta-type	—	—	—	7	—	
Ranunculus flammula	—	—	—	2	—	10,16
Various:						
Agrostis spec.	9	21	18	870	3	16,24,25
Atriplex patula/prostrata	33	1000	131	1500	15	11,12,16,17,24
Bromus cf. hordeaceus	—	—	—	15	—	
Carex distans	—	—	—	2	—	16,24
Carex oederi s.l.	—	—	—	3	—	
Carex spec. tricarpellate	—	—	—	1	—	
Cirsium arvense/palustre	—	1	2	3	—	
Eupatorium cannabinum	1	—	—	—	1	17,25
Euphrasia/Odontites spec.	—	—	1	11	—	
Gramineae indet.	21	—	—	271	—	
Juncus articulatus-type	—	—	—	16	—	
Juncus spec.	750	32	440	—	8	
Mentha aquatica/arvensis	—	—	—	4	—	12,13,16,19
Molinia-type stems	—	3	—	—	—	
Plantago coronopus	—	1	1	—	—	10,12,16,23
Rumex spec.	—	—	—	27	—	
Selaginella spec.	—	—	—	—	1	
Taraxacum officinale s.l.	—	—	—	1	—	16,25
Trifolium spec. flower	—	1	1	16	—	
Umbelliferae spec.	—	—	—	3	—	
Xanthium strumarium	—	1	spines	spines	—	

seeds as well as of pollen from these droppings revealed that it comprised of almost pure *Myrica gale* remains. Since present-day sheep are reputed to dislike the bitter taste of bog myrtle (cf. Therkorn *et al.* 1984; *5.2.1*), similar droppings with *Myrica* remains in the Assendelver polders are attributed to goats. However, the prehistoric demands made by domesticates may have differed from what can be observed today. Leaf-fodder for cows is very different from the present west European cow diet, but none the less this was widely used in prehistoric times (cf. Rasmussen 1990). The same might apply to sheep and bog myrtle.

The remaining samples concern hearths (3001, 3009, 3049 and 3056). The results correspond to those obtained by the analyses of the section samples. Stenoecious cropweeds are remarkably scarce. Whereas in Roman Rockanje especially *Sonchus* species occurred very regularly in considerable numbers (see *4.6.10*), in Nieuwenhoorn they were found only rarely. As a result of the presence of numerous seeds of

Table 26. Botanical macroremains of Rockanje II, trench 2. Counted numbers, * = carbonized.

Sample depth (cm ÷ NAP)	67-72	74-79	87-92	110-113	117-122	124-127	129-134	136-137	144-149	150-151	152-156	2-0-1 hearth	Alternative classes
Context					all heightening material								
Volume (l)	0.75	0.75	0.75	0.5	0.75	0.5	0.75	0.25	0.75	0.25	0.75	0.5	
Crop plants:													
Cerealia indet. embryo	—	—	—	—	—	—	—	—	—	—	—	4*	
Cerealia indet. fr.	—	—	—	—	—	—	—	—	—	—	—	100*	
Hordeum vulgare	—	—	—	—	—	—	—	1,2*	8	—	—	18*	
cf. Hordeum vulgare	—	—	—	—	—	—	—	1	2	—	—	40*	
Hordeum vulgare internode	—	—	—	—	—	9	—	10	24,12*	1	—	—	
Water plants (cl.3-5):													
Zannichellia palustris	—	—	—	1	—	—	1	—	—	1	1	—	
Chara spec. oospores	—	—	11	9	16	100	464	16	32	16	48	—	
Therophytic saltmarsh pioneers (cl.8):													
Salicornia europaea	—	—	—	—	4	—	5	—	2	—	—	—	24
Tide-mark plants (cl.9):													
Atriplex littoralis-type	—	—	—	—	—	—	5	—	—	—	—	—	
Matricaria maritima	—	—	—	2	23	56	18	16	240	28	10	—	
Suaeda maritima	—	—	—	—	—	1	1	—	2	—	—	—	
Ephemeral plants (cl.10):													
Centaurium spec.	—	—	—	72	16	38	—	32	32	—	—	—	16,24
Juncus bufonius	—	8	—	18	11	—	64	—	320	—	32	1	12,13,16,24
Therophytic nitrophilous pioneers (cl.11):													
Chenopodium rubrum	—	—	—	—	6	4	8	7	68	7	2	—	12
Ranunculus sceleratus	—	—	—	2	4	1	2	2	8	3	4	—	
Rumex maritimus	—	—	—	—	2	—	—	—	—	1	—	—	
Summercrop weeds (cl.12):													
Capsella bursa-pastoris	—	—	—	—	—	2	—	—	8	—	—	—	11,16
Chenopodium ficifolium	—	—	—	19	8	13	111	38	884	53	10	—	
Lepidum ruderale	—	—	—	—	—	8	1	16	—	—	—	—	
Polygonum aviculare	—	—	—	5	20	112	127	83	420	73	9	2	24
Polygonum lapathifolium	—	—	—	—	1,1*	16	5	5	20	5	—	—	11
Sonchus asper	—	—	—	11	10	92	11	28	220	12	2	1	
Sonchus oleraceus	—	—	—	9	18	29	19	23	16	6	1	—	
Stellaria media	—	—	—	—	7	13	13	4	24	1	—	—	
Wintercrop weeds (cl.13):													
Matricaria recutita	—	—	—	—	—	—	—	—	16	—	—	—	
Tread resistant plants (cl.16):													
Alopecurus cf. geniculatus	—	—	—	1	—	—	—	3	18	—	—	—	
Carex cuprina-type	—	—	—	3	1	—	—	—	—	—	—	—	25
Carex hirta	—	—	—	21	2	—	—	1	8	1	—	—	25
Leontodon autumnalis	—	—	—	1	31	18	13	83	—	—	—	—	10,24,25
Plantago major	—	—	—	125	785	764	305	77	348	37	73	1	10,12,13,24
Poa annua	—	—	—	9	—	—	99	16	8	8	8	—	10,11,12
Poa trivialis-type	—	—	—	34	8	—	23	76	100	32	32	32	17,33
Potentilla anserina	—	—	—	62	292	82	122	22	110	21	17	—	10,24
Ranunculus repens-type	—	—	—	—	—	—	—	1	4	—	—	—	10,12,13,25
Ranunculus sardous	—	—	—	—	1	1	3	—	2	1	—	—	10,25
Perennial ruderals (cl.17):													
Apium graveolens	—	—	—	—	4	—	2	1	—	—	—	—	
Artemisia cf. vulgaris	—	—	—	—	—	—	170	32	28	8	—	—	12
Cirsium cf. vulgare	—	—	—	—	—	—	—	1	—	—	—	—	25
Juncus maritimus	—	—	—	—	—	—	—	—	—	—	32	—	16
Solanum dulcamara	—	—	—	—	—	—	—	—	4	—	—	—	19,33,35
Reedswamp plants (cl.19):													
Alisma spec. embryo	—	—	—	—	—	—	—	1	—	—	—	—	33
Berula erecta	—	—	—	3	1	6	—	3	—	—	—	—	25,33,35

Sample depth (cm ÷ NAP)	67-72	74-79	87-92	110-113	117-122	124-127	129-134	136-137	144-149	150-151	152-156	2-0-1	
Context				all heightening material								hearth	Alternative
Volume (l)	0.75	0.75	0.75	0.5	0.75	0.5	0.75	0.25	0.75	0.25	0.75	0.5	classes
Carex riparia	—	—	—	—	1	—	—	—	—	—	—	—	35
Cladium mariscus	—	—	—	4,1*	—	—	2	1	10	1	48	—	
Eleocharis palustris	—	—	—	20	3	4	3	11	4	2	1	—	10,16,24
Lycopus europaeus	—	—	—	5	—	—	—	2	4	—	—	—	35
Phragmites australis	—	—	1	36	24	—	16	3	2	—	—	—	17,24,27
Scirpus lacustris tabernae-montani	—	—	—	63,2*	114	43	152	60	216	101	414	2	
Typha spec.	—	2	8	—	4	50	17	17	32	48	32	—	25
Plants of dry grasslands (cl.21):													
Trifolium arvense	—	—	—	—	—	—	—	—	—	—	—	10*	
Saltmarsh plants (cl.24):													
Aster tripolium	—	—	—	21	2	3	1	1	44	—	1	—	17
Glaux maritima	—	—	—	—	7	3	1	1	—	—	—	—	10,27
Juncus gerardi	32	227	375	4500	318	6000	8000	1842	5720	360	480	118	10,16,25
Plantago maritima	—	—	—	8	—	8	1	—	—	—	—	—	12
Puccinellia distans	—	—	—	—	—	2	4	—	—	—	—	—	16
Scirpus maritimus	—	—	—	—	1	—	—	4	12	2	2	—	17,19
Spergularia maritima/salina	—	—	—	27	16	300	400	134	432	210	112	48	16
Triglochin maritima	—	—	—	43	56	—	33	39	8	2	1	—	
Plants of damp grassland (cl.25):													
Carex disticha	—	—	—	3	1	—	—	3	4	4	—	—	16
Lythrum salicaria	—	—	—	—	—	—	—	18	—	—	—	—	19,35
Heathland and bog plants (cl.27-30):													
Erica tetralix	—	—	—	—	—	—	—	16	16	—	—	—	25,32
Erica tetralix leaf	—	—	—	—	—	—	—	1	—	—	—	—	25,32
Hydrocotyle vulgaris	—	—	—	2	2	—	—	—	—	4	—	—	10,16,19,33
Potentilla erecta-type	—	—	—	—	—	—	—	—	4	—	—	—	
Sphagnum spec. leaf	—	—	—	—	—	1	—	—	—	—	—	—	
Various:													
Agrostis spec.	—	—	—	36	20	—	48	27	64	8	—	—	16,24,25
Atriplex patula/prostrata	—	—	—	69	127	176	281	140	868	46	12	29	11,12,16,17,24
Avena spec. awn fr.	—	1	—	—	—	—	—	—	—	—	—	—	
Carex acuta-type	—	—	—	3	—	—	—	—	—	—	—	—	15
Carex oederi s.l.	—	—	—	3	—	—	—	—	4	—	—	—	
Centaurea spec. non cyanus	—	—	—	—	—	—	—	—	—	1	—	—	
Cirsium cf. arvense	—	—	—	—	—	—	2	—	16	—	—	—	13,17,25
Compositae indet.	—	—	—	—	—	—	—	—	36	—	—	—	
Eupatorium cannabinum	1	1	5	—	—	—	—	—	—	—	—	—	17,25
Euphrasia/Odontites spec.	—	1	—	1	19	14	1	4	4	—	—	1,1*	
Gramineae indet	—	—	—	27	30	45	80	2	36	16	16	16	
Juncus articulatus-type	—	—	—	—	—	—	—	28	—	—	—	—	10,16,25
Juncus spec.	18,1*	31	30	—	6	—	—	85	160	16	—	288	
Mentha aquatica/arvensis	—	1	—	6	1	7	1	1	—	2	—	—	12,13,16,19
Rumex spec.	—	—	—	—	—	—	1	1	4	—	—	2	
Sagina apetala/procumbens	—	—	—	—	—	—	—	16	—	—	—	—	
cf. Selaginella spec.	1	—	6	—	—	—	32	—	32	8	—	—	
Taraxacum officinale s.l.	—	—	—	—	—	—	—	—	—	1	—	—	16,25
Trifolium spec. flowers	—	—	—	—	5	5	4	1	—	—	—	1	
Umbelliferae indet.	—	—	—	7	—	—	—	1	4	—	—	—	
Xanthium strumarium	—	—	—	—	24	spine	spines	spines	—	—	—	—	

Scirpus maritimus, the salt marsh plants are strongly represented. In view of the fact that habitation was founded on a raised bog, the salt marsh plants will most probably not have occurred locally, but will instead have been collected for hay at some distance from the site. Several of the species found in Nieuwenhoorn characterize the transition from salt to fresh conditions (compare *4.6.1.3*).

The presence of some carbonized *Vicia faba* seeds might

Table 27. Botanical macroremains of Rockanje II, trench 10. Counted numbers, * = carbonized.

Sample	10-1-4	10-1-5	10-2-52	10-2-53	10-2-56	10-2-58	
Volume (l)	4	2.5	4	4	4	3	Alternative
Context	floor	hearth	pit	pit	floor	floor	classes
Crop plants:							
Cerealia indet.	12*	2*	—	—	—	—	
Cerealia indet. embryo	6*	—	—	—	—	—	
Hordeum vulgare	67*	—	—	—	25*	—	
cf. Hordeum vulgare	1*	—	—	—	—	—	
Hordeum vulgare internode	163*	3*	4,2*	—	1,57*	—	
Hordeum spec. awn fr.	—	—	—	—	12*	—	
Hordeum/Triticum spec.	2*	—	—	—	—	—	
Hordeum/Triticum internode	1*	—	—	—	—	—	
Triticum cf. aesticum	1*	—	—	—	—	—	
Triticum cf. dicoccum	4*	—	—	—	—	—	
Triticum dicoccum glume base	6*	—	—	—	—	—	
Water plants (cl. 5):							
Ceratophyllum spec.	—	—	—	—	1	—	
Chara spec. oospores	—	—	—	—	132	—	
Potamogeton spec.	—	—	—	2	8	—	
Zannichellia palustris	—	—	3	23	84	20	
Therophytic saltmarsh pioneers (cl. 8):							
Salicornia europaea	1*	—	4	98	20	18	24
Tide-mark plants (cl. 9):							
Atriplex littoralis-type	—	—	6	9	4	4	
Matricaria maritima	7*	—	21	—	—	82	
Suaeda maritima	—	—	9	108	4	—	
Ephemeral plants (cl. 10):							
Centaurium spec.	800	—	244	—	60	19	16,24
Juncus bufonius	405	—	80	200	768	550	12,13,16,24
Linum catharticum	—	—	4	—	32	—	10,25
Therophytic nitrophilous pioneers (cl. 11):							
Alopecurus aequalis	—	—	4	—	—	—	
Chenopodium rubrum	94,15*	—	31	16	159	229	12
Ranunculus sceleratus	—	—	4	2	68	10	
Summercrop weeds (cl. 12):							
Chenopodium ficifolium	25	—	—	—	29	—	
Echinochloa crus-galli	3*	—	—	—	—	—	
Lepidium ruderale	—	—	—	—	—	23	
Polygonum aviculare	8*	1*	174	—	4	—	24
Polygonum lapathifolium	—	—	16	—	11,2*	—	11
Solanum nigrum	—	—	—	2	—	—	11
Sonchus cf. arvensis	—	—	—	—	27	—	
Sonchus asper	—	—	14	1	60	186	
Sonchus oleraceus	—	—	6	92	20	208	
Stellaria media	18	—	35	2	21	—	
Tread resistant plants (cl. 16):							
Alopecurus geniculatus	—	—	4	—	12	2	
Carex cuprina-type	1*	—	—	—	13	—	25
Carex hirta	—	—	17	—	18	1	25
Juncus effusus-type	1620	—	—	—	—	—	
Leontodon autumnalis	2*	—	58	—	2	4	10,24,25
Plantago major	10*	1*	419	336	93,12*	144,51*	10,12,13,24
Poa annua	6?*	—	—	—	—	4	10,11,12
Poa trivialis-type	—	—	92	—	120	16	17,33
Potentilla anserina	9	—	34	—	181	2	10,24
Ranunculus repens-type	—	—	—	—	7	—	10,12,13,25
Ranunculus sardous	—	—	2	—	18	—	10,25

Sample	10-1-4	10-1-5	10-2-52	10-2-53	10-2-56	10-2-58	
Volume (l)	4	2.5	4	4	4	3	Alternative
Context	floor	hearth	pit	pit	floor	floor	classes
Perennial ruderals (cl. 17):							
Apium graveolens	—	—	10	242	76	364,69*	
Cirsium cf. vulgare	—	—	—	—	1	—	25
Juncus maritimus	—	—	680	9700	—	2775	16
Juncus cf. maritimus	—	—	—	—	—	1550*	16
Juncus maritimus capsule	—	—	—	—	—	359	16
Solanum dulcamara	—	—	—	—	4	—	19,33,35
Urtica dioica	4	—	—	—	4	2	33,38
Reedswamp plants (cl. 19):							
Carex paniculata-type	—	—	6	—	—	—	35
Cladium mariscus	8*	—	98,2*	4	37	—	
Eleocharis palustris	7*	—	65	2	154,4*	2	10,16,24
Glyceria maxima	—	—	4	—	—	—	33
Glyceria spec.	—	—	4	—	—	—	
Lycopus europaeus	—	—	4	—	—	—	35
Oenanthe aquatica	—	—	2	—	—	—	
Phragmites australis	—	—	757	877	136	104	17,24,27
Phragmites australis stem	—	—	100-s	—	—	—	17,24,27
Poa cf. palustris	—	—	4	—	—	—	16
Scirpus lacustris tabernaemontani	2,14*	—	355	187	165	12	
Scutellaria galericulata	—	—	—	—	1	—	35
Typha spec.	—	—	80	59	24	29	25
Plants of dry grasslands (cl. 21):							
Trifolium cf. arvense	2*	—	—	—	—	—	
Saltmarsh plants (cl. 24):							
Aster trifolium	—	—	27	39	54	8	17
Glaux maritima	—	—	8	17	54	6,4*	10,27
Juncus gerardi	51000	—	1520	3370	4716	175	10,16,25
Plantago maritima	—	—	9	4	—	4	12
Plantago maritima capsules	—	—	6	—	—	—	12
Puccinellia distans	—	—	24	—	8	95	16
Scirpus maritimus	1*	—	11	—	31	—	17,19
Spergularia maritima/salina	—	—	1150	213	276,12*	242	16
Triglochin maritima	—	—	60	230	312	75	
Plants of damp grasslands (cl. 25):							
Daucus carota	—	—	—	—	46	—	
Lychnis flos-cuculi	2	—	40	—	—	—	
Lythrum salicaria	—	—	10	—	—	—	19,35
Prunella vulgaris	1*	—	—	—	4	—	10,33
Scirpus sylvaticus	—	—	—	—	20	16	
Stachys palustris	—	—	4	—	—	—	12,13,33
Heathland and bog plants (cl. 27-30):							
Danthonia decumbens	—	—	—	—	94	—	25
Erica tetralix leaf	1	—	—	—	—	2*	25,32
Eriophorum vaginatum spindles	—	—	—	19	—	—	
Hydrocotyle vulgaris	—	—	10	—	12	—	10,16,19,33
Menyanthes trifoliata	—	—	—	—	143,10*	—	19
Potentilla erecta-type	—	—	—	7	69	—	
Ranunculus flammula	—	—	—	—	31	—	10,16
Rhinanthus cf. minor	—	—	—	—	35	—	
Rhynchospora alba	—	—	2	—	—	—	
Sphagnum spec. leaf	—	—	—	—	2	—	
Various:							
Agrostis spec.	—	—	239	22	188	52	16,24,25
Atriplex patula/prostrata	22,54*	—	173	45	745,1*	34	11,12,16,17,24
Avena spec.	2*	—	—	—	—	—	
Carex distans/extensa	514	—	5	—	2	—	16,24

Sample	10-1-4	10-1-5	10-2-52	10-2-53	10-2-56	10-2-58	
Volume (l)	4	2.5	4	4	4	3	Alternative
Context	floor	hearth	pit	pit	floor	floor	classes
Carex oederi s.l.	21	—	5	—	384	1	
Carex cf. pilulifera	—	—	—	—	8	—	
Carex cf. remota	—	—	—	2	11	—	
Carex spec.	—	1	—	—	—	—	
Anagallis minima/Samolus valerandi	—	—	—	119	—	10	6
Cerastium spec.	—	—	4	7	1	—	
Elymus repens/athericus	—	—	17	—	—	—	
Eupatorium cannabinum	8	—	—	—	—	1	17,25
Euphrasia/Odontites spec.	6,10*	—	58	7	464	—	
Festuca rubra	—	—	4	—	8?	—	
Gramineae indet.	—	4*	126	22	40	—	
Juncus articulatus-type	3240	—	80	—	480	—	10,16,25
Juncus spec.	8*	—	—	—	—	—	
Lotus spec.	1*	—	—	—	—	—	
Mentha aquatica/arvensis	2	—	53	15	8	4	12,13,16,19
Oenanthe spec.	—	—	—	18	—	6	
cf. Rosa spec.	—	—	—	—	1	—	
Rumex acetosella	—	—	—	—	8	—	12,13
Rumex spec.	—	—	—	—	17	—	
Trifolium spec. calyx	—	—	—	—	5	—	
Trifolium spec. flower	—	—	7	—	—	—	
Umbelliferae indet.	—	—	—	—	5	—	

indicate large scale use in view of their small chance to get carbonized (see *4.4.7*). Unfortunately, uncarbonized bean straw could not be demonstrated in the samples analysed.

4.6.10   THE MACROREMAINS OF ROCKANJE II

In this native Roman settlement, located on clayey sediments, two sections were sampled, in two different houses. In one of these houses, a hearth was also sampled (sample 2-0-10). Another six samples from a third house were analysed, one from a hearth (10-1-5), three from floor-layers (10-1-4; 10-2-56 and 10-2-58) and two from pits (10-1-5 and 10-2-52). The location of the samples is indicated in figure 44a and b. The results are presented in tables 25-27.

The lowermost samples in both sections already show many traces of human influence, although the natural subsoil was reached. Settlement evidently started directly on the natural subsoil.

The semi-marine location is clearly expressed in the number of seeds of salt marsh plants in the samples. These numbers are, with those of Rockanje 08-52, by far the largest of all the sites examined (see further *4.7.2.1*). The share of summercrop weeds is indisputably the largest of all sites, wheras in contrast grassland species are much scarcer than on most other sites, even if the species of class 24 are also looked upon as representing grazing territory.

The tread resistant plants are present in large numbers again. Of this class, several species are also indicative of grazing, particularly *Leontodon autumnalis*, *Trifolium repens* and *Potentilla anserina* (Van Zeist 1974: 334). It is remark-

able that the samples from the third house (trench 10) differ from the other two houses. Crop weeds and tread resistant plants are less important, while salt marsh plants in contrast are of much greater importance in this house. One possibility is that the third house actually was a cattle shed. The different architecture of this house, with an A-frame, may be the result of its different function. However, the fact that a hearth with many carbonized crop plant remains occurs in the third house pleads against a shed. Hearths where food was processed are generally found in those parts of houses where people lived (see also Haarnagel 1984: 168). The different composition of species can also be explained by assuming that the third house was the first to be built, in a relatively undisturbed salt marsh environment. Later, when houses one and two were inhabited, vegetation was more strongly influenced by man. If this assumption is correct, the environment must have desalinated in the course of the 2nd and 3rd centuries AD, in view of the lower quantities of salt marsh plants in the first and second house.

4.6.11   CONSPICUOUSLY ABSENT WILD PLANTS

It is not very informative to list all the plants that have not been found in the present study. However, one absentee is otherwise very common in palaeo-ethnobotanical studies and its absence does provide useful information. It concerns *Chenopodium album*. From anthropogenic deposits from the *Linear Bandkeramik* onwards, this is often the weed most frequently reported. Still, it is completely absent in the material from Voorne-Putten. This species favours high nitrogen
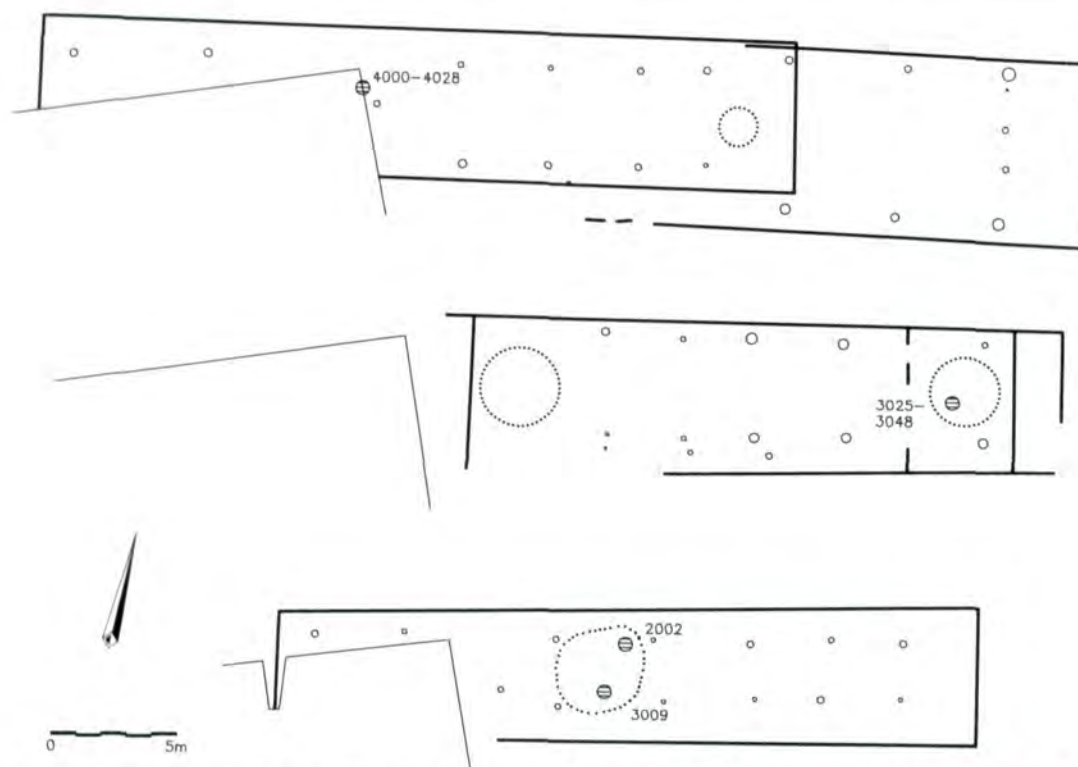
Fig. 42 Location of samples for botanical macroremains in the houseplan of Nieuwenhoorn 09-89, scale 1:300. Dotted line = hearth.
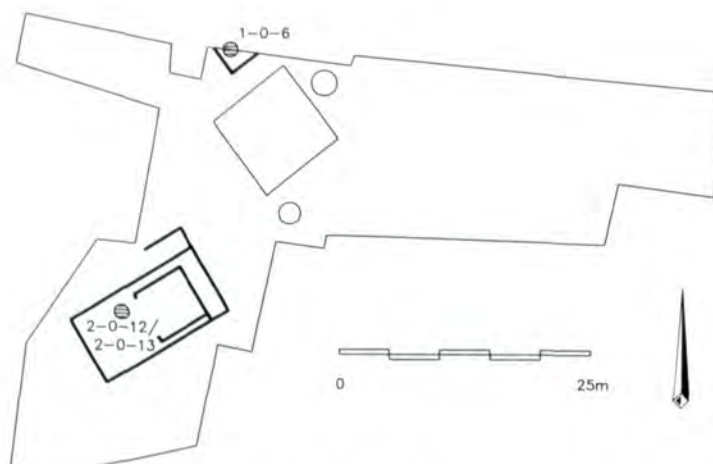
Fig. 44a Location of samples for botanical macroremains in the houseplans 1 and 2 of Rockanje II, scale 1:750. The two wells and the square granary have been indicated.
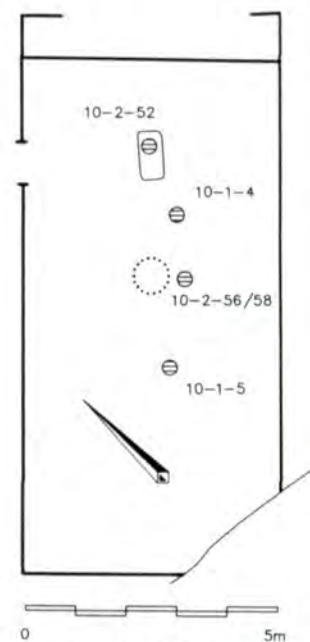
Fig. 44b Location of samples for botanical macroremains in the houseplan 3 of Rockanje II, scale 1:150. Dotted line = hearth.

contents and occurs among others in arable fields and ruderal places.

A second absent species is *Plantago lanceolata*. In pollen diagrams this species commonly occurs. Its presence has often been regarded as an indication of pastoralism (see *2.4.1*). The seeds, however, are not only absent on Voorne-Putten, but are rarely found in any palaeo-ethnobotanical studies (see Behre 1983).

4.7   A comparison of the sites on Voorne-Putten.
4.7.1   MULTIVARIATE ANALYSES

It will be clear from the above that the data discussed are quite heterogeneous. For further exploration of these data, numerical analyses can be a fruitful approach to discover patterns. As Hodson (1971) stated,

"the method of proceeding from the relevant raw material to a useful interpretation depends on the basic, simple axiom that patterns or regularities in material remains may be expected to reflect patterns in the agency that produced them".

Therefore, the present data have been subjected to multivariate analyses to discover patterns that might be interpreted in terms of past environment, human behaviour, etc. For this study, the statistical software of C.S.S. (Complete Statistical System) has been used.

For further statistical treatment of data, in which many variables are involved, deductive procedures of multivariate analyses can be applied. As Madsen (1988) observed,

"inductive statistics require a detailed knowledge of distributional qualities of the populations to which we apply the inferences. At the same time, they require that we have complete control of the formation of the samples from which we infer. None of these requirements are met in archaeology".

Only deductive procedures can be used with confidence. Concerning these deductive procedures, Madsen (1988) stated that

"it is very important to stress that deductive statistics are descriptive. They have no inferential value whatsoever. (...) They cannot in any way produce the conclusions for us".

These deductive procedures can be subdivided into two groups, of which Principal Components Analysis (P.C.A.) and Cluster Analysis are the major representatives.

P.C.A. is a procedure which orders the data. Formally, this ordering should be compared with hypotheses formulated beforehand. It is a problem-oriented procedure (cf. G.E.M. Jones 1991). Cluster analysis is a pattern-searching procedure in which no predetermined hypotheses need to be formulated. It allows unexpected patterns to emerge, which can subsequently be interpreted (G.E.M. Jones 1991: 70). In P.C.A. and the related Factor Analysis, higher demands are made on the basic data than in cluster analysis. Madsen (1988) stated that

"P.C.A. can be used safely only with data to which it is meaningful to apply the concepts of covariance and correlation, and this is true with reasonably normally distributed measurement data only".

These requirements are not met with in palaeo-botanical data. Especially the large numbers of zero scores are problematic (Dr. P. van der Velde *pers. comm*; Drs. E. Meelis *pers. comm.*). The newest ordination method, Correspondence Analysis, does not make such high demands on the data.

Whittaker and Gauch (1973) showed, in a comparison of then available techniques for ordination, that the mathematically more formal procedures of P.C.A. and Factor Analysis produced the worst results when applied to plant community research. Similarity indices were more effective "in the sense of producing interpretable results at least". Thus, cluster analysis seems to be the most appropriate method to apply to the present material. Canonical Correspondence Analysis would present the opportunity to obtain information by means of an alternative method. Unfortunately, this method is not included in C.S.S. It appeared impossible to use the S.P.S.S. version of Correspondence Analysis in the short time available.

Results of a cluster analysis are presented in dendrograms. The "distance" of all samples in relation to each other can be assessed by a range of indices. All are in some way based on presence/absence data (qualitative distance indices) or on the quantitative information (quantitative indices). For the present material, the quantitative distance index "Pearson's r" was found to produce dendrograms that could be interpreted more satisfactorily than those resulting from Euclidean, Squared Euclidean or Manhattan City-Block distances. The linkage of the distance data to dendrograms was by means of the "weighted pair-group average" method, which largely prevents "chaining" (clustering of many variables at a single level), which does occur in single linkage.

For numerical analyses, the results of all sites were stored in two large databases, one for waterlogged (uncarbonized) and one for carbonized remains. Subsequently, the numbers of seeds were standardized to numbers per litre of sediment. To reduce the effect of very large numbers, the logarithm (^{10}log) of the data has been used. Next, samples with less than two taxa in the uncarbonized matrix were deleted. These were sample numbers 10-1-5 from Rockanje II and 230 from Rockanje 08-52. In the matrix for the carbonized remains, 68 samples contained at least two taxa. In the following, the results obtained through cluster analyses will be discussed and interpreted. Probably, the robustness of these results can be controlled by means of Canonical Correspondence Analyses in the future.

4.7.2 CLUSTER ANALYSES OF THE SAMPLES ON THE BASIS OF WATERLOGGED BOTANICAL MACROREMAINS

In C.S.S., the data matrix may contain 80 variables at the maximum. Since the matrix of uncarbonized remains consists of 107 samples, only part of the matrix can be processed at the same time. It was decided to run a cluster analysis of all samples from sites on Putten first.

Figure 45 shows the results of this cluster analysis (of the sites discussed in *4.6.2* to *4.6.7*) on the basis of uncarbonized remains.

The first cluster (I) is composed of the two samples from the Early Iron Age site of Rotterdam-Hartelkanaal. The second cluster contains one sample each from Spijkenisse 17-30 and 17-34. These four samples in the first two clusters are very different from all other samples. These samples have in common that they revealed very low numbers of species.

Cluster III consists of six of the nine samples from Spijkenisse 17-30 and five of the eight samples from 17-35. In cluster IV, we find the remaining two samples from 17-30. These first four clusters contain all the Early Iron Age samples, except the samples 598 and 600 from 17-35, which occur in cluster V. Particularly these two samples were suspected of not being *in situ*, although they were assumed to date to the Early Iron Age (see *4.7.3*). Only two Middle Iron Age samples (17-35: 615 and 616) belong to these four clusters.

The large cluster V contains nearly all the samples from Spijkenisse 17-34 (M.I.A.). The above-mentioned two redeposited samples from 17-35 as well as the sample from Abbenbroek 17-22 are also included. Cluster Va contains most samples from the ditch of 17-34, as well as the floor sample (279), one sample from dung (289) and one hearth sample (580). Cluster Vb comprises the remaining ditch samples (311) and three samples from layers of dung (411, 534 and 535). Apparently, there is a difference in these samples, depending on the context. Thus, the variation on this site would have been underestimated if a particular type of context had not been sampled.

The sixth cluster consists of the three samples from Geervliet 17-55 (M.I.A.), the two samples from Zuidland 17-27 (L.I.A.), both in separate smaller clusters, and the remaining Middle Iron Age sample from 17-35. Cluster VII comprises the single sample from Zuidland 16-15 (L.I.A.) and a dung sample from 17-34, the last cluster (VIII) contains the two remaining samples from 17-34, one hearth- and one dung sample.

In view of the results, it seems justified to conclude that the samples are adequate to characterize the sites and to reveal differences between the sites. Since all the samples can be conceived as "judgement samples", this observation is of great interest in the discussion on sampling strategies. At least in the present study on wetland sites, the random

sampling strategy advocated by M. Jones (1978, 1985, 1991) and Van der Veen (1984, 1987) appears to be not the only way to make inter-site comparisons. Van der Veen (1987) also admitted that on upland sites the results produced by judgement sampling are comparable to those produced by random sampling. She stated:

"when we compare the diagrams of the random samples and the judgement samples, the similarity is striking. The main difference lies in the fact that the quantity of seeds in the judgement samples is greater than in the random samples: (...) the excavators prefer to select the rich, ashy deposits on the site."

Thus, the sampling of all different contexts represented on a site seems to be of greater importance than the need for random sampling. Interestingly, Van der Veen (1991), in a recent paper also stated that random sampling or an attempt to collect samples from all contexts is required for inter-site comparisons.

The second cluster analysis concerned all the sites on Voorne. The Late Iron Age site of Rockanje 08-52 as well as the native Roman settlements of Nieuwenhoorn 09-89 and Rockanje II are included. The resulting dendrogram is presented in figure 46.

The first cluster consists of two distinctly separated samples from Nieuwenhoorn, the goat droppings of sample 2002 and the hearth sample 3009. Cluster II also includes samples from Nieuwenhoorn exclusively. It consists of the *Scirpus* dominated samples from the section (samples 3037-3043), in which *Juncus gerardi* is not abundant (see also *4.6.9*). Furthermore, hearth sample 3056 is also included in this cluster.

The third cluster contains all the samples from natural subsoils, three from Nieuwenhoorn and one from Rockanje 08-52. These subsoils were all composed of *Sphagnum* peat. The fourth cluster comprises the samples from the upper part of the section (3025-3036) and sample 3049, which is the hearth of the second building phase, also present in the top of the section (next to samples 3027 and 3028). Sample 3001, which is also a hearth belonging to the second building phase, is included in this cluster as well. One single sample from Rockanje (10-1-4) occurs in this cluster, too. In the first four clusters, there are only two samples which have not come from Nieuwenhoorn. Furthermore, only one sample from Nieuwenhoorn is not present in these four clusters. This is sample 3026, which is distinctly different, as is demonstrated by the very high linkage level. This sample contains hearth material with only three waterlogged taxa.

Cluster V exclusively comprises samples from Roman Rockanje, in which the samples from the third house (trench 10) in cluster Va, are separated from those from the first and second house. This confirms the observation in paragraph 4.7.9 on the deviating character of the samples from the third house. The first and second house are represented in cluster Vb. All remaining samples from Roman Rockanje

are represented in cluster VI, all taken from the second
house.

The seventh cluster consists of two hearth samples from
Rockanje 08-52 (L.I.A.) and cluster VIII represents all the
samples from the stalls of this site. Again, within a single
site, the samples are separated corresponding to their
context, as in Spijkenisse 17-34. The last cluster (IX)
contains two samples that are highly dissimilar to all other
samples. One sample has been taken from the hearth of 08-
52 and one from a hearth in Nieuwenhoorn.

Again, the results show that the variation within the sites
is smaller than the variation between the sites, although
within the sites some subgroups of samples can be observed.

To decide whether the environmental setting of the sites is
the dominant factor, or whether the dating of the sites is of
primary importance, the sites represented in the two cluster
analyses discussed above should be combined in one ana-
lysis. Since only a maximum of 80 variables (in this case
samples) can be clustered, 25 samples will have to be ex-
cluded (Rock.10-1-5 and Ro08-52: 230 had already been
excluded because only one uncarbonized taxon occurs in
these samples). Firstly, all natural subsoils were excluded.
They are Nh09-89: 3044, 3046 and 3048 and Ro08-52: 1070.
They are clearly distinguished in the previous cluster ana-
lysis and do not provide information on the site during hab-
itation. For further selection, the previous two cluster ana-
lyses were used to select the remaining 21 samples to be
excluded. Pairs of samples were selected with low clustering-
distances between the pairs. The samples must also have
come from the same site within each pair. From 21 of these
pairs, one sample has been excluded in the following cluster
analysis. Thus, the remaining samples still showed as much
variation as possible. The following samples were excluded:
Sp.17-30: 152; Sp.17-34: 278, 327, 337, 411; Sp.17-35: 598,
604; Gv.17-55: 2; Ro08-52: 1069, 1076; Nh09-89: 3027,
3029, 3031, 3035, 3037, 3043; Rock: 1-131, 2-67, 2-110, 2-
129, 10-2-53.

The dendrogram resulting from the 80 remaining samples
is presented in figure 47. The clusters that resulted from this
cluster analysis closely follow the results obtained from the
first two cluster analyses. The samples from Putten and
those from Voorne are separated with surprising accuracy.
Only one sample (Sp17-34: 515) does not occur among the
clusters of Putten.

Since the main division is between sites on Putten on the
one hand and sites on Voorne on the other, it can be
concluded that the location is of greater influence than the
age of the sites. If age was the dominating factor, the Late
Iron Age sites on Putten and the one on Voorne would have
formed closely related clusters. Any changes in economic
conditions at the beginning of the Roman occupation are
overshadowed by environmental differences influencing the
vegetation around the sites (see further 4.8). Therefore, it is

all the more regrettable that no reliable samples from
Roman sites around the Bernisse could be included in this
study.

4.7.3   CLUSTER ANALYSIS OF THE SAMPLES ON THE BASIS
         OF CROP PLANTS

Since crop plants are a very important source of informa-
tion on the economy of the sites, they were included in a
third data matrix for cluster analysis. The evidence of crop
plants is provided by waterlogged as well as carbonized
remains. For this reason both categories have been included
in this cluster analysis. In total, 68 samples contained crop
plant remains.

The resulting dendrogram is given in figure 48. The first
cluster consists of nearly all the samples from Spijkenisse 17-
30, where *Brassica rapa* is an important element and *Hor-
deum vulgare* is completely absent. Most of the remaining
clusters are very heterogeneous with respect to the sites from
which the samples originated. Only the samples from Geer-
vliet 17-55 and those from Zuidland 17-27 form homoge-
neous clusters.

Summarizing the results, we can conclude from this
cluster analysis that the Early Iron Age site of Spijkenisse
17-30 is the only site that differs from all other sites. These
results will be further evaluated in chapter 6 in the light of
the economy of the sites.

Since it is also of great interest to know whether there are
differences (or similarities) in the crop weeds of the sites, it
was decided to run another cluster analysis on the uncarbon-
ized macroremains, now only on the basis of crop weeds. If
the resulting clusters are dominated by one or two sites, as
in the clusters of all the uncarbonized remains discussed
above, this will then indicate that the crops of the various
sites differ in their crop weed vegetation. This in turn indi-
cates different locations for the cultivated fields, with respect
to soil type, moisture and probably other key factors
regulating crop weed vegetation. In this cluster analysis, not
only the character species of the crop weeds (class 12) were
included, but also differential species. They are particularly
important for separating weed vegetations with different
reactions to moisture, too important a factor to be neglected
in the wetland area studied. In total, 98 samples contained
one or more crop weeds. Because of the low number of
species concerned, all samples could be included.

The resulting dendrogram does not show the sites separ-
ately (*fig. 49*). This means that the fields of all periods
concerned did not differ markedly in their weeds. Even the
site of Spijkenisse 17-30, which was clearly separated in the
cluster analysis on crop plants, is now mixed in with the
other sites.

4.7.4   CLUSTER ANALYSES OF THE TAXA

In all the cluster analyses discussed so far, samples were

clustered. It is also possible to make the different taxa the subject of cluster analysis. This has been carried out for two data sets. The resulting clusters ideally consist of taxa belonging to similar vegetation types, since such taxa have a greater chance to occur combined in the samples.

The results of the cluster analysis of the waterlogged taxa from Nieuwenhoorn are presented in figure 50. Only cluster X, which contains only bog plants, corresponds to the ideal situation. All other clusters are very heterogeneous with regard to vegetation types represented by the taxa. This can only lead to the conclusion that the great majority of the samples contain seeds from very different origins. Körber-Grohne's (1967) "*reine Proben*" ("pure samples"), which contain the remains of only one type of vegetation, are apparently hardly represented in Nieuwenhoorn.

A second cluster analysis of waterlogged taxa has been executed for the Roman site of Rockanje. Figure 51 shows the resulting dendrogram. Although some smaller clusters, which ecologically make sense, can be designated (e.g. *Apium graveolens, Salicornia europaea* and *Atriplex littoralis*-type), the overall picture is a combination of ecologically very different taxa. As in Nieuwenhoorn, the samples contain a heterogeneous mixture of plants from different habitats. Thus, the waterlogged samples in most cases do not represent an original combination of taxa (*palaeobiocoenosis sensu* Willerding 1979, 1991) but a secondary mixture of plants from different vegetation types (*thanatocoenosis*).

4.7.5   CLUSTER ANALYSIS OF THE SAMPLES ON THE BASIS OF CARBONIZED BOTANICAL MACROREMAINS

The data matrix of the carbonized remains consists of 66 samples, in which 134 taxa are found. Figure 52 shows the dendrogram of the cluster analysis of these samples. In the waterlogged remains, the corresponding dendrogram gave a fairly good separation concerning the different sites. Especially the sites on Voorne on the one hand and those on Putten on the other were distinctly separated.

The dendrogram of the carbonized remains shows a much greater mixture of the different sites. The carbonized remains are, therefore, not as characteristic of a particular site as the waterlogged material. Several causes may be put forward to explain this observation. Firstly, carbonized remains are much scarcer than waterlogged ones. In most samples, only few carbonized taxa were found. The result is that the combined occurrence of taxa in two samples (which is the basis of cluster analysis) is very much influenced by chance processes. Secondly, some taxa have a much greater chance than others to become carbonized. Cultivated plants, especially hulled/glume cereals, and waste products from crop processing run a much greater risk of carbonization than plants from the natural vegetation around the sites. These crops and crop weeds belong to a limited set of

species, with relatively large similarities between the sites. This also results in a great inter-site similarity.

This observation is of great interest, as in many upland archaeological sites only carbonized material is preserved. In a comparison between such "upland sites", the differences between sites will, therefore, be smaller than in "wetland sites". On the other hand, the processed sample volume is in general much larger when only carbonized remains have survived as flotation techniques allow processing of large samples. As a result, in general more taxa of carbonized macroremains are found in samples from upland sites. This offers better possibilities for cluster analysis, as samples with very few common taxa will easily resemble each other. The recovery of more taxa provides possibilities of detecting differences.

In the cluster analyses discussed here, the total of the waterlogged remains produced the greatest inter-site differences, crop plants (both waterlogged and carbonized) still showed some, but less distinctive, inter-site variation. Crop weeds showed an even greater similarity between the sites, while the carbonized remains showed the greatest resemblance. In order to investigate the nature of the dissimilarities in waterlogged remains between the sites, some detailed information has been worked out in the following paragraphs.

4.8   The nature of differences and similarities between the sites

The cluster analyses revealed differences between the sites investigated, but they did not demonstrate the underlying cause of these differences. In order to obtain further knowledge about these differences, the information provided by the botanical macroremains has been examined from several angles.

In view of the results of the cluster analyses discussed above, it seems justified to lump together the data per site, as most of the remains are waterlogged. This allows a manageable summary of the data. The results for Spijkenisse 17-35, the two-period site, should be treated with extra caution, in view of the results of the cluster analyses.

For a first summary of the data, it was decided not only to lump together the data per site but also per syntaxonomical class (see *4.6*). The total values thus obtained are still absolute ones. Owing to the great differences in the total numbers of "seeds" per site, they still cannot be compared directly between the sites. Therefore, the number of seeds belonging to each class per site have been calculated as a percentage of the total number of seeds per site.

Before applying such percentage ratios, several constraints must first be made clear. Miller (1988) discussed relevant assumptions in the use of ratios. Although she claims that

the ratio eliminates the effects of varying conditions of de-
position and preservation, Kadane (1988) in the same
volume showed that differential decay of the taxa in the
numerator in comparison to the denominator, may result in
apparent changes through time caused by post-depositional
processes irrespective of possible similarities at deposition.
The influence of these post-depositional processes is even
more distorting if one particular class comprises many spe-
cies that are highly susceptible to decay. In view of the
waterlogged preservation of organic remains on all the sites
examined, it is considered improbable that differential decay
produced differences between the sites. Besides, any trend of
increasing numbers of taxa on younger sites, which may be
the result of a shorter period of decay, cannot be observed
in the present data. Moreover, samples that showed traces
of less favourable preservation, e.g. a small number of
mainly very resistant seeds (*Scirpus*, *Atriplex*, *Eleocharis*),
were discarded.

To calculate an average ratio, as is the case for the
percentages per class per site, we must ask ourselves whether
all the samples should be given the same weight, or whether
a weighting factor for each sample must be assessed. In the
present case, it might be expected that the larger samples
provide a more accurate reflection of the importance of the
different taxa on a site. By not standardizing the samples
according to volumes, the larger samples are given a corres-
pondingly larger importance in the ratio. For this reason,
the volumes of the samples were not standardized.

Differences in seed production and retrievability may also
be relevant. For instance, the class of ephemeral plants,
which are pioneers of open soils (the present Isoeto-Nano-
juncetea), has relatively few character species. These plants
frequently produce extremely small seeds that will often be
washed through the sieves (even through a 0.25 mm mesh).
It is therefore not surprising that this class is of minor
importance on all sites. Its share relative to other classes
may not be very conclusive, however, the share of such a
class can still be compared between different sites.

In the calculations of the importance of the different
classes per site, seeds of plants that are regularly over-rep-
resented have been omitted. The taxa concerned show a very
uneven distribution in the samples, they are either absent or
they are found in vast numbers. The taxa omitted are all
Juncus, *Typha*, *Sagina* and *Centaurium* species. They are also
the most important species of the 0.25 mm sieve fraction.
Furthermore, awn fragments have been excluded and
remains of cryptogams (*Chara*, *Sphagnum*, etc.) have not
been considered either. The share of seeds of unknown
ecology differs greatly from site to site. Since this category
does not provide useful information, it was also left out in
the calculations. The share of crop plants fluctuates
considerably among the various sites. Although this fact is

of great interest, it does have a strong influence on the
ratios of the other classes. The most elegant solution to this
problem seems to be the calculation of the importance of
crop plants on the basis of the sum of the other classes
(excluding seeds of unknown ecology), which is analogous
to assessing percentages outside the pollen sum in pollen
diagrams.

4.8.1   RATIOS OF SYNTAXONOMICAL CLASSES

In table 28, the percentages per class (crop plants and
"unknown" excluded in the denominator) are listed. Crop
plants are especially common in Geervliet, where the many
threshing-remains of mainly *Camelina sativa* account for the
high score, and in Zuidland 17-27, where *Linum usitatissi-
mum* is predominant. On all other sites, cultivated plants
play only a very minor part in all botanical macroremains.

The data about the other classes will be briefly discussed
per site. Most information has already been presented in
paragraph 4.6. The predominance or scarcity of a syntaxo-
nomical class in table 28 can only be evaluated with regard
to the presence of this class on other sites, as in general
some classes are better or worse represented, as explained
above.

In Spijkenisse 17-30, the most remarkable result is the
extremely low representation of crop weeds (cl. 12), despite
the fact that crop plants are fairly well represented. Plants
from damp grasslands (cl. 25) in contrast reach a high share.
In my opinion, this is a reflection of the economy of the site,
which will be discussed in more detail in chapter 6.

In Spijkenisse 17-35, the other (partly!) Early Iron Age
site, the crop weeds are much better represented. Remark-
able is the high score of perennial ruderals (cl. 17) in a
Middle Iron Age sample from Spijkenisse 17-35 (nr. 612).
Lambrick (1978) conceived the presence of perennials as an
indication for prolonged habitation. However, in contrast is
the observation that more intense cultivation conditions
result in the increase of annuals. Similarly, deficient manur-
ing causes a reduction of annual weeds, whereas perennials
flourish on such plots (Brenchley/ Warington 1930: 264).
Apparently, the subject is too complex to allow very
straightforward interpretations.

The samples of Spijkenisse 17-34 clearly show the
influence of the ditches near the house. Both water plants
(cl. 5) and reed marsh (or belt) vegetations (cl. 19) predom-
inate. Crop weeds show a low share while damp grasslands
show the highest value of all sites examined.

In Geervliet 17-55, crop weeds are better represented,
which is no surprise in view of the wealth of threshing-
remains on this site. Remarkable is the universality of
remains of *Myrica gale* (cl. 32). It could probably spread on
the peat which was desiccated due to drainage by gullies
during the Dunkirk I transgression phase. The predom-

Table 28. Relative importance of syntaxonomical classes per site (crop plants and unknown excluded from "seed-sum"). **xx** = high value for that class, *xx* = low value for that class, 0.0 = < 0.05%.

class	RH.10-69	Sp.17-30	Sp.17-35	Sp.17-34	Gv.17-55	Ab.17-22	Zl.16-15	Zl.17-27	Ro.08-52	Nh.09-89	Rock.1	Rock.2	Rock.10
Cl. 5	—	—	0.0	12.9	0.2	0.7	—	—	0.0	—	0.0	0.0	1.4
Cl. 8	—	0.6	0.0	0.0	—	—	—	0.2	5.8	0.8	0.0	0.1	1.4
Cl. 9	—	—	0.0	0.0	—	—	—	0.0	5.1	0.7	1.8	4.4	2.6
Cl. 10	—	—	—	—	—	—	—	—	—	—	—	—	1.7
Cl. 11	3.7	29.9	14.8	12.2	6.6	39.5	29.5	13.9	2.0	18.5	16.0	1.4	6.7
Cl. 12	—	0.2	9.9	3.7	11.2	7.8	4.9	13.4	9.4	2.7	22.7	28.5	10.4
Cl. 13	—	—	—	0.0	—	—	—	—	—	0.0	—	0.1	—
Cl. 16	22.2	6.6	11.5	9.1	31.1	1.3	4.7	16.9	33.0	9.2	54.3	43.1	20.4
Cl. 17	—	7.4	23.2	2.6	0.2	3.1	23.1	0.2	14.2	1.2	0.0	2.7	8.2
Cl. 19	11.1	34.9	27.7	38.0	22.2	33.9	32.8	48.1	7.2	19.6	3.5	14.5	29.5
Cl. 24	—	—	0.0	0.0	14.5	5.8	3.1	1.2	4.8	25.3	1.6	3.5	11.5
Cl. 25	18.5	16.3	11.7	19.1	2.1	3.1	1.9	3.1	12.5	18.8	0.0	1.2	1.6
Cl. 27-30	3.7	3.3	1.0	1.3	9.8	4.0	—	2.5	10.0	2.3	—	0.5	4.6
Cl. 32	—	—	0.0	0.6	2.1	0.9	—	0.0	0.7	0.7	—	—	—
Cl. 35	40.7	0.8	0.1	0.4	—	—	—	0.3	0.2	0.0	—	—	—
Cl. 38	—	0.0	0.8	0.0	—	—	—	0.0	1.0	—	—	—	—
Crop plants	—	3.2	1.0	2.1	48.2	0.8	4.1	21.9	1.2	1.8	1.1	2.5	3.8
# seeds	27	6,056	44,707	245,165	1101	627	913	8872	58,494	101,610	16,521	9275	9454
# samples	2	9	8	19	3	1	1	2	11	23	5	12	6
total vol. (l)	0.75	10.15	15.0	30.1	1.5	3	3	9.5	5.35	21.51	3.0	7.25	21.5

inance of *Myrica* remains in sheep/goat excrements found in Nieuwenhoorn is interesting. Similar observations are known from Iron Age contexts in the Assendelver Polders (Therkorn *et al.* 1984) and in Midden-Delfland (Kuijper *pers. comm.*). *Myrica* seems to have been collected deliberately for animal fodder. It was also used for brewing beer in medieval times, as is evidenced by botanical investigations as well as by written sources (cf. Behre 1984b; Greig 1991). Whether or not this was already practised in prehistoric times cannot be decided on the basis of the available data. As in the sites discussed above, the proportion of grassland plants in Geervliet 17-55 is high. Remarkably enough, the four sites dating from the Early and Middle Iron Age show the highest share of grassland plants of all sites examined.

The samples from Abbenbroek and Zuidland 16-15 (each one sample) show high percentages for therophytic pioneers of places rich in nitrogen (dried-up ditches and the like; cl. 11). As in all sites on Putten, salt marsh vegetations (cl. 8, 9 and 24) are of less importance.

Zuidland 17-27, where many remains of cultivated plants occurred (see above), also shows a strong representation of crop weeds. The numbers of grassland plants in the three Late Iron Age sites on Putten are remarkably low compared to their older counterparts. On all sites on Putten, plants from heathlands and bogs (cl. 27-30) are scarce. This is a reflection of the location of the sites, which is in eutrophic reed vegetations (see also *2.5.1*).

On the Late Iron Age site near Rockanje (08-52), the heather and bog plants do show a high percentage, reflecting the location of this site on a raised bog (see *4.6.8*). All salt marsh vegetations (cl. 8,9 and 24) are also important. These two groups of vegetations are mutually exclusive as salinity prevents the further growth of raised bogs. Bog plants are concentrated in the sample of the natural subsoil, which is likely to reflect an earlier time than that in which human habitation coincided with the occurrence of the salt marsh plants. This confirms the data provided by the pollen diagram from this site, which also shows sharply increasing saline conditions during the habitation of the site. In Rockanje 08-52, the reed vegetations hardly occur at all, which in all probability is a result of the high salinity. Stems of *Phragmites*, however, are abundantly present. Nowadays, reed does occur at higher salt levels, but in this case remains in a vegetative state. Most other species of (fresh) reed vegetations (cl. 19) do not occur (see further *4.6.7*).

In Nieuwenhoorn, plants of damp grasslands are as important as in the Early Iron Age sites. This site was founded on a desiccated raised bog, as was shown by the analysis of section samples from this site (see *4.6.9*). Here too, perennial salt marsh plants predominate, mainly on account of *Scirpus maritimus*. This species mainly occurs in brackish environments. This implies that the surroundings of Nieuwenhoorn were not as saline as those of Rockanje.

The three houses excavated in the native Roman site near Rockanje do not all provide the same picture. The third house, in trench 10, is different from the other two houses. In the third house, salt marsh plants are more important, while in houses one and two crop weeds and tread resistant plants predominate. The third house has a deviating, A-shaped construction, which might also point to a deviating date. The more natural vegetations represented in the remains in the third house and the indicators of anthropogenic activity in the first and the second houses suggest that the third house was built first, in a relatively undisturbed environment. The first and the second house were built in an environment which showed traces of longer occupation.

4.8.2   CONSPICUOUSLY ABSENT CLASSES

In the list of classes represented on the sites of Voorne-Putten, several classes are not included, as they are absent on all investigated sites. Since the absence of several classes is also informative, these classes will be discussed here.

The most saline type of vegetation in the Netherlands is characterized by *Zostera* species (cl. 2). They occur in the range between well below Mean Low Water level through Mean High Water level. They have never been described in archaeological contexts, only Raven and Kuijper (1981) found *Zostera* seeds in a natural deposit in the Netherlands. Their absence in the Voorne-Putten material is an indication that the sites were not founded in the littoral zone of a salt marsh, which is the logical way to avoid daily inundations.

Spartina species, characterizing class 14, occur around M.H.W., especially on soft mud flats. They grow above the zone characterized by *Salicornia* species that have been found in the present study. As far as I know, *Spartina* has never been reported from archaeological material.

Species of the present Ammophiletea (cl. 15) occur in the sandy habitats between the coastline and the dunes. If such vegetations were exploited, for instance for animal fodder, their seeds might be found on the sites. As these seeds are absent, the exploitation of the dunes is not demonstrated.

Plants that characterize places with felled or burnt trees (cl. 18) are also wanting. This absence is a first indication of the openness of the terrain. This is further evidenced by the extreme scarceness of plants characterizing brushwood (cl. 32-34) and forests (cl. 35-38), as well as the absence of herbal taxa that occur on the fringes of forests on dry soils (cl. 31). Character species for riverine willow shrubs and -forests (cl. 33: *Weichholz-Aue*) have not been found in the present study. Unfortunately, only *Salix* species are character species for this class, and *Salix* seeds do notoriously preserve badly. They have, for instance, never been found in the German settlements on the levees along the Ems either (Behre *pers. comm.*). Of the differential species, many potential indicators of this class do occur very regularly (e.g. *Alisma, Eleocharis, Hydrocotyle, Berula, Stachys*, etc.). Since

these are character species of other very common classes, the importance of willow shrubs and -forests is difficult to assess. *Moehringia trinervia*, character species of forests on rich soils (cl. 38), may also have come from riverine forests. It is regularly represented in peaty environments on the sites on Voorne-Putten. Van Zeist (1989) found this species in Middelstum-Boerdamsterweg. This site lies in the former coastal area in the vicinity of peaty areas in northern Groningen. In the publication by Westhoff *et al.* (1971), a possible explanation of the occurrence of *Moehringia* can be found; in medieval times, it also occurred on peaty ridges along drainage ditches. Apparently, decomposing peat provides suitable growing conditions.

Species of dry grasslands on sandy and calcareous soils (cl. 20 and 21) are also lacking. This indicates that dry soils were not present in the immediate surroundings of the sites, or at least were not used for grazing livestock.

4.8.3   SALT MARSH PLANTS VERSUS FRESHWATER PLANTS

In his investigations of the northern German coastal area, Behre (1985) calculated the importance of halophytes (salt marsh plants) versus glycophytes (freshwater plants) for several sites. He developed this method during his investigation into early medieval Niens (Behre 1991b). The large difference in numbers of seeds preserved, related to different seed production per species, led Behre to conclude that quantitative ratios, based on numbers of seeds, are not applicable. He therefore selected sixteen halophytes and as many glycophytes, and recorded presence or absence on the site. The ratio of the number of these halophyte- and glycophyte-taxa gives an indication of the salinity of the environment of a site, respectively of different periods within a site. The taxa concerned are listed in table 29. Behre selected the taxa on the following criteria:

1. regular occurrence in fossil salt marsh samples; identification possible with certainty.
2. limitation to grassland species, which are the best indicators of salinity; weeds and ruderals are excluded.
3. exclusion of reed swamp species (*Phragmites, Typha, Scirpus*), which may have been transported from afar for roofing, litter and the like.

The proposed use of qualitative data (presence/absence) only, has one major implication. On thoroughly investigated sites, the scarcer category (halophytes in a freshwater environment and glycophytes in salt marshes) can still be reasonably well represented in the number of taxa, although only in a few samples and in small quantities. For this reason, not only Behre's purely qualitative ratio has been applied for the sites in the present study, but so has a second ratio, for the sake of comparison. This second ratio was established on the basis of the frequencies of the species concerned. The frequency equals the number of samples per

Table 29. Presence and frequency of halophytes and glycophytes and their ratios for the sites studied.

number of samples:	Sp.17-30 9	Sp.17-35 8	Sp.17-34 19	Gv.17-55 3	Ab.17-22 1	Zl.16-15 1	Zl.17-27 2	Ro.08-52 8	Nh.09-89 26	Rock.1 5	Rock.2 12	Rock.10 6
Halophytes												
Salicornia europaea	2	2	1	—	—	—	1	5	5	2	3	5
Suaeda maritima	—	—	—	—	—	—	—	5	4	2	3	3
Puccinellia maritima	—	—	—	—	—	—	—	1	—	—	—	—
Aster tripolium	—	1	—	—	1	—	2	—	9	2	7	4
Limonium vulgare	—	—	—	—	—	—	—	3	—	—	—	—
Triglochin maritima	—	—	1	—	—	—	—	4	7	3	7	4
Spergularia marginata/salina	—	—	1	1	—	—	2	6	3	5	9	4
Cochlearia anglica/officinalis	—	—	—	—	—	—	—	1	—	—	—	—
Puccinellia distans	—	—	—	—	—	—	—	2	1	3	2	3
Plantago maritima	—	—	—	—	—	—	—	4	—	1	3	3
Glaux maritima	—	—	1	—	—	—	—	5	1	3	4	4
Juncus gerardi	8	2	8	1	—	—	—	7	18	5	12	5
Armeria maritima	—	—	—	—	—	—	—	—	—	—	—	—
Carex distans	—	—	—	—	—	—	—	—	—	1	—	3
Apium graveolens	—	—	—	—	—	—	—	5	4	2	3	4
Centaurium cf pulchellum	—	—	—	—	—	—	1	1	2	2	5	4
Glycophytes												
Lycopus europaeus	8	8	16	3	1	1	2	2	19	—	3	1
Bidens tripartitus	—	4	5	3	—	1	2	—	4	—	—	—
Galium palustre	4	7	7	2	—	—	1	3	6	—	—	—
Rhinanthus cf minor	—	2	4	2	—	1	—	—	3	—	—	1
Lythrum salicaria	7	8	15	2	—	1	2	4	19	1	1	1
Lychnis flos-cuculi	5	5	14	3	1	1	1	4	2	—	—	2
Ranunculus lingua	—	—	—	—	—	—	—	—	—	—	—	—
Hydrocotyle vulgaris	5	6	15	1	1	1	1	6	6	—	3	2
Phalaris arundinacea	1	2	4	—	—	—	1	—	—	—	—	—
Stachys palustris	7	7	10	—	—	1	1	—	—	—	—	1
Hippurus vulgaris	—	—	1	—	—	—	—	—	—	—	—	—
Prunella vulgaris	—	1	2	2	—	—	2	—	2	—	—	2
Ranunculus flammula	—	—	—	—	—	—	—	1	—	1	—	1
Alisma plantago-aquatica	—	3	15	—	1	1	1	—	—	—	1	—
Filipendula ulmaria	—	2	8	3	—	—	—	—	1	—	—	—
Glyceria fluitans	—	3	15	1	—	—	2	—	—	—	—	—
Presence ratio	22.2	18.8	26.3	16.7	20.0	0.0	21.4	68.4	52.6	85.7	73.3	63.2
Frequency ratio	21.3	7.9	8.4	8.3	20.0	0.0	27.3	71.0	46.2	93.9	87.9	82.1
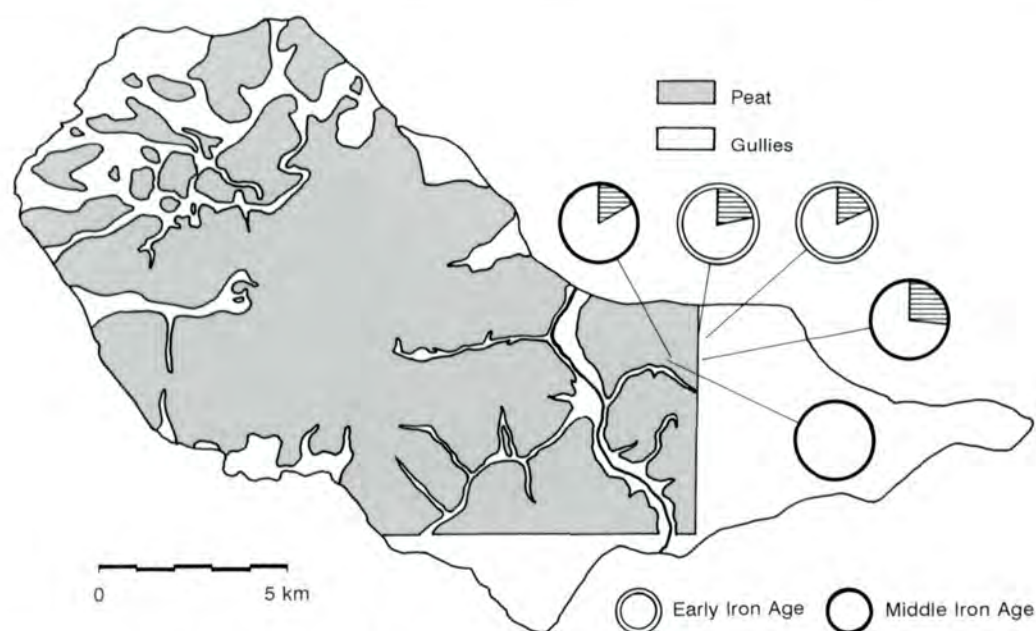
Fig. 53a Salinity ratios based on presence in the Early and Middle Iron Age. Hatched = halophytes,
White = glycophytes.
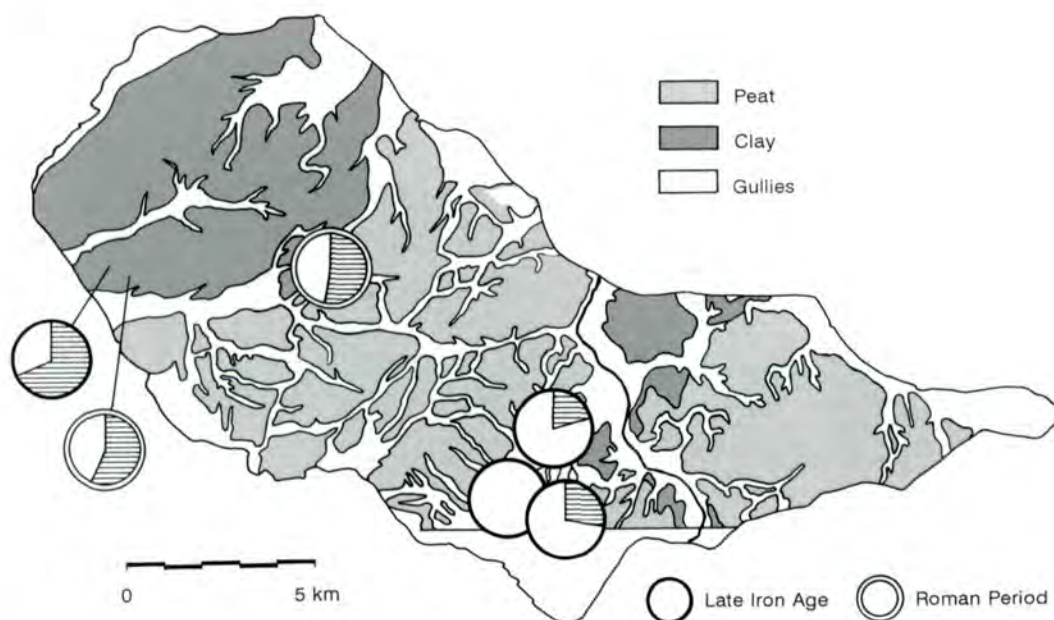
Fig. 53b Salinity ratios based on presence in the Late Iron Age and Roman Period. Hatched = halophytes,
White = glycophytes.

site in which a species occurs, irrespective of quantity, divi-
ded by the total number of samples of the site concerned. In
this way, absolute numbers are avoided but some quantitat-

iveness is introduced. The following example may elucidate
the calculation of the frequency ratio. In Spijkenisse 17-30,
the sum of the frequencies of the 16 halophytes is 10 and
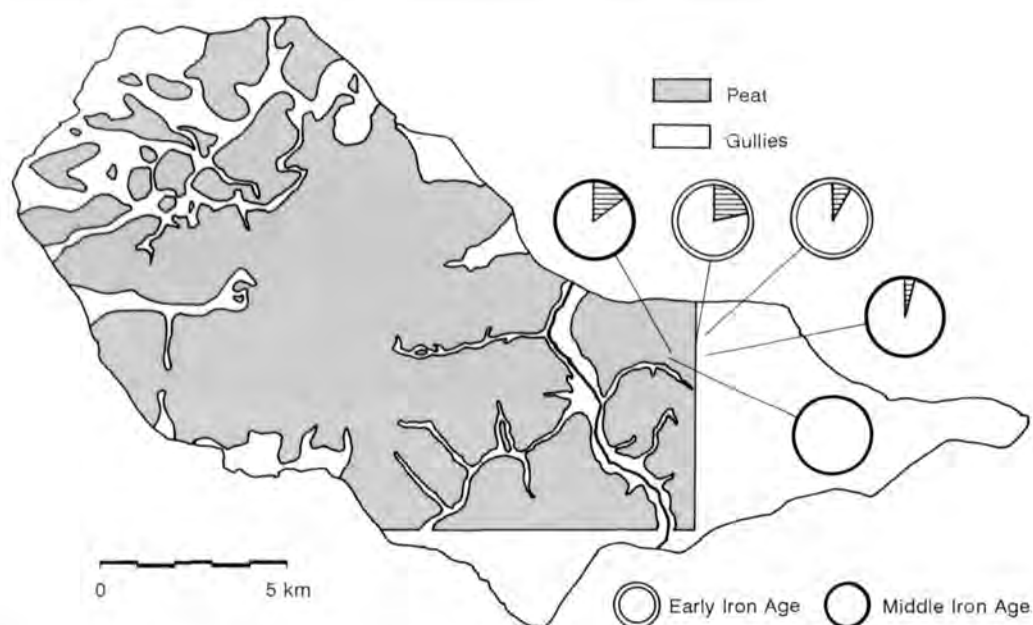
Fig. 54a Salinity ratios based on frequency in the Early and Middle Iron Age. Hatched = halophytes, White = glycophytes.
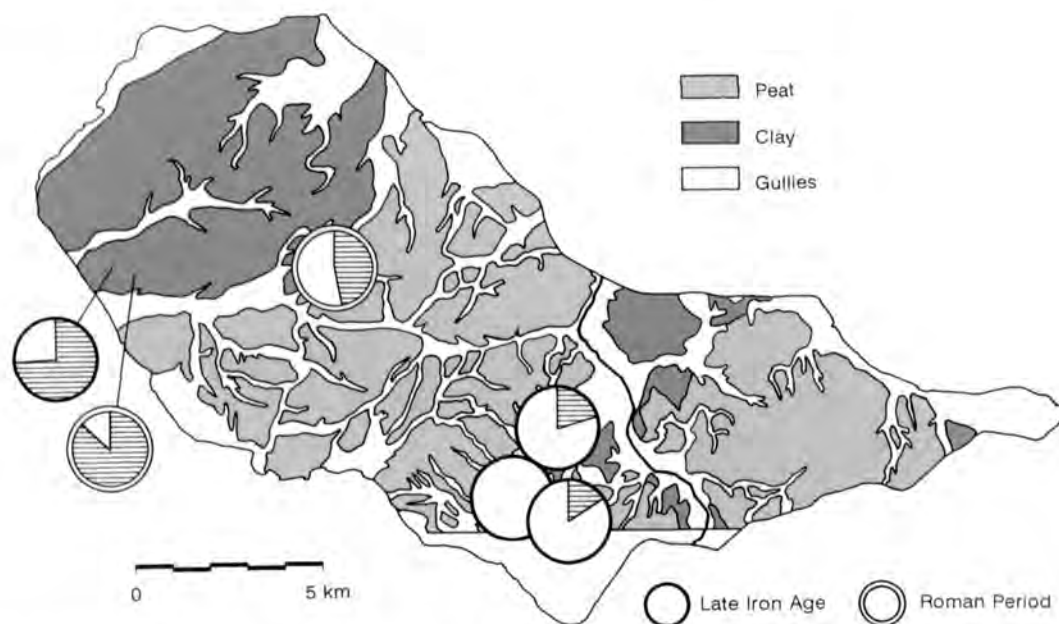
Fig. 54b Salinity ratios based on frequency in the Late Iron Age and Roman Period. Hatched = halophytes, White = glycophytes.

that of the 16 glycophytes is 37. The corresponding ratio is 10/47 or 21.3%. This may lead to a refinement of Behre's ratio. Both ratios have been listed in table 29.

A visual representation of the ratios based on presence is shown in figure 53a and b and that for frequency ratios in figure 54a and b. Particularly table 29 shows that rarely

occurring salt marsh plants greatly influence the presence ratios. This occurs most markedly in Spijkenisse 17-34, of which a relatively large number of samples were analysed. The ratio based on frequency, in my opinion, gives a better reflection of the salinity or non-salinity of a site. Similarly, the presence-based ratio on the sites near Rockanje is influenced by scarcer glycophytes and the frequency ratios show higher salinity values here.

Behre (1991b) arranged the species in a descending order of salt tolerance. This order is also used in table 29. The lowermost taxa (*Phalaris arundinacea — Glyceria fluitans*) are indeed scarce on the coastal sites. Remarkable is the occurrence of *Ranunculus flammula*, which has only been found on the sites near Rockanje, albeit in small numbers. These sites have the highest salinity. According to Weeda *et al.* (1985), *Ranunculus flammula* occurs in the coastal area in desalinated, wet dune valleys and in marshy grasslands. Its presence on the sites with the highest salinity is thus very remarkable, but must remain unexplained.

4.8.4   CROP WEEDS VERSUS MEADOW PLANTS

Reconstructions of the economy of the sites is one of the major aims of the present investigations. The role of pollen analysis in this respect appears to be limited at the present state of palynological research (see *2.4.1*). Moreover, the faunal remains do not provide any information on the relative importance of arable farming or pastoralism in the economy of the site concerned. For this reason, an attempt is made here to gain an insight into this special problem. A more extensive discussion of the agricultural economy will be presented in a later chapter (*ch. 6*).

In this paragraph, the relative abundance of arable weeds and meadow plants will be discussed. The underlying thought is that on a site where cultivation of crops is the main farming activity, arable weeds will be of greater importance than plants from meadows and pastures, which in their turn are supposed to be more common on "pastoral" sites. I realize that when a purely pastoral site imports its vegetable food products, arable weeds will still end up on this site, but they will mainly be crop impurities that are not removed until the final preparation of the product. They will be much less important than on an "arable" site, where far larger quantities of crops and their weeds circulate. Furthermore, "pastoral" and "arable" sites are of course part of a continuum. However, the relative share of meadow/pasture plants and arable weeds may roughly indicate the place of a site in this continuum. Since the processes related to deposition are completely different for crop weeds and hay plants, no 1:1 relationship in comparing these categories may be assumed. It is to be expected that hay plants will in general be less well represented, since the hay will have been "harvested" before most seeds have ripened. By the time seeds are ripe, the nutritional value of hay has strongly decreased

(cf. Knörzer 1979; Jacomet *et al.* 1989). Greig (1984) observed that grassland plants in general produce fewer seeds than crop weeds, which also favours the quantity of crop weeds relative to grassland plants. Thus, if on a site "pasture" scores 60%, this is only significant in relation to other sites (with "more" or "less" "pasture"), no absolute value may be given to this percentage.

If single samples were dominated by one of these categories (for instance in residues from crop processing or from hay), this would introduce a severe bias. If only few samples of a site have been investigated, this can distort the ratio considerably. However, it has been attested by means of cluster analyses that the samples within the site discussed here are relatively homogeneous, great differences between samples of one site are exceptions. Combined with the fact that of most sites several different contexts were analysed botanically, this homogeneity might meet any distortions to a certain degree.

This first attempt to quantify the economy of a site with botanical macroremains can undoubtedly be improved upon. However, in view of the fact that pollen and bones hardly ever provide reliable data, the potential of macroremains should in my opinion be exploited. Application of possibly adjusted ratios on other sites may show the value of the present approach.

For calculation of the ratios, ten crop weeds and as many meadow/pasture plants have been selected. The crop weeds are all from summercrops, since no wintercrop weeds occur in the present study. As in Behre's salinity indicators, the commonness of taxa in palaeo-ethnobotanical literature has been considered. *Spergula arvensis* was therefore included, despite its absence in the present study. On a site with both summer- and wintercrop weeds, it might be necessary to calculate another ratio.

In table 30, the presence- as well as the frequency ratios were calculated again. The results seem to indicate that the role of arable farming in the Early Iron Age was very limited. Especially the frequency ratios show a more or less steady increase of crop weeds through time. The ratios of the three Late Iron Age sites around the Bernisse are based on only one or two samples, which makes these ratios more liable to bias. The sites near Rockanje show relatively high arable components. The native Roman site of Nieuwenhoorn shows a much lower ratio than the sites near Rockanje do.

In chapter 6, the implications of these data will be discussed in a more general view, in relation to existing models of prehistoric agriculture.

4.9   The use of indicator values

A different approach to the results obtained by the analysis of botanical macroremains is furnished by the use of indicator values. These indicator values, as published by Ellenberg

Table 30. Presence and frequency of selected arable and meadow plants and their ratios for the sites studied.

	Sp.17-30	Sp.17-35	Sp.17-34	Gv.17-55	Ab.17-22	Zl.16-15	Zl.17-27	Ro.08-52	Nh.09-89	Rock.10	Rock.2	Rock.1
number of samples:	9	8	19	3	1	1	2	8	26	6	12	5
dating:	E.I.A.	E./M.I.A.	M.I.A.	M.I.A.	L.I.A.	L.I.A.	L.I.A.	L.I.A.	R.P.	R.P.	R.P.	R.P.
Crop weeds												
Polygonum lapathifolium	—	—	—	—	1	1	2	6	4	2	6	4
Polygonum persicaria	—	2	4	—	—	—	—	—	3	—	—	—
Sonchus asper	—	2	7	2	1	1	2	5	2	4	9	5
Sonchus oleraceus/arvensis	—	1	1	1	—	—	—	3	2	4	8	4
Echinochloa crus-galli	—	2	3	3	—	—	2	—	—	1	—	—
Spergula arvensis	—	—	—	—	—	—	—	—	—	—	—	—
Euphorbia helioscopia	—	—	—	—	—	—	—	—	—	—	—	1
Chenopodium polyspermum	—	—	1	—	—	—	—	—	—	—	—	—
Erisymum cheiranthoides	—	1	—	1	—	—	—	—	—	—	—	2
Anagallis arvensis	—	—	—	1	—	—	—	—	—	—	—	—
Meadow plants												
Carex disticha	—	4	17	3	1	1	2	—	3	—	5	—
Hypericum quadrangulum	3	7	9	1	—	1	—	—	2	—	—	—
Lychnis flos-cuculi	5	7	14	3	1	1	1	4	2	2	—	—
Lythrum salicaria	7	8	15	2	—	1	2	5	19	1	1	1
Prunella vulgaris	—	1	2	2	—	—	2	—	2	2	—	—
Trifolium repens/arvensis	2	2	—	3	—	—	—	4	2	2	5	3
Leontodon autumnalis	—	—	1	—	—	—	—	—	—	4	5	2
Poa trivialis-type	6	7	17	3	—	1	2	7	4	3	8	5
Ranunculus repens-type	—	3	12	3	—	—	1	1	—	1	2	1
Agrostis spec.	8	7	10	3	1	—	2	7	13	4	6	5
Presence ratio	0.0	38.5	35.7	35.7	40.0	28.6	30.0	33.3	33.3	35.3	30.0	45.4
Frequency ratio	0.0	14.8	14.2	25.8	40.0	28.6	33.3	33.3	19.0	36.7	41.8	48.5

Spijkenisse 17-30 (E.I.A.)
Moisture values
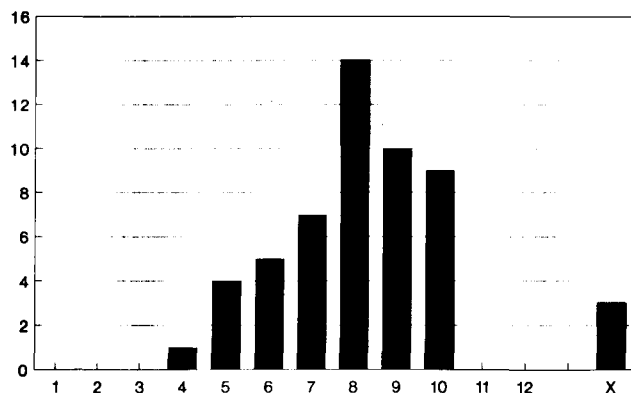
Geervliet 17-55 (M.I.A.)
Moisture values
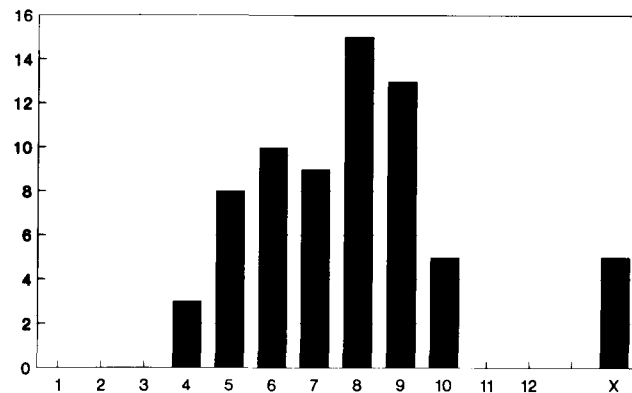
Spijkenisse 17-35 (E.\M.I.A.)
Moisture values
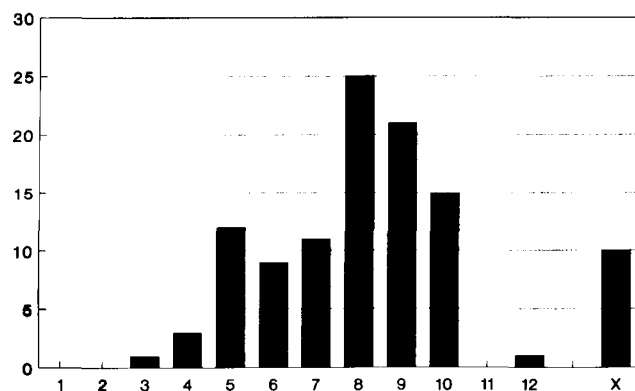
Late Iron Age
Moisture values
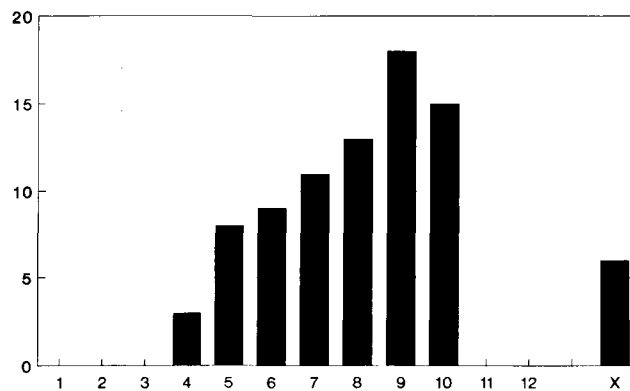
Spijkenisse 17-34 (M.I.A.)
Moisture values
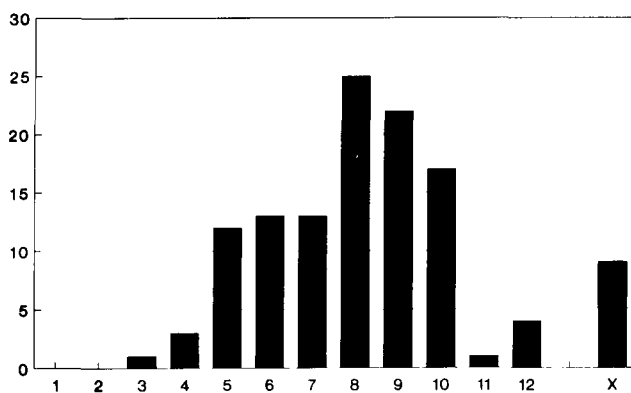
Rockanje 08-52 (L.I.A.)
Moisture values

Nieuwenhoorn (R.P.)
Moisture values

Rockanje, house 2 (R.P.)
Moisture values

Rockanje, house 1 (R.P.)
Moisture values

Rockanje, house 3 (R.P.)
Moisture values
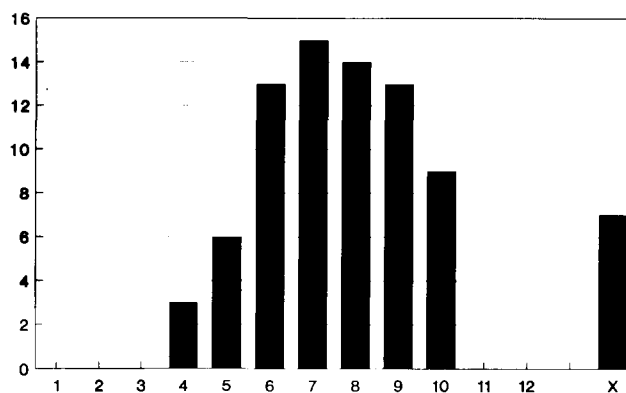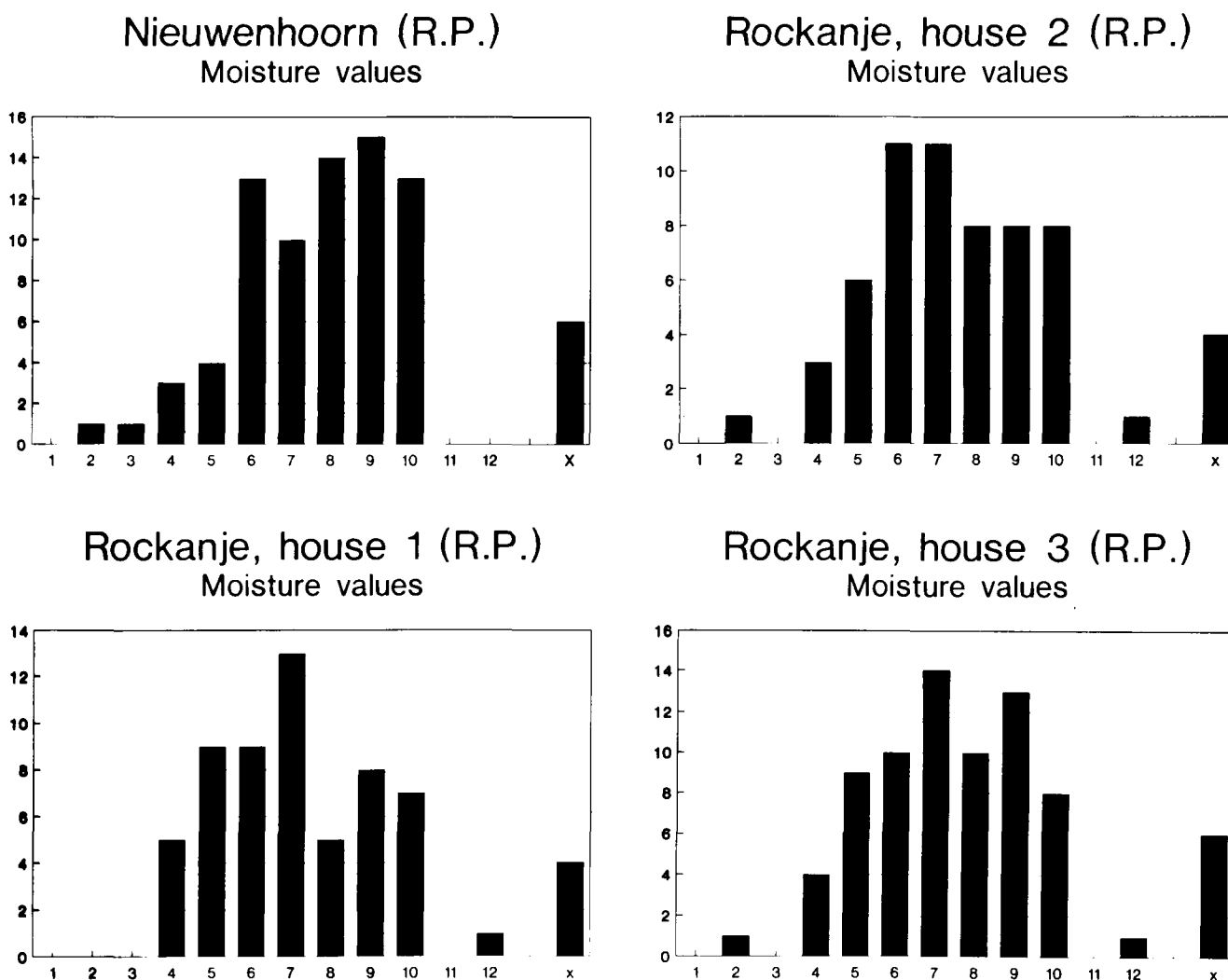
Fig. 55 Eco-diagrams for moisture. Late Iron Age = excluding Rockanje 08-52.

(1979) are an attempt to assign values to certain environmental parameters for individual species. The parameters dealt with by Ellenberg are Light, Moisture, pH, Nitrogen, Temperature and Continentality. For each parameter Ellenberg gave values between 1 and 9 (or to 12 for Moisture), in which 1 stands for a low and 9 for a high value of a parameter for the species concerned. X means an indifferent reaction of the species to a particular parameter. A species of dry, calcareous sand dunes for instance may score 1 for Moisture and 9 for pH, a plant averse to shade may score 9 for light. Willerding (1978) introduced the application of these "Ellenberg-values" for palaeo-botanical data.

In this study, the list of species found on a particular site was used as a basis. With a DBase program, which was

placed at my disposal by Drs. H. van Haaster (I.P.P.), it was possible to list the different Ellenberg-values of the species found on a site. Subsequently, the frequency of each value per parameter was established and presented as a bar diagram. These diagrams were called "palaeo-ethnobotanical eco-diagrams" by Willerding (1978).

The results obtained for the sites on Voorne-Putten will be discussed in the following. The results will be treated per eco-factor, since the results obtained per site proved to be comparable. The eco-factors of Temperature and Continentality will not be treated here, as these are only of interest in a comparison of sites that are hundreds of kilometres apart, at least in a flat country like the Netherlands.

Spijkenisse 17-30 (E.I.A.)
Acidity values
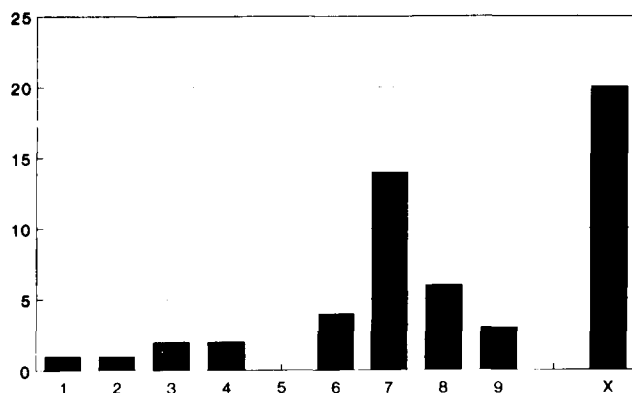
Geervliet 17-55 (M.I.A.)
Acidity values
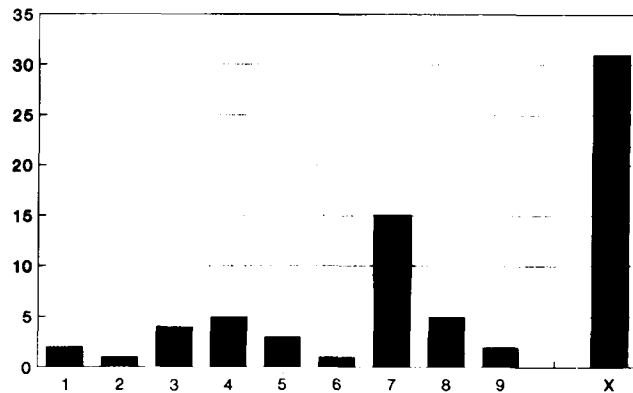
Spijkenisse 17-35 (E.\M.I.A.)
Acidity values
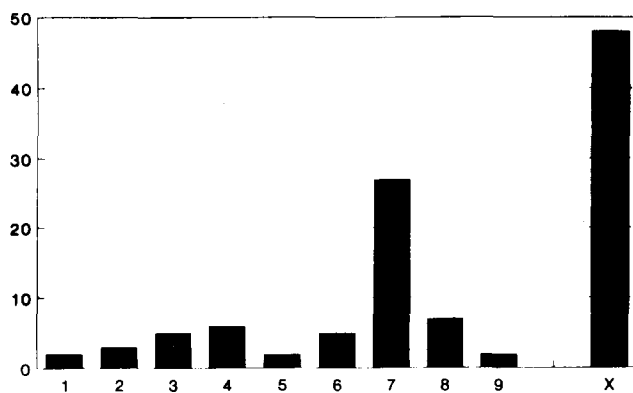
Late Iron Age
Acidity values
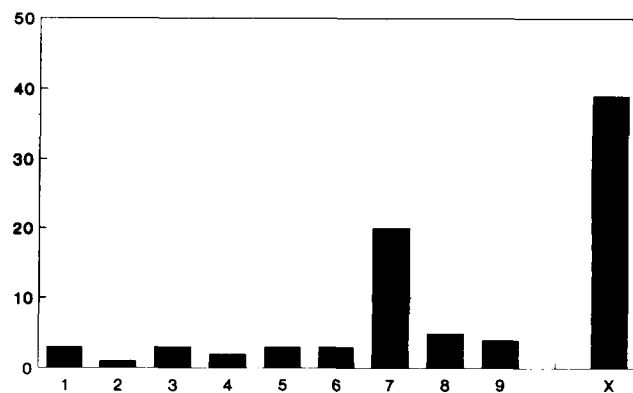
Spijkenisse 17-34 (M.I.A.)
Acidity values
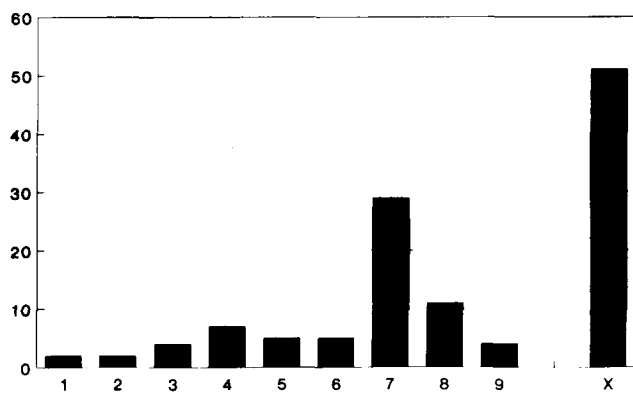
Rockanje 08-52 (L.I.A.)
Acidity values

Nieuwenhoorn 09-89 (R.P.)
Acidity values

Rockanje, house 2 (R.P.)
Acidity values

Rockanje, house 1 (R.P.)
Acidity values

Rockanje, house 3 (R.P.)
Acidity values
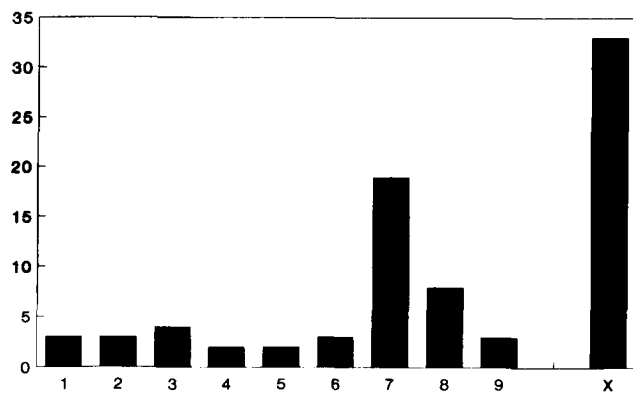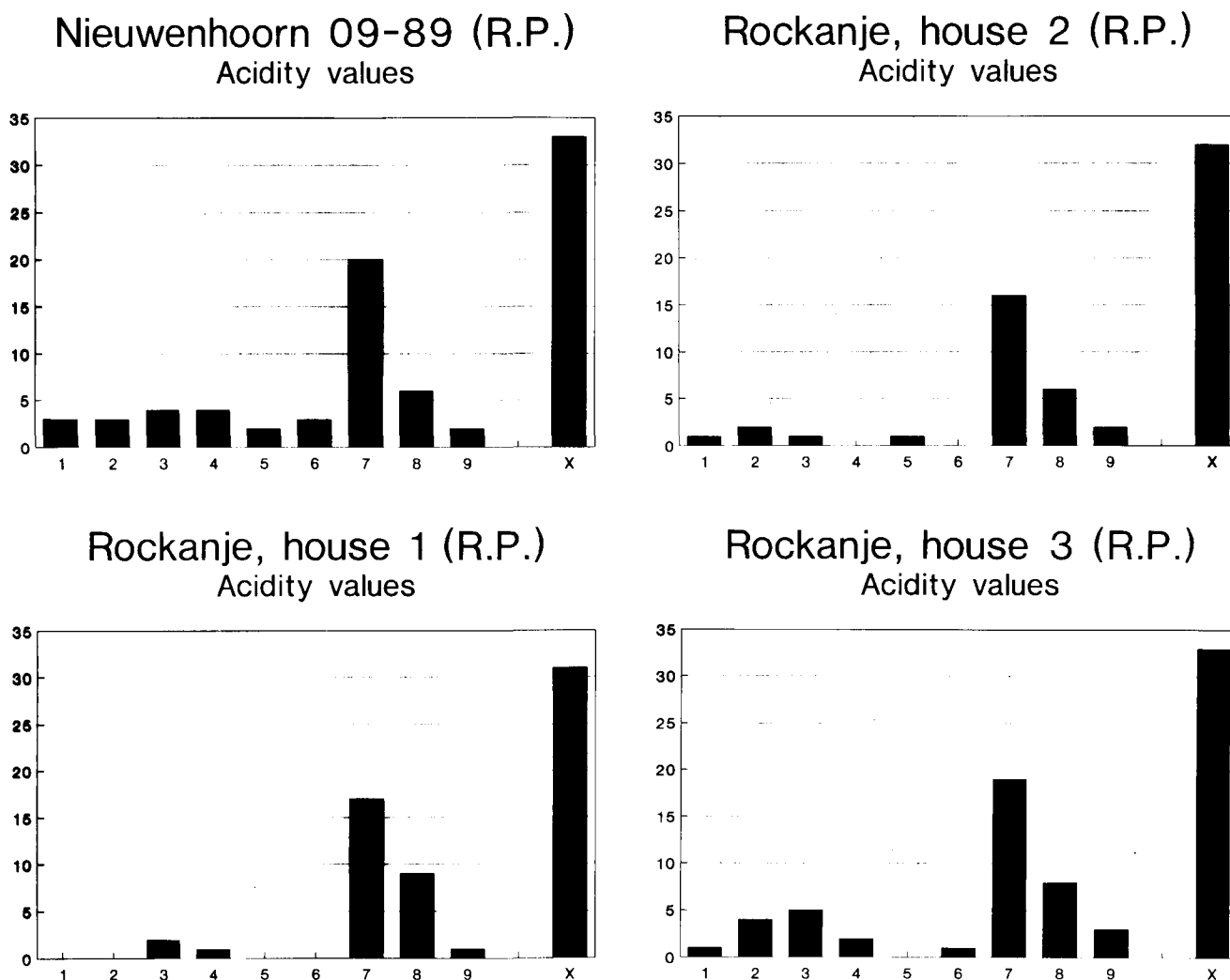
Fig. 56 Eco-diagrams for pH. Late Iron Age = excluding Rockanje 08-52.

4.9.1   MOISTURE VALUES

The moisture values 10, 11 and 12 indicate aquatic environments. As figure 55 illustrates, all Iron Age sites on Voorne-Putten show an eco-diagram with a maximum frequency at a Moisture value of 8, which means that the plants found as botanical macroremains are indicative of damp to wet environments. The Late Iron Age samples from the banks of ditches even show a maximum Moisture value of 9. The Roman site near Nieuwenhoorn shows two maxima, one at a value of 9 and a smaller one at 6. The other sites on Voorne show less extreme moisture conditions in comparison to the sites on Putten, with maxima around a value of 7, which is still damp. Willerding (1980) observed that on sites in central Germany the Moisture values generally lie round a value of 5, which is clearly drier than on the present sites.

4.9.2   pH VALUES

All sites show a distinct maximum at a pH indicator value of 7, which indicates slightly acid to slightly alkaline conditions (see *fig. 56*). The fact that Nieuwenhoorn and Rockanje 08-52 were founded on a raised bog does not have an appreciable influence. For the German sites, Willerding found pH indicator values ranging from 2 to 7 or even 9, which he interpreted as evidence that the arable fields were located on different soil types. The fact that crop weeds play a subordinate role among the botanical macroremains in the

Spijkenisse 17-30 (E.I.A.)
Nitrogen values
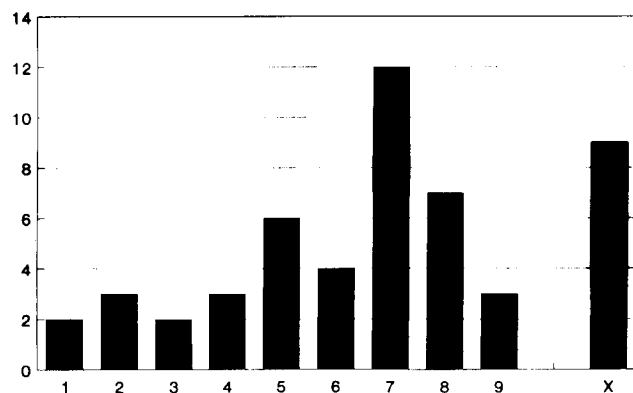
Geervliet 17-55 (M.I.A.)
Nitrogen values
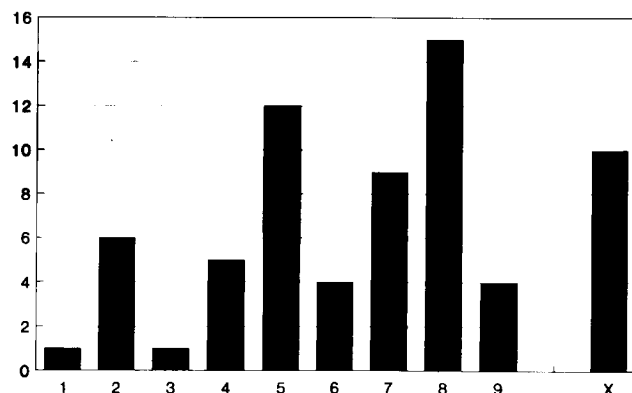
Spijkenisse 17-35 (E.\M.I.A.)
Nitrogen values
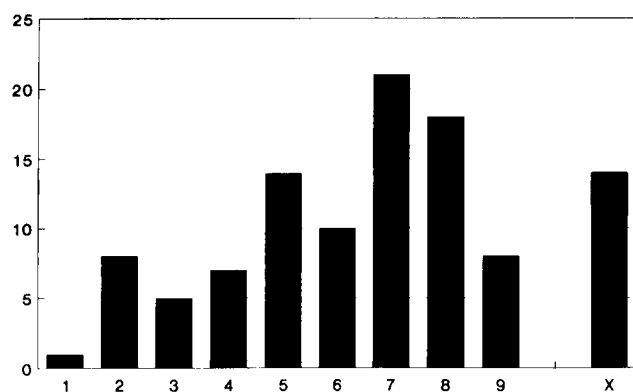
Late Iron Age
Nitrogen values
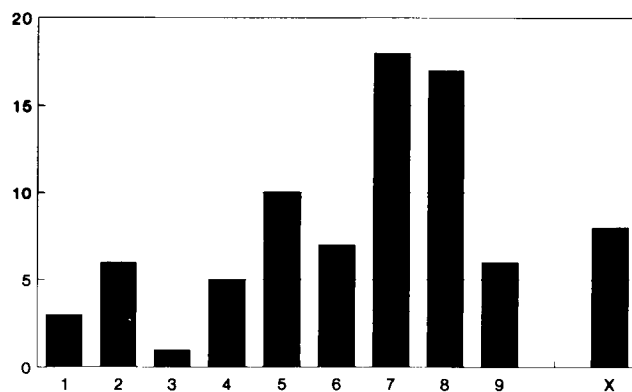
Spijkenisse 17-34 (M.I.A.)
Nitrogen values
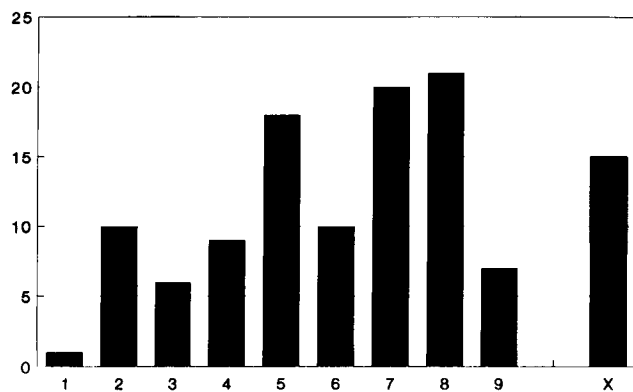
Rockanje 08-52 (L.I.A.)
Nitrogen values

Rockanje, house 1 (R.P.)
Nitrogen values

Rockanje, house 2 (R.P.)
Nitrogen values

Nieuwenhoorn 09-89 (R.P.)
Nitrogen values

Rockanje, house 3 (R.P.)
Nitrogen values
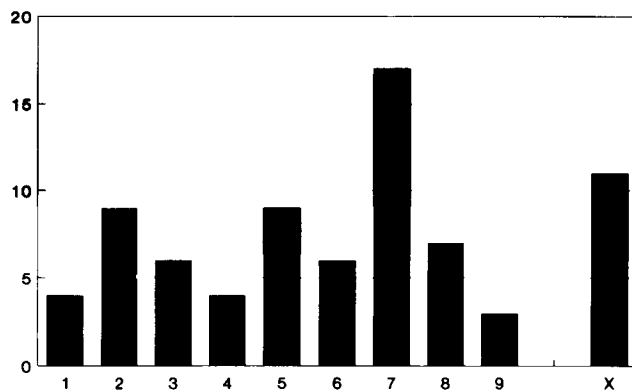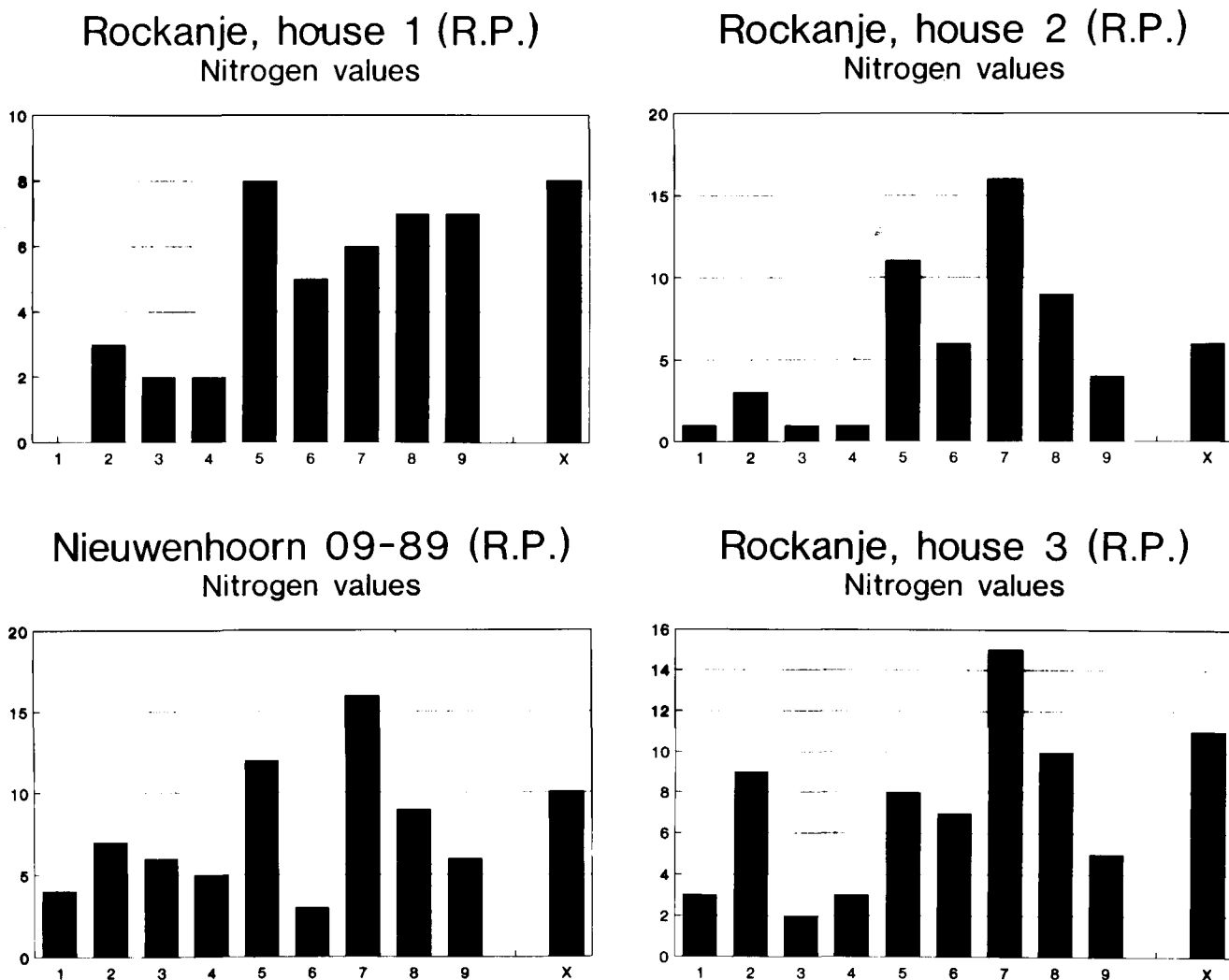
Fig. 57 Eco-diagrams for nitrogen. Late Iron Age = excluding Rockanje 08-52.

present study invalidate a similar conclusion for Voorne-Putten.

4.9.3   NITROGEN VALUES

All eco-diagrams for Nitrogen show maxima around the values 7 and 8, which indicates the presence of Nitrogen-rich soils around the settlements (see *fig. 57*). Two of the sites were founded on raised bogs, viz. Rockanje 08-52 and Nieuwenhoorn 09-89. None the less, the plants characteristic of Nitrogen-poor vegetations that occur on raised bogs do not predominate on these sites, although the lower Nitrogen values are slightly better represented. Willerding (1980) also found predominating Nitrogen values of 7 to 9 on German sites. He concluded that Nitrogen-deficiency (on the arable

fields) was apparently rare. Van Zeist (1983) found equally high Nitrogen values for Iron Age Noordbarge. He suggested the possibility of fertilising the fields with dung to account for these high values, but also stated that the plants might equally well have come from refuse dumps around the settlements. The greater part of the species that play a role on the sites on Voorne-Putten has not come from arable fields, and thus do not allow statements about arable fields exclusively.

4.9.4   LIGHT VALUES

The Ellenberg-values discussed above show a striking resemblance between the various sites, but the Light values are in this respect even more uniform. As figure 58 shows, do all

Spijkenisse 17-30 (E.I.A.)
Light values
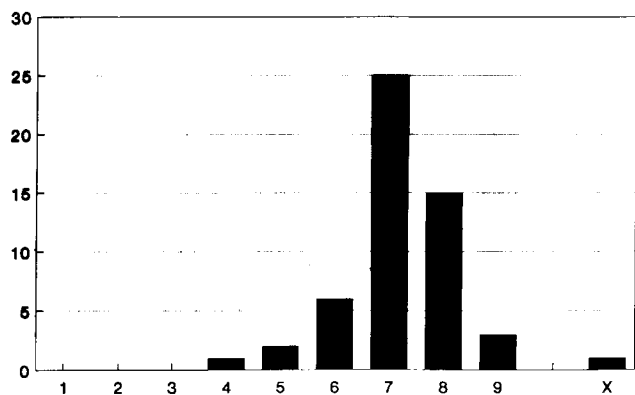
Geervliet 17-55 (M.I.A.)
Light values
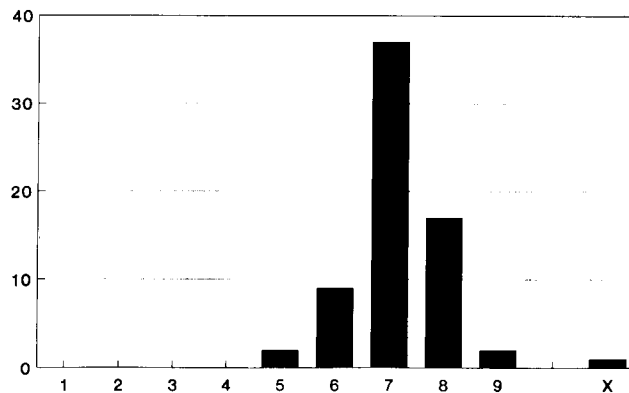
Spijkenisse 17-35 (E.\M.I.A.)
Light values
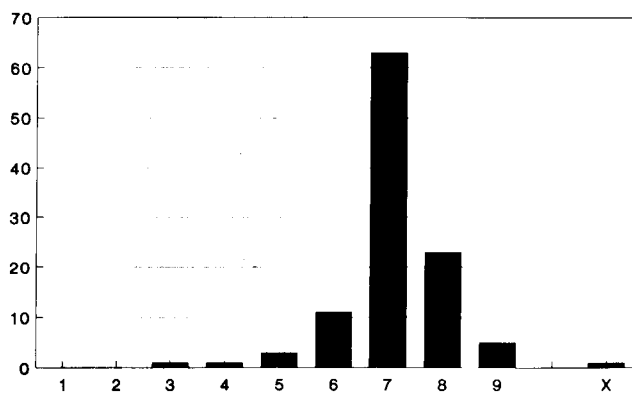
Late Iron Age
Light values
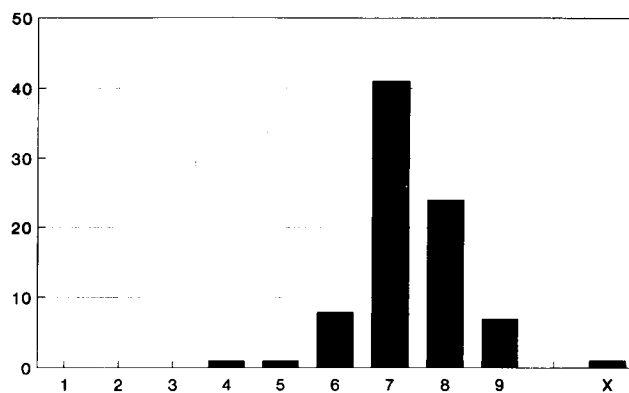
Spijkenisse 17-34 (M.I.A.)
Light values
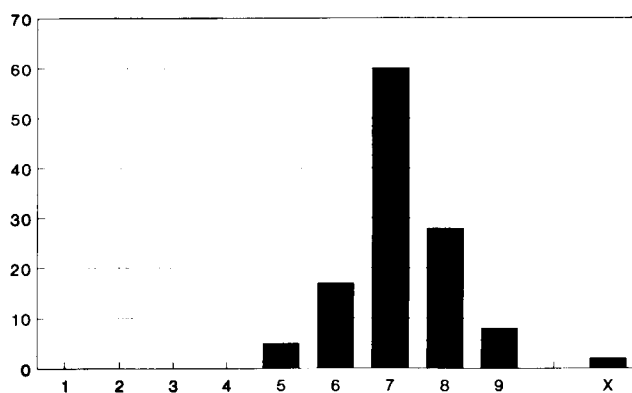
Rockanje 08-52 (L.I.A.)
Light values

Nieuwenhoorn 09-89 (R.P.)
Light values

Rockanje, house 2 (R.P.)
Light values

Rockanje, house 1 (R.P.)
Light values

Rockanje, house 3 (R.P.)
Light values
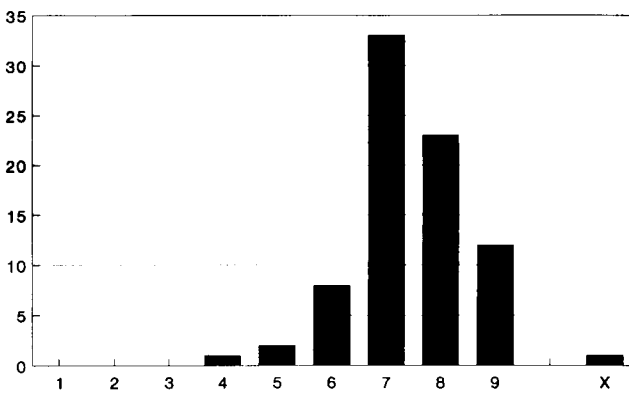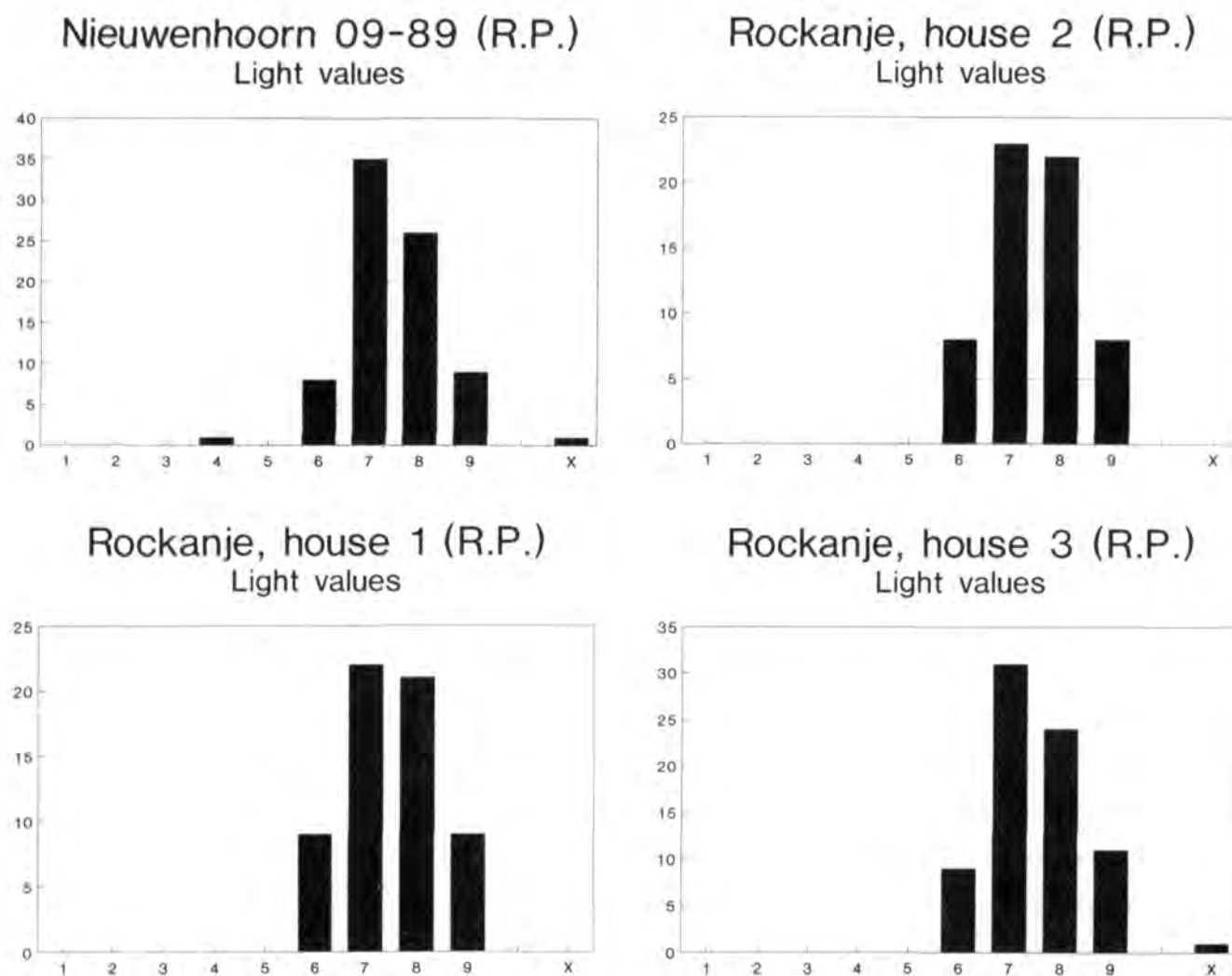
Fig. 58 Eco-diagrams for light. Late Iron Age = excluding Rockanje 08-52.

diagrams show a maximum Light value of 7, which indicates an open environment, devoid of tree cover on any appreciable scale. The open landscape that already appeared from the pollen analysis is thus clearly supported by the macro-remains.

For Germany, Willerding (1980) found that the most common Light values are 5 and 6, indicating more closed types of vegetation than on Voorne-Putten.

4.9.5   SALINITY
Ellenberg did not publish as detailed a scale for Salinity as he did for the other eco-factors. A value of 3 indicates that the species is an obligatory halophyte, a value of 2 repres-

ents "facultative" (optional) halophytes and a value of 1 indicates species from freshwater environments that tolerate some salinity. No indication means no salt tolerance. The salinity diagrams can be compared to the halophyte/glycophyte ratios discussed in paragraph 4.8.3.

The salinity diagrams referring to the sites on Putten differ considerably from their counterparts on Voorne; Nieuwenhoorn is more or less intermediate (see *fig. 59*). This also applies to the halophyte/glycophyte ratios. The results produced by these different approaches are quite comparable. The fact that of all eco-factors, salinity shows the greatest inter-site differences, indicates that this is the parameter with the greatest influence on the differentiation of the plant cover on Voorne-Putten. Therefore, salinity is also the

Spijkenisse 17-30 (E.I.A.)
Salinity
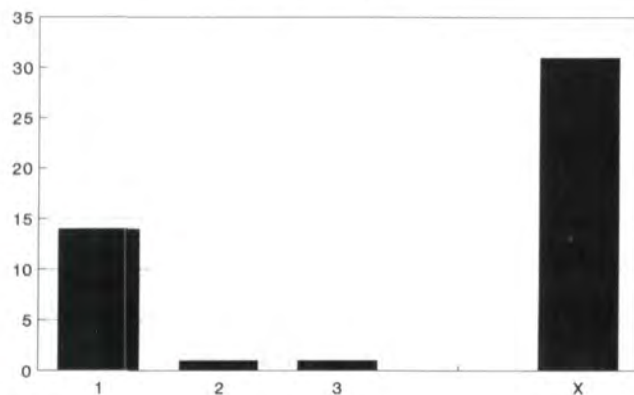
Geervliet 17-55 (M.I.A.)
Salinity
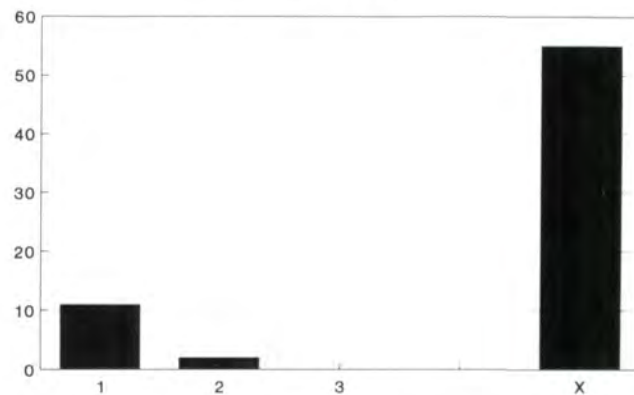
Spijkenisse 17-35 (E.\M.I.A.)
Salinity
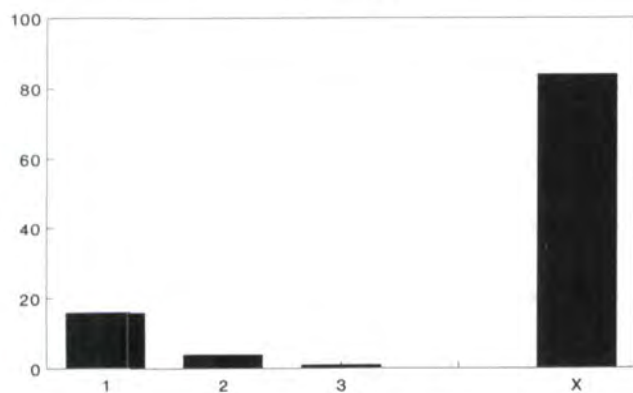
Late Iron Age
Salinity
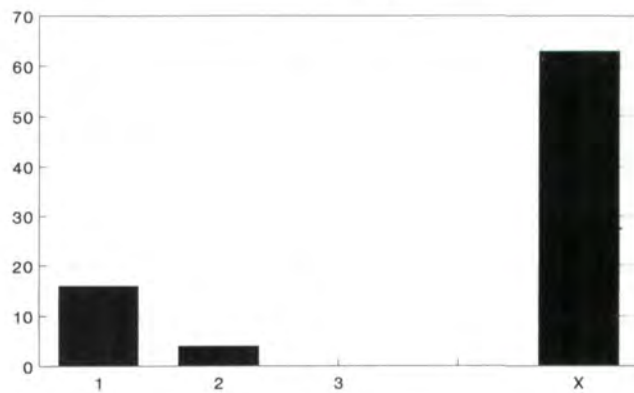
Spijkenisse 17-34 (M.I.A.)
Salinity
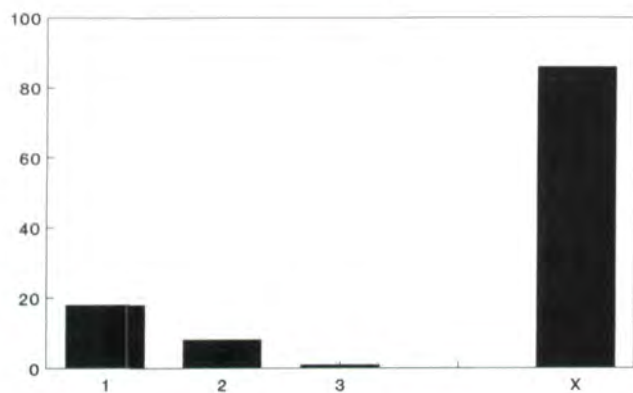
Rockanje 08-52 (L.I.A.)
Salinity

Nieuwenhoorn 09-89 (R.P.)
Salinity

Rockanje, house 2 (R.P.)
Salinity

Rockanje, house 1 (R.P.)
Salinity

Rockanje, house 3 (R.P.)
Salinity
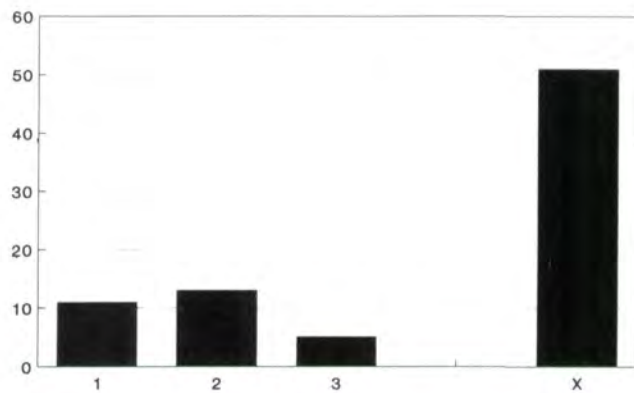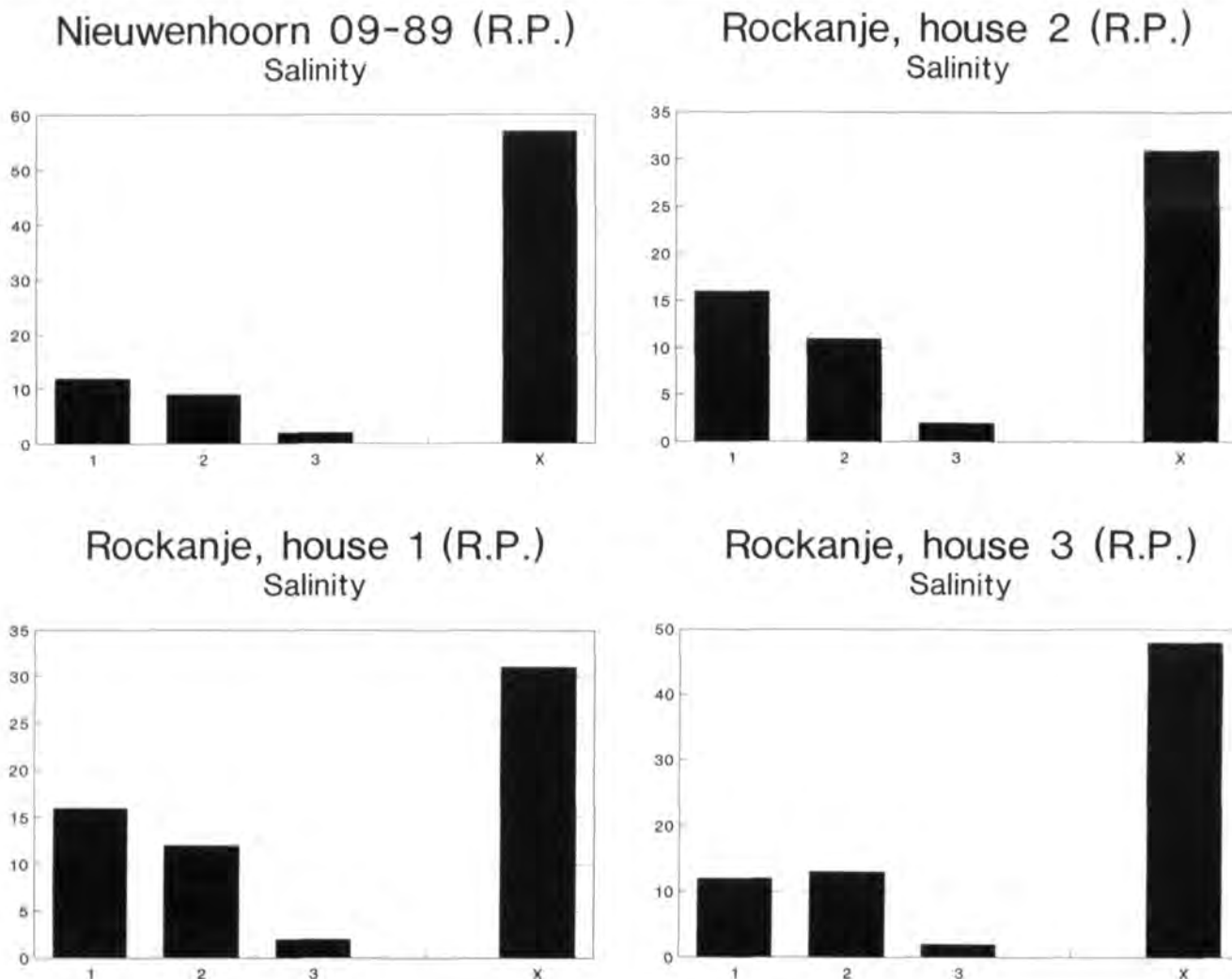
Fig. 59 Eco-diagrams for salinity. Late Iron Age = excluding Rockanje 08-52.

dominant factor producing the separation of the sites in the cluster analyses discussed in paragraph 4.7.

4.10   Summary

The study of botanical macroremains comprised 105 samples from twelve different sites. The samples were preserved under waterlogged conditions so that the major part of the material is uncarbonized. The samples are all judgement samples; a random sampling strategy was not applied.

The analyses demonstrated four-row hulled barley to be the most common cereal in all sites with the exception of the Early Iron Age site of Spijkenisse 17-30. On that site emmer wheat and broomcorn millet were found. The latter species only occurs on this site. Emmer wheat is regularly found in all Iron Age sites while it is remarkably less common in the Roman Period.

Linseed and gold of pleasure are the two most important crops cultivated for oil-rich seeds during the Iron Age. Again, Spijkenisse 17-30 forms an exception in that it lacks both species, and rapeseed was found in this site instead. Whether this was a cultivated crop or whether the seeds were gathered cannot be assessed. Crops with oil-rich seeds are much less represented in the native Roman settlements. The remaining crop plant found, Celtic bean, only occurs in the Roman site of Nieuwenhoorn.

Manna grass was gathered for consumption in the Middle Iron Age site of Spijkenisse 17-34. It will have been used as a source of carbohydrates during a shortage of cereals. Other deliberately gathered species occur only very rarely.

The crop weeds found in all sites belong exclusively to weeds of summercrops (Chenopodietea). Remarkable is the absence of the elsewhere often commonly occurring species *Chenopodium album*.

By means of cluster analyses on the basis of waterlogged remains it became clear that in general the sites were separated. Each cluster mainly comprised of samples from one single site. The inter-site variability is considerably larger than the intra-site variation. The judgement samples appeared useful in a comparison between the sites. Sub-clusters sometimes revealed a grouping according to contexts within sites. Therefore, as many different context types as possible should be studied in order to be able to assess the variation within a site.

The analyses of macroremains confirm several conclusions which were drawn on the basis of pollen analysis. The Early and Middle Iron Age settlements around the Bernisse were founded in a fen peat environment dominated by reed. Trees were absent in the surroundings of the sites. The Late Iron Age settlement near Rockanje and the Roman one near Nieuwenhoorn were built on a raised bog. The common occurrence of bog myrtle demonstrates that these bogs were subjected to oxidation and mineralisation, most probably due to natural drainage of the peat.

A cluster analysis exclusively on the basis of the waterlogged and carbonized crop plant remains, still revealed some groups of samples from one site, but the separation was less clear than in all waterlogged remains together. Cluster analyses based on the crop weeds and on the carbonized plant remains failed to discriminate between the sites. Apparently the natural vegetation around the sites produced the greatest inter-site variation in the botanical macroremains.

The groups formed on basis of cluster analyses of taxa could not be interpreted in view of plant communities. Apparently the samples contain plants from very different origins and became mixed on the site.

Through the ecology of the individual species (autecological approach), it could be demonstrated that salinity is the ecological key-factor determining the occurrence of plants around the settlements.

The share of crop weeds is much lower in the Early Iron Age settlements than in the later sites. Plants of meadows and pastures, in contrast, are more important in the Early Iron Age sites. The native Roman settlement near Nieuwenhoorn had a high share of meadow and pasture plants as well.

5 The faunal remains

5.1 Results

Investigations concerning the animal bone remains found in Iron Age contexts on Voorne-Putten have been conducted by Dr. W. Prummel (*Biologisch Archaeologisch Instituut, Rijksuniversiteit Groningen*). She kindly offered me the text of a Dutch manuscript (Prummel *in press*). An English publication appeared recently (Prummel 1991). In these publications, she reviews the results of nineteen Iron Age sites:

Early Iron Age:	Spijkenisse 17-35.
Middle Iron Age:	Geervliet 10-74; 17-40; 17-55; Spijkenisse 17-34; 17-35; 17-51; 18-06; 18-28; 18-29; 18-30; Simonshaven 17-56.
Late Iron Age:	Rockanje 08-06; Nieuwenhoorn 09-08; Geervliet 10-110; 17-41; 17-44; Spijkenisse 17-23.
Middle/Late Iron Age:	Spijkenisse 17-33; Geervliet 17-36.

She also summarized unpublished data from another seven Iron Age sites and three Roman ones on Voorne-Putten, which were collected by Drs. P.J.A. van Mensch:

Early Iron Age:	Rotterdam-Hartelkanaal 10-69
Middle Iron Age:	Spijkenisse 10-28; 18-30; 18-50; Simonshaven 17-14; 17-18.
Late Iron Age:	Abbenbroek 17-22.
Roman Period:	Oudenhoorn 25-3; Spijkenisse 17-07, 10-45.

Prummel counted and weighed the bones per species, whereas Van Mensch only counted them. According to Prummel, the proportions in counted numbers reflect the proportions in numbers of slaughtered animals. The bone weight proportions indicate the relative amount of meat of the respective species consumed. In her thesis, Prummel (1980) discussed the different methods used to quantify faunal remains. The number of remains (N.R.) is assessed by simply counting the numbers of (fragments of) bones per species/taxon. This method favours those animals of which bones are often fragmented, since each (identifiable) fragment is counted. As a result, a bias in favour of large animals, such as cattle, should be kept in mind. The weighing of bones rectifies this problem, since two halves of the same bone weigh about the same as an unfragmented one. The contribution of larger species to the diet is more

pronounced in this method. Prummel (*in press*) did not calculate meat weights, since this would only introduce additional uncertainties.

Prummel (1980) further stated that differences in soil conditions may cause different changes in weights of bones. In fact, this also plays a role in the N.R.-method, since differential decay of smaller bones introduces a bias in favour of large bones (cf. Brandt *et al.* 1984). Van Wijngaarden-Bakker (1988) indicated that taphonomic processes result in clayey sediments preserving much more bone than peat. This might play a role in the comparison between the Early and Middle Iron Age sites in a peaty environment on the one hand and the Late Iron Age and Roman sites on clay on the other.

Owing to the unfavourable conditions for preservation of bone in the peaty matrix present on most sites, the amount of bones found is rather small. Prummel concluded that the quantities of faunal remains per site were too low for an inter-site comparison. She combined the results per period, which still yielded rather small numbers for the Early and Late Iron Age (see *table 31*). For the data per site, the reader is referred to Prummel's original publication.

5.2 The Iron Age

5.2.1 DOMESTICATES

In all but one period, the bones from domesticates exceed 90%, both in numbers and in weight. Prummel's results concerning the Late Iron Age are different. The high amounts of sturgeon (*Acipenser sturio*) disturb the picture. However, as Prummel indicates, this may be due to distortion because of the low total amount of remains in this period. This seems to be confirmed by Van Mensch' data. He found 97.4% domesticates among the Late Iron Age bones in the site he studied. The domesticates were the dominant meat suppliers in all periods concerned.

Cattle are by far the most important domesticates. Prummel observed that the bones of cattle, sheep and pigs were badly fragmentated, in contrast to those of horses and dogs. From these data she inferred that horses and dogs were not eaten. Prummel (1991) mentioned one horse bone with a cut mark, but this may be an exception.

After cattle, sheep/goats were the second important slaughtered animal species. Only parts of the skeletal ele-

Table 31. Numbers and weights of animal bones found on Iron Age and Roman sites on Voorne-Putten (after Prummel in press).

	Early I.A. Prummel				v. Mensch		Middle I.A. Prummel				v. Mensch		Early/Middle I.A. Prummel				Late Iron Age Prummel				v. Mensch		Middle/Late I.A. Prummel				Roman Period v. Mensch		
	n	%-id	w(g)	w-%	n	%-id	n	%-id	w(g)	w-%	n	%-id	n	%-id	w(g)	w-%	n	%-id	w(g)	w-%	n	%-id	n	%-id	w(g)	w-%	n	%-id	
Domesticates:																													
dog	—	—	—	—	—	—	12	1.3	469	3.0	3	0.9	1	1.0	37	1.8	—	—	—	—	—	—	1	0.8	16	0.4	20	1.6	Canis familiaris
horse	—	—	—	—	3	37.5	5	0.5	530	3.4	7	2.0	18	17.8	75	3.7	—	—	—	—	5	6.6	2	1.7	364	10.2	36	2.8	Equus caballus
pig	—	—	—	—	—	—	69	7.4	795	5.0	30	8.7	—	—	—	—	—	—	—	—	2	2.6	3	2.5	29	0.8	139	10.8	Sus domesticus
cattle	19	79.2	277	92.6	5	62.5	683	73.1	13129	83.0	280	81.4	58	57.4	1786	89.0	10	35.7	107	69.9	56	73.7	90	76.3	2981	83.2	706	54.6	Bos taurus
sheep	1	4.2	6	2.0	—	—	12	1.3	102	0.6	—	—	2	2.0	7	0.3	—	—	—	—	—	—	6	5.1	51	1.4	2	0.2	Ovis aries
sheep/goat	2	8.3	13	4.3	—	—	143	15.3	708	4.5	21	6.1	18	17.8	74	3.7	4	14.3	9	5.9	11	14.5	14	11.9	136	3.8	332	25.7	Ovis/Capra
total	22	91.7	296	99.0	8	100	924	98.9	15733	99.5	341	99.1	97	96.0	1979	98.6	14	50.0	116	75.8	74	97.4	116	98.3	3577	99.8	1235	95.6	Sum domesticates
Wild Mammals:																													
beaver	—	—	—	—	—	—	3	0.3	35	0.2	—	—	1	1.0	9	0.4	—	—	—	—	—	—	—	—	—	—	8	0.6	Castor fiber
fox	—	—	—	—	—	—	1	0.1	20	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Vulpes vulpes
otter	—	—	—	—	—	—	—	—	—	—	—	—	1	1.0	5	0.2	—	—	—	—	—	—	—	—	—	—	—	—	Lutra lutra
red deer	—	—	—	—	—	—	1	0.1	18	0.1	2	0.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	7	0.5	Cervus elaphus
roe deer	—	—	—	—	—	—	—	—	—	—	1	0.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	0.2	Capreolus capreolus
elk	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	0.1	Alces alces
Birds:																													
grey heron	—	—	—	—	—	—	1	0.1	2	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Ardea cinerea
mute swan	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	3.6	2	1.3	—	—	—	—	—	—	—	—	Cygnus olor
mallard	1	4.2	1	0.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Anas platyrhynchos
bird indet.	—	—	—	—	—	—	3	0.3	1	0.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11	0.9	Aves indet.
Fishes:																													
sturgeon	1	4.2	2	0.7	—	—	1	0.1	4	0.0	—	—	2	2.0	14	0.7	13	46.4	35	22.9	—	—	1	0.8	7	0.2	28	2.2	Acipenser sturio
mullet	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	0.8	1	0.0	—	—	Liza/Chelon spec.
bream	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	2.6	—	—	—	—	—	—	Abramis brama
total ident.	24		299		8		934		15813		344		101		2007		28		153		76		118		3585		1292		total ident.
Not identified:																													
cattle size	9		32		—		435		1381		—		31		131		4		16		—		33		141		—		
sheep size	9		8		—		183		190		—		2		2		8		8		—		9		15		—		
unknown size	—		—		32		152		110		675		1		1		1		1		35		3		3		1100		

ments of sheep and goats can be distinguished from each other, the remaining bones have been listed as sheep/goat. Since only sheep have been attested with certainty, Prummel concludes that probably all the sheep/goat bones belonged to sheep. In sharp contrast to the zoological evidence is the occurrence of excrements of sheep/goats inside the farm of Nieuwenhoorn 09-89 (see *4.6.9*), which contain virtually nothing but bog myrtle (*Myrica gale*). These excrements, with similar contents were also found in Assendelft site Q, which dates from the Early Iron Age. Pals (1983) and Therkorn *et al.* (1984) stated that these excrements belonged to goats, as sheep dislike the bitter taste of bog myrtle. Tiesing observed that sheep avoid bog myrtle in Drenthe's heathlands (Edelman 1974). Corbet/ Harris (1991) also stated that bog myrtle is readily eaten by goats, but rarely by sheep. Van Wijngaarden-Bakker (*pers. comm.*) added that the oval shape of the prehistoric droppings also points to goats. Van der Bilt (*pers. comm.* with W. Prummel) also observed that sheep nowadays avoid *Myrica* in the *Gasterse Duinen* (Drenthe, the Netherlands). His suggestion that we are dealing with deer in the prehistoric situation can be dismissed, in view of the presence of quantities of droppings inside farms. Van Wijngaarden-Bakker (1988) suggested that the discrepancy in the data concerning goats might be explained by assuming that the goats were primarily kept for their milk and not for their meat, resulting in an under-representation of the bones.

The third domesticate in quantity of meat consumed is the pig. Prummel attributed the subordinate role of the pig to the scarcity of large deciduous forests in the surroundings of the sites that lie in peaty environments. In his studies on faunal remains from northern Germany, Reichstein (1975) also observed that cattle and sheep dominate in scarcely or non-forested areas, because they require grass. In densely forested areas, pigs predominate.

The stalls present in the Iron Age farms most probably served for housing cattle and probably some goats. Goats are the most sensitive to cold conditions in winter. Sheep can stand cold best of all domesticates. This is a further indication that the droppings inside the house in Nieuwenhoorn belong to goats and not to sheep. Only during severe colds sheep might have needed shelter, probably provided by the overhanging roof outside the building (Van Wijngaarden-Bakker 1988).

Waterbolk (1975) established the average width of bays in the course of pre- and protohistory. Partitions wider than 1.30 m are considered as "double" ones, where two head of cattle could be housed, below 1.20 m they are single. He found an average width per cow of 1.10 m in Bronze Age houses, of 1.00 m during the Iron Age and around 0.90 m during the Roman Period. Furthermore, the width of partitions in the clay district of Groningen is generally higher than in the sandy areas of Drenthe. Waterbolk attributed

this to better grazing conditions on the fertile clay soils than on the acid heather soils.

For the Iron Age farmsteads on Voorne-Putten, I also established the average widths of the bays. The values range from 1.50 m in Rotterdam-Hartelkanaal to 1.80 m in Spijkenisse 17-34 and apparently housed two head of cattle. Seeing the absence of unambiguous bone remains of goats, it can safely be assumed that the bays mainly served for housing cattle. The width of the partitions per cow (0.75-0.90 m) is smallish in comparison with Waterbolk's measurements. Seemingly, cattle were small on Voorne-Putten during the Iron Age. Prummel calculated a height at the withers between 1.07 and 1.15 m for the material of Voorne-Putten.

The dominance of cattle could indicate that milk was an important element in the diet of the former inhabitants of Voorne-Putten. Sheep and goats could also have provided milk. For further investigations concerning this subject, Prummel determined the age of slaughter on the basis of jaws and epiphyses.

For cattle, only the Middle Iron Age material provided enough data (130 determinations) to produce reliable data. Circa 10% of the cattle died or were slaughtered in the first year, another 10% were between one and two years of age. The group from 2 to 3.5 years amounted to 20%, 25% were between 3.5 and 4.5 years old. The remaining 35% was older than 4.5 years. These data indicate that calves were only rarely eaten. Probably only some steer calves, which were not essential for maintaining of the herd, were slaughtered. Osteological indications for the presence of oxen have not been found. The low amount of cattle killed in the first year is an indirect indication for the use of oxen, since they apparently were not killed as younger animals. Since breeding, and thus milk production, in unimproved breeds of cattle does not occur before the age of 3.5 to 4 years (cf. Gregg 1988), relatively many animals were killed before this age. In Bronze Age Bovenkarspel, IJzereef (1981: 41) established that 64.7% of the cattle were slaughtered at an age of over four years. This high age at slaughter indicates the importance of milking on that site. Because of the earlier age at slaughter in the present material, the role of milk must not be over-emphasized for Voorne-Putten.

Prummel (1991) observed that the distribution of the identified remains of cattle over the skeleton is rather even. This indicates that complete carcasses were butchered on the sites and that no joints or partial carcasses were imported or exported. Any import or export will have occurred on the hoof.

Concerning sheep from the Middle Iron Age, Prummel observed that 35% were killed or died in the first year, ca. 25% in the second year and the remaining ca. 40% in the third and fourth year (on the basis of 39 determinations). The many sheep killed in the first year were probably mainly rams, not needed for breeding.

The pig remains only allowed age class determinations for all Iron Age material together, because of the low amounts per phase. Circa 10% of the pigs of all Iron Age periods were slaughtered in the first year, about 35% in the second and 55% after the second year. Probably, the sows could not breed before the second year, seeing the relatively advanced age at slaughter. On the other hand, as Gregg (1988) noted, pigs attain much of their body weight after the second summer.

In view of the age structures of the different domesticates and in view of the numbers of bays in the Iron Age farms, Prummel reconstructed hypothetical herds, for a farm of six and one of ten bays. She assumed that the bays were mainly filled with cattle. Prummel (1991) demonstrated that an even occurrence of cattle and sheep/pigs would definitely have been insufficient in the long run for the small farm. Besides, this does not fit in with the proportions of these species in the faunal remains. Prummel's reconstructed herds and the inferred numbers of slaughtered animals have been reproduced in table 32.

Prummel concluded that the slaughtering pattern for cattle was suitable for keeping up the livestock and for slaughtering some cattle for their own demand and probably also for exchange. The herds of sheep seems to have been stable, with probably some overproduction. She thus assumes that the ca. 100-200 grams of meat plus any milk produced exceeded the needs of the inhabitants of the farms themselves. Prummel, however, does not indicate the required daily amount of meat on which these statements were based. Furthermore, she does not explicitly state the caloric contents of the meat and milk and the role of vegetable

Table 32. Hypothetical livestock in a small and a large Iron Age farm on Voorne-Putten (after Prummel *in press*).

number of stalls	6	10
stalls for cattle or horse	5	8
stalls for sheep or pig	1	2
estimated number of animals:		
cattle	9	14
horses	1	2
sheep	2	4
pigs	1	2
yearly number of litter:		
calves	3-4	4-7
lambs	1-2	2-3
piglets	2	4
number of slaughtered animals per year:		
cattle	2-3	3-5
sheep	1	1-2
pigs	1	2
number of milk-producing animals:		
cows	3-4	4-5
ewes	1	2-4

foods. This gives these observations a provisional character. In the following chapter (*ch. 6*), these data will be included in a more general model concerning prehistoric food production and -consumption on Voorne-Putten.

5.2.2   WILD ANIMALS

Hunting, fowling and fishing only played a marginal part from a dietary point of view. Thus they have not been included in Prummel's calculations. Their role was probably to provide diversity. Besides, beaver, fox and otter will have been hunted primarily for their fur, although their meat may have been eaten.

Antlers from deer may have been collected, instead of having been taken from hunted animals. However, post-cranial skeletal elements from red deer (*Cervus elaphus*) have also been found, which is evidence of hunting. From roe deer (*Capreolus capreolus*) only antlers have been found, so they were not necessarily hunted.

Fowling was of minor importance, bird bones have been attested only sparsely. The grey heron (*Ardea cinerea*) and the mallard (*Anas platyrhynchos*) will have been present all the year round. The mute swan (*Cygnus olor*) was a rare winter visitor. Its presence indicates fowling in winter. All birds occur in watery environments, which will have been abundant on Voorne-Putten.

Fishing was probably more important, especially during the Late Iron Age, although the small number of data available does not justify any definite conclusions. Sturgeon (*Acipenser sturio*) was the most important fish species. The sturgeon swims up the rivers to its spawning grounds from May to the end of July and may have been caught in the Bernisse and its tributaries. The mullet also migrates into the estuaries in summer. According to Prummel, mullet was probably a by-product of sturgeon fishing.

5.3   The Roman Period

The data concerning the Roman Period, from Van Mensch' investigations, deviate to some extent. The leading role of cattle still exists, but sheep are increasingly important in the three sites concerned. The landscape changed in the period concerned from mainly peaty to an environment where clay deposits are more important. These deposits developed owing to increased marine influence. Reichstein (1975: 222) observed a dominance of sheep in Elisenhof, the site with the strongest marine influence of all the sites he investigated in northern Germany. This is reconstructed on the basis of the importance of obligate halophytic plants. According to Reichstein, sheep make lower demands upon their food quality than cattle, and as a result can feed on a vegetation rich in halophytes. Besides, Prummel (1979: 97-98) observed that liver-fluke does not occur in saline environments, because the intermediate host, a snail (*Galba truncatula*), cannot thrive under conditions of high salinity.

Unfortunately, the Roman sites which were subjected to Van Mensch' faunal studies are located on clayey soils, while the Iron Age sites in most cases were founded on peat. Thus it cannot be excluded that the increase in importance of sheep/goats is due to better preservation conditions on the Roman sites in comparison with those of the Iron Age. The relatively high share of pig bones may be the result of better preservation as well.

As has been indicated in paragraph 1.3.1.4, the plans of the excavated native Roman houses on Voorne-Putten do not show the characteristic bays that do occur in their Iron Age counterparts. Thus, the potential influence of the Roman occupation upon cattle size, as Waterbolk observed for the Roman influenced site of Wijster, cannot be assessed. Clason (1967: 103) demonstrated that the size of cattle diminished from Neolithic to Roman times and increased again in the Early and Late Middle Ages. The variation is largest during the Roman Period, probably as a result of the improved breeding methods of the Romans. Van Mensch could establish the height at the withers of cattle on one single bone. It proved to be ca. 1.18 m, which is relatively tall.

The absence of bays during the Roman Period is an important observation concerning the role of stock-breeding in these periods, as will be elaborated in the following chapter.

Comparison of the zoological data concerning the Roman Period with botanical evidence is hampered by the fact that no botanical investigations have been conducted in the years that the sites studied by Van Mensch were excavated. The sites which were investigated botanically produced only very few faunal remains. Rockanje only yielded one horse and a foal in a well (cf. Brinkkemper *et al. in press*). In Nieuwenhoorn hardly any bones were found. Moreover, these fauna remains have not yet been studied (Van Trierum *pers. comm.*).

6.1   Introduction

In the preceding chapters, the basic data on "ecological" investigations of Iron Age and Roman settlement sites on Voorne-Putten were presented. The interpretation of these data in relation to the location of the sites in the natural environment was discussed in the corresponding chapters. After these reconstructions of environments and related subjects, a major field has remained largely unexplored. This subject, the "palaeo-economy" (cf. Higgs 1975) will be elaborated upon in the present chapter. Although economy may be defined in a very broad sense, in the present study, palaeo-economy mainly focusses on the agricultural sector of the economy. Important fields in this study are amongst others the roles that stock raising and arable farming played and whether an autarkic subsistence economy or an economy involving surplus production and exchange was practised.

To provide a base for the reconstruction of agricultural economies of the sites under review, the following paragraphs supply basic data on crop plants and livestock which played a role in the economies of the sites. The data were obtained from ethnohistorical sources and experimental archaeology, as well as from models for prehistoric situations published by a range of researchers. Subsequently, these data will be elaborated upon in an attempt to draw up models for the agricultural economies of the sites investigated.

6.2   Characteristics of crop plants found in the present study

6.2.1   HULLED, FOUR-ROW BARLEY (*HORDEUM VULGARE SSP. VULGARE FO. TETRASTICHUM*)

Among the crop plants, barley and wheat (*Triticum* spec.) are the predominant cereals in the Iron Age. In the settlements near the coast of Voorne, dating from the Late Iron Age and Roman Period, barley is of even greater importance and it is virtually the only cereal found in Roman Rockanje.

According to Körber-Grohne (1987), four-row barley is mainly cultivated as a winter crop.

Barley is the least demanding cereal species as far as soil conditions are concerned (Körber-Grohne 1987: 46). In

medieval times, barley and rye were cultivated on artificially drained peaty soils in the western part of the Netherlands (Van der Linden 1956: 68). These soils are probably comparable to the peaty soils on Voorne-Putten. Thirsk (1965: 36) demonstrated that barley was the main crop on peaty soils in sixteenth century Fenlands in Britain, while wheat was of limited importance. Of special relevance is barley's tolerance to salinity. This is confirmed in laboratory experiments by Baykal (1979). He found that the wheat species he studied were more sensitive to salinity than barley, especially four-row barley. Bernstein (1958 cited in Baykal) also reported that a greater salt tolerance was evident in barley varieties compared to wheat varieties.

In salt marsh environments, experiments have been conducted by Körber-Grohne (1967) in Cappelersiel (northern Germany) and by Van Zeist *et al.* (1977) and Bottema *et al.* (1980) in Ulrum near Groningen (northern Netherlands). Both experiments showed that among the cereals, four-row barley is the only cereal that produced reasonable yields in these saline environments, but it could only be cultivated as a summercrop due to flooding in winter.

In Körber-Grohne's experiment, barley showed an input/yield ratio of 1:10. In the ten years' experiments in Groningen, the yield ratio ranged from zero to 1:13.2 (input 175 kg/ha sown in rows; Van Zeist *et al.* 1977). The highest yield corresponds to 2360 kg/ha.

Ripe grains consist for 61-73% of carbohydrates and for 9-12% of proteins. In cool and damp climates, less protein and more carbohydrates are produced than in warm and dry climates. The energy content of barley is 3180 kcal/kg.

6.2.2   WHEAT (*TRITICUM* SPEC.).

The genus wheat embraces several species that can be subdivided into naked and glume wheats, which can both be further divided into several species, each with a different number of chromosomes. In glume wheats, the grains are invested tightly by the lemmas and paleas and they cannot be separated by flailing, whereas naked, free-threshing wheats can.

Glume wheats are predominant in the present material, probably with emmer (*Triticum dicoccum*) being the only glume wheat cultivated (see *4.4.2*). Only one probable grain of the naked bread wheat (*Triticum* cf. *aestivum*) was found

in Rockanje. *Triticum dicoccum* was found on the Iron Age sites and -less frequently- in Roman contexts.

Renfrew (1973) mentioned that the majority of emmer varieties grown in Europe is winter-sown. Spring-sown varieties do also exist in Europe (cf. Percival 1921), but, according to Renfrew, the winter forms give heavier yields. Körber-Grohne (1987: 326), in contrast, stated that emmer is sensitive to frost and therefore is mostly cultivated as a summer crop in Germany. Hillman (1981) disclaimed emmer as a summer crop, arguing that wild emmer germinates in the autumn. He further pointed to higher yields in winter crops. In my opinion, the climate in which wild emmer can thrive is highly variable and therefore emmer does not necessarily have to be a winter crop in our regions.

Wheats are the most demanding cereal species in their cultivation as they need a humus-rich loamy soil and are very sensitive to salinity (Körber-Grohne 1987: 28). Renfrew (1973: 66) stated that wheat does not thrive well on loose sandy or peaty soils nor on wet clays, while it tends to lodge when grown in rich, damp bottom land. According to Enklaar (1850), spelt and bread wheat pose higher demands on soil quality than emmer.

The salt sensitivity of wheat species is clearly apparent in the experiments in the Groninger salt marsh. As Bottema *et al.* (1980) concluded neither bread wheat, nor spelt nor emmer were cultivated successfully in three years of trials. This salt sensitivity is also apparent in the laboratory experiments on bread wheat reported by Baykal (1979).

Concerning yields of emmer wheat, the experiments carried out by Reynolds on Butser Farm are of great relevance. The calcareous soil of Butser Farm was in use for pasture prior to the crop experiments. In present-day terms, it is not particularly suitable for arable farming (Reynolds 1987a). Although the soil differs from the soils on Voorne-Putten, it is the only long-term experiment published to date. Van der Veen (1989) started a comparative experiment of yields in locations dispersed all over Great-Britain, but data are not yet available.

In Reynolds' experiments, 61 kg/ha of seed grain was planted in rows at 30 cm intervals. According to him, planting in rows is much more economic than broadcast sowing, as a greater portion of the sowing grain is consumed by birds when the seeds are scattered. Steensberg (1955) stated that sowing in rows only required half the amount of seed as broadcast sowing. Furthermore, hoeing is possible between the rows, which is anything but superfluous because of the weeds.

Harsema (*pers. comm.*) commented upon the large amount of work required to sow more than a few ares (100 m²) of grain in rows. The following calculation may elucidate this point. In Butser Farm, the rows are at 30 cm intervals. In one ha (100 x 100 m), 333 rows of 100 m length each would have to be planted resulting in 33.3 km of rows

per ha. For the Iron Age, Reynolds (1987b: 29) assumed the use of a seed-furrow ard which forms a narrow drill for the seed in the prepared tilth. The Danish Hvorslev and Vebbestrup ards have been used successfully for this purpose on Butser Farm. However, the widespread use of this sophisticated type of ard is still to be substantiated in our area. If in broadcast sowing a strip of 5 m width is sown, the corresponding distance covered on foot would be 2 km per ha. These data are of importance in assessing the time budgets and limits for the prehistoric agricultural economy, which will be discussed in 6.6.4.2.

Reviewing eight years of yields without additional fertilization, Reynolds (1981b) found emmer yields of 400-3700 kg/ha, which corresponds to a yield ratio of 1:7 to 1:59. A steady decline, owing to exhaustion of the soil, could not be observed. Chemical analyses revealed only minor changes in soil structure and nutrient content. Emmer on plots manured with dung showed even higher yields, viz. 3200-4600 kg/ha or 1:51 to 1:74. Interestingly, Reynolds (1987a) demonstrated that modern bread wheat reached a much smaller yield in unfertilized plots, which is attributed to the greater nitrogen demand of modern cultivars. Körber-Grohne (1987: 42) also found that the more primitive crops emmer and einkorn showed higher thousand-grain weights if cultivated on "biological" fields, where no use is made of artificial fertilizers. In contrast, bread wheat, spelt and rye produced higher thousand-grain weights if fertilized with mineral nitrogen.

All things considered, the yields in Butser Farm never dropped below 1:7. Worth mentioning is that spring sown emmer does about as well as winter sown varieties (Reynolds 1987a). Reynolds also reported on a one year's trial on first class arable soil near Fishbourne. Here, the yield for (winter sown) emmer was 1:91 (ca. 5700 kg/ha).

Slicher van Bath (1987) provided data on often quoted yields in medieval times when the average fluctuated between 1:2 and 1:3. However, as he also observed (1987: 194-196), some farms did produce significantly higher yields. In northern France (Artois), the average yield in 2 × 9 years was about 1:10 in the 14th century, and never below 1:7.3. He attributed this to a more efficient organisation, these farmers sowed 141 litres per ha, where in other places 200 liters per ha were sown. He suggests that planting was probably done in rows, thus explaining the lower amount sown.

Of similar importance as the method of sowing is an observation put forward by Mercer (1981). According to him, the medieval yield data have often been questioned because they were used for purposes as rental, tithe and tax assessments. Farmers therefore had a reason to keep their official yields low. Kohl (1948: 114) lively illustrated the same practice for the 19th century. As shown in the minutes of the agricultural society of 1878, it was still common

practice among farmers to estimate yields far too low, knowing the positive influence on the taxes to be paid.

Reynolds' experiments indeed suggest that prehistoric wheat yields may be estimated higher than Slicher van Bath's data indicate. In view of Reynolds' data, and those from Artois in Slicher van Bath's publication, a yield of 1:7 in prehistoric times will be regarded as a lower limit.

According to Körber-Grohne (1987: 326), emmer grains consist for 55-61% of carbohydrates and for 15-21% of proteins. The protein content is considerably higher than the 10-13% of modern bread wheat. The calorific value of emmer is unknown to me, that of bread wheat is 3300 kcal/kg.

6.2.3   BROOMCORN MILLET (*PANICUM MILIACEUM*)

The last cereal species dealt with in the present study is millet. Its importance on Voorne-Putten is considerably less than that of barley and wheat, as it occurs on only one site, and in only one sample. Remarkably, *Panicum* occurs regularly on west European Iron Age and Roman sites outside Voorne-Putten (cf. Bakels 1991; Knörzer 1991).

Millet is very sensitive to frost and thus an obligate summer crop, sown in mid-May (see also Enklaar 1850).

Von Lengerke (1840 cited in Körber-Grohne 1987: 331) indicated that millet is the most appropriate crop for a sandy soil, as well as for peat. Columella stressed the importance of a humid soil to millet (Ahrens 1972: 84). Heresbach basing himself on classical authors, stated that *Panicum* favours a damp, marshy soil, while dry and calcareous soils are disliked (cf. Dreitzel 1970). Unfortunately, these observations apply to the Mediterranean area, as do all other classical communications on agriculture. Bottema *et al.* (1980) concluded that millet cannot be grown in brackish surroundings. Data on yields of *Panicum miliaceum* are unknown to me.

Körber-Grohne (1987: 331) gave the following components of millet: 11-14% water, 68-72% carbohydrates, 10-11% proteins, 2-5% fat, 0.7-2.4% minerals and 0.6-2.1% fibres.

6.2.4   OATS (*AVENA SATIVA*)

It is highly questionable whether oats were cultivated on Voorne-Putten during the Iron Age and/or Roman Period. On the basis of flower bases, only *Avena fatua* has been attested with certainty. The twisted awn fragments most likely originated from this species too[1]. If oats did play a role in the economy of any of the sites, it must have been a very subordinate one.

Oats are sensitive to frost, so they are cultivated as a summer crop in western Europe.

In northern Germany, they are cultivated on heavy clay in the coastal area (Körber-Grohne 1987). Cultivation of oats

in the salt marsh area of northern Groningen was relatively successfull.

6.2.5   LINSEED OR FLAX (*LINUM USITATISSIMUM*)

The remains of linseed/flax found in the present study suggest the use of the oil-rich seeds for consumption (see also *4.4.4*). Whether the stems were also used for flax-fibres could not be demonstrated. It is assumed that linseed was of nutritious value for the former inhabitants of Voorne-Putten.

Linum is usually cultivated as a summercrop, although a winter-sown variety exists as well (Körber-Grohne 1987: 367).

Linseed, cultivated for the oily seeds, favours warm, dry climates, whereas flax for fibres grows best in temperate, damp climates (Körber-Grohne 1987: 366-372). Although would this suggest a cultivation for fibres in western Europe, this is not corroborated as clearly in the archaeological record.

According to Renfrew (1973), *Linum* is best suited to fertile, deep, well-drained loams. Light soils are unsuited to seed flax, particularly in areas of deficient rainfall. Seegeler (1983) stated that the only soils unfit for linseed cultivation are dry sands, wet and compact clays, and marshy or very acid grounds (see also Gregg 1988: 78). Flax is reported to be a poor competitor with weeds. It is usually necessary to weed one to three times.

Seed yields can range to 800 or even more than 1000 kg/ha in unmechanized cultivation in Ethiopia (Seegeler 1983: 186). The experiments in the Groninger salt marsh revealed that flax can be cultivated with success in such environments, although the next oil crop to be discussed, *Camelina sativa*, produces even better results (Van Zeist *et al.* 1977; Bottema *et al.* 1980). In Ulrum, the yield ratio varied between zero and 1:14.5. The highest yield corresponds to 1175 kg/ha. In Cappelersiel, *Linum* yielded 1:3.9 in a plot with less storm flood damage.

According to Körber-Grohne, the seeds consist of 6-14% water, 22-44% oil, 17-31% proteins and 18-29% carbohydrates. The oil contains 17-31% of linoleic acid, an essential fatty acid. To use this valuable seed content, the seeds must be broken as the thick wall cannot be digested.

The calorific content of *Linum* is unknown to me as well as to the Dutch *Instituut voor Levensmiddelentechnologie (Landbouw Universiteit Wageningen).*

6.2.6   GOLD OF PLEASURE (*CAMELINA SATIVA*)

Gold of pleasure is the second crop cultivated for its oily seeds. It is a summer crop which already can be harvested 12 to 14 weeks after sowing. This makes it an ideal substitute for frozen winter crops (Körber-Grohne 1987).

Camelina sativa does not pose high demands on soil quality, it can still be grown on dry, sandy soils, although it

favours a sandy, calcareous loam. Plessers *et al.* (1962) stated that although *Camelina* will grow on most soils, it is not recommended for heavy clay or peaty soils. An important characteristic of gold of pleasure is its tolerance for salinity.

As the experiments by Körber-Grohne (1967) and Van Zeist *et al.* (1977) showed, *Camelina* is the crop most resistant to salt, producing yield-ratios of 1:13 to 1:20 in Cappelersiel. In northern Groningen, the ratios were between 1:25.5 and 1:57.5, which corresponds to 690-1555 kg/ha. During two years with extensive flooding during the seedling stage, all the crops, including *Camelina*, failed in Ulrum.

The seeds consist of ca. 27% oil, 17% proteins and 17% carbohydrates (Körber-Grohne 1987: 391). According to Plessers *et al.* (1962), ca. 91% of the fatty acids in *Camelina* is unsaturated and among other things consist of 16.4% linoleic acid. The calorific content of gold of pleasure seeds is unknown to me and the Dutch *Instituut voor Levensmiddelentechnologie (Landbouw Universiteit Wageningen)*.

6.2.7 RAPE (*BRASSICA RAPA*)

Rape is the last potential oil seed crop found in the present study. It is mainly present in the Early Iron Age site of Spijkenisse 17-30. Collection of the seeds from wild plants cannot completely be ruled out. Rape is normally grown as a winter crop (Körber-Grohne 1987: 162)

According to Körber-Grohne (1987), rape can be cultivated on poor, light soils. It is also more or less salt tolerant. Bottema *et al.* (1980) showed that *Brassica rapa* has a reasonable yield as a summer crop in the salt marsh environment, up to 1:28.3, corresponding to 805 kg/ha.

According to Körber-Grohne (1987: 149), rape seeds consist of 32-50% oil, 16-27% proteins and ca. 23% carbohydrates. According to Plessers *et al.* (1962), the fatty acids consist for 97% of unsaturated fatty acids, among which ca. 15% is linoleic acid. The calorific content of the oil is ca. 9000 kcal/kg (*Voorlichtingsbureau voor de Voeding* 1980).

6.2.8 CELTIC BEANS (*VICIA FABA* VAR. *MINOR*)

Seeds of Celtic bean were only discovered in some samples from the native Roman settlement Nieuwenhoorn.

The plants are more frost-tolerant than most other cultivated leguminous crops, but they freeze at temperatures below -4°C. They require humid conditions, so they are sown early in spring (February-March).

Körber-Grohne (1987 citing Fruwirth 1921) further stated that heavy clayey or peaty soils are best suited for the cultivation of Celtic beans. Calcareous or sandy soils are only suitable if the precipitation is sufficiently high.

The experiments in Cappelersiel and Ulrum have demonstrated Celtic beans growing successfully in most years at the salinity conditions prevailing there. In years in which the crop was flooded in an early stage of development, no yield

could be obtained in Ulrum. In more favourable years, the yield could reach 1:16.5, corresponding to 4240 kg/ha (Bottema *et al.* 1980). According to Enklaar (1850), in less extreme situations Celtic beans yielded 1:16.7 to 1:32 if planted in rows, broadcast sowing in contrast almost halved the yields.

According to Körber-Grohne, ripe seeds of Celtic bean consist among other things of 25.3% proteins, 48.3% carbohydrates and 1.7% fat. According to the *Voorlichtingsbureau voor de Voeding* (1980), fresh (unripe) Celtic beans contain 360 kcal/kg, whereas dried beans (*Phasaeolus*) contain 2700 kcal/kg. The calorific content of ripe Celtic beans may also be this high.

6.3   Characteristics of livestock

For the review on livestock, three publications were mainly consulted. Prummel (*in press*) discussed the bone remains of Iron Age sites on Voorne-Putten (see further *ch. 5*). IJzereef (1981) published data on the basis of his investigation on Bronze Age animal bones found in Bovenkarspel, in the northwestern part of the Netherlands. Gregg (1988) published data gathered from a wide range of references of relevance to the neolithic situation modelled by her. It should be noted that the sizes of domesticates changed through prehistoric and historic times; Neolithic cattle is larger than Bronze Age cattle, which is in turn somewhat larger than that of the Iron Age (Clason 1967). IJzereef's and Gregg's data should thus be treated with caution.

6.3.1   CATTLE (*BOS TAURUS*)

Cattle provide a potential source of meat, milk and leather, they can be used as traction units and the bones can be made into implements. According to Van Wijngaarden-Bakker (1988), cattle is reasonably well adapted to damp soil conditions.

Characteristics of the life cycle of cattle have been provided by Gregg (1988). Weaning takes place after ca. 200 days and heifers of unimproved breeds of cattle normally calve when they are 3.5 to 4 years old. Gregg further stated that although cattle do not have a specific breeding season, a calving season can be created by allowing bulls access to cows only for a restricted period. According to her, there are particular advantages to a late winter/early spring calving season. The cows are stalled over winter, so they can be watched and may be helped in calving if necessary. Besides, cows provide more and better milk on spring and summer pastures than on autumn pastures and winter fodder. Thirdly, spring calves will be weaned by the start of winter, with a high body weight, so well-prepared to withstand the winter.

According to Gregg's references, 80% of the mature cows calve and, of the calves born, 20% do not survive to weaning. IJzereef (1981: 37) assumed that 30% of the cows

do not give birth or give birth to a calf that dies in infancy, while Gregg's data correspond to a figure of 36%.

Prummel (*in press*) assumed a meat supply of 100 kg for mature Iron Age cattle, which corresponds to a live weight of ca. 200 kg. IJzereef determined live weights of Bronze Age cattle with the aid of several extrapolations from bone weights. He concluded an average of ca. 200 kg for adult cattle, and ca. 100 kg for 2-3 year old heifers. Reichstein (1984) assumed a live weight of 150-250 kg for cattle in northern Germany during the Iron Age and Roman Period. Since slaughter of younger animals did play an important role in the investigated sites (see *ch. 5*), IJzereef's data are the most appropriate as he provided data for several age-classes. His data are more or less applicable to the situation on Voorne-Putten, in view of the similar estimated weights for adult cattle.

IJzereef (1981) assumed that the amount of usable meat is 30% in adults and 40% in calves. In addition adults yield 20% fat. For 1-3 year old cattle, the fat yield amounts to 15% and for 0-1 year old individuals to 10%. Furthermore, IJzereef also assumed an additional 10% of the live weight for blood, organs, brains, intestines and bone marrow. IJzereef took the calorific value of meat to be 1430 kcal/kg for calves and 1970 kcal/kg for adult cattle. He assumed a calorific value for fat of 8000 kcal/kg, the 10% "rest" is estimated at 2000 kcal/kg.

If IJzereef's data are used to calculate the energy provided by an adult head of cattle (of 200 kg!), 60 kg of meat (1970 kcal/kg), 40 kg fat (8000 kcal/kg) and 20 kg organs (2000 kcal/kg) result in 478,200 kcal. According to IJzereef's data, a 1-3 year old head of cattle (heifer) weighs 80 kg, of which 35% is meat (1700 kcal/kg), 15% is fat (8000 kcal/kg) and 10% forms the remaining edible component (2000 kcal/kg). The total calorific output thus is 159,600 kcal. According to Gross *et al.* (1990), the protein content of beef is 168 g/kg. The protein content of veal is 200 g/kg (*Voorlichtingsbureau voor de Voeding* 1980). The proteins provided by one adult head of cattle amount to 16.8 kg and by a heifer to 5.6 kg.

Prummel (*in press*) assumed a yearly milk production of 100 kg per cow as an average for all cows. Haarnagel (1979) assumed that the surplus of milk was 600 kg/year during the Roman Period. He based this assumption on recent data from Balkan cattle that are also small and living under comparable environmental conditions. The above shows that milk production is difficult to quantify. Prummel's data will be used here to obtain a minimum value. IJzereef and Gross *et al.* (1990) set the energy content of milk at 600 kcal/kg. The protein content of milk is 30 g/kg (Gross *et al.* 1990).

Van Wijngaarden-Bakker (1988) noted that cattle primarily have a grazing strategy of feeding, which implies that they need food with a high nutritional value, mainly grasses. They are specialised in digesting unlignified cell walls, in contrast to browsers such as goats, which can digest woody

tissues. Of great interest in relation to cattle is the research in the Dutch "*Oostvaardersplassen*" by Drost (1986). The vegetation of this area predominantly consists of reedlands, with small patches of more grassy terrain with *Poa trivialis*. Ruderal areas with nettle (*Urtica dioica*) and thistle (*Cirsium arvense*) and shrubs occur. Drost's investigations demonstrated that grasses are the main food suppliers in spring and autumn, while reed (*Phragmites australis*) is the main food in summer. After the end of December, the cattle has to get additional food, since they appear not to eat dead reed. They can only eat twigs then which do not provide enough energy.

Interestingly, Drost (1986: 28) observed that cattle grazing in reedlands caused an increase in plants of ruderal situations. In particular these plants are of important nutritious value in autumn, when reed cannot be digested by cows any longer.

Gregg (1988) provided details on winter fodder requirements for domesticates, on the basis of observations on recent animals. She stated that the share of straw in winter fodder may not exceed 40% of the diet. Barley straw, however, may constitute ca. 80% of the fodder of present-day beef cows (Reynolds *pers. comm.*). Straw was not found in the byres of the excavated farms on Voorne-Putten during the Iron Age and Roman Period. Thus, straw was not used as winter fodder for the stalled animals on such a scale that we still find traces. Instead, reed stems (*Phragmites australis*) occur abundantly. Most probably, the reed was not only used for litter but also for food. Drost (1986) demonstrated that reed may indeed serve as food for cattle, but the dead winter stems are not palatable. During July to September, the calorific value of reed stems is even higher than that of other grasses.

The fact that seeds of plants that decay easily in autumn (e.g. *Lychnis, Lythrum*) are very commonly associated with the reed stems found in the material from Voorne-Putten indicates that they were harvested before the winter. Twigs do not occur on any appreciable scale in the layers of dung in the byres of the excavated farms. Apparently, leaf hay was not used extensively for fodder, which is not surprizing in view of the scarcity of trees around the settlements. Green, dried reed with many other herbaceous plants will have formed the dominant part of the winter fodder on Voorne-Putten.

Gregg quoted a requirement of 400 kg of hay per head of cattle per month in a recent Alpine village, Reynolds (1987b) suggested 450 kg. Gregg's Neolithic cows were assumed to weigh 400 kg, whereas Prummel, IJzereef and Reichstein arrive at ca. 200 kg for Iron Age cattle. Reduction of the requirements proportionally, would produce figures of 200-225 kg of hay per adult head of Iron Age and Roman cattle per month. It is assumed here that this hay requirement was mainly fulfilled by dried reed mixed with

forbs. The animals will have been stalled for four months of the year at maximum, so 800-900 kg of reed is required per head of cattle. Shorter stalling-periods can be imagined as well, it could even be defended that the byres were only used when the fields were covered by snow. The hay requirements would be less. The amount of hay needed for four months will be the basis of the calculations in this chapter. If the farmers could harvest a four months' hay requirement, a smaller requirement would definitely have been manageable.

Slicher van Bath (1987: 325) stated that an adult cow requires 1.5 ha for summer- and winterfodder if grazing occurs exclusively on grassland. IJzereef assumed 1 ha for Bronze Age cattle, Fokkens (1991) based himself on other references and also arrived at 1 ha per year and the same area for two calves per year. According to Drost, four to ten heifers could graze on 20 ha of reedland. This figure (2-5 ha per animal) is used here for the adult Iron Age cattle (with comparable weight). In the eight months that cattle were not stalled, they probably required 8/12 of 2-5 ha = 1.3-3.3 ha per head. In salt marsh conditions, one adult head of cattle can graze on 1 ha during six months (Ooster-veld *pers. comm.*). The smaller Iron Age cattle may have required 1 ha of salt marsh per head per year. Again, these low numbers of cattle per area will be used here to explore potential limits for the economy, in this case in land requirements.

6.3.2   Sheep and goats (*OVIS ARIES* and *CAPRA HIRCUS*)

Sheep and goats are difficult to distinguish in palaeozoological studies (see *5.2.1*). Prummel's data suggest that probably only sheep occurred, at least in the Iron Age, on Voorne-Putten. On the other hand, the droppings in the native Roman settlement Nieuwenhoorn 09-89 contained *Myrica gale* remains. For the Iron Age site of Assendelft Q, droppings containing *Myrica* have been conceived as evidence for goat, since sheep strongly dislikes the bitter taste of bog myrtle (see *5.2.1*). The identifiable sheep/goat bones in Assendelft all belonged to sheep (Van Wijngaarden-Bakker 1988), as on Voorne-Putten. The latter author suggested that this discrepancy between botanical and zoological evidence could be explained by assuming that the goats were primarily kept for their milk production. This would result in few animals being slaughtered. The use of goats mainly for their skin, which is very easy to work up (Groen-man-van Waateringe *pers. comm.*), may also explain the absence of bones in the farms themselves. Besides, Van Wijngaarden-Bakker (1988: 161) also stressed the sensitivity of goats to coldness. This will also have necessitated the indoor housing of goats, which was much less urgent for sheep. IJzereef (1981) also assumed that sheep were only rarely to be found in byres.

Sheep and goats may have provided the inhabitants of

Voorne-Putten with meat, milk, wool (or hair), fleeces and bones. As for cattle, Gregg (1988) reviewed characteristics of sheep and goats. In temperate regions, the breeding season of caprovids, which is controlled by photoperiodicity, occurs primarily in September/October. The age of first parturition is normally at two years. Ewes and does can be expected to bear young for up to eight years. Gestation lasts for five months, lambing and kidding normally takes place in February or March. Does frequently bear twins, ewes usually have single births.

According to Van Wijngaarden-Bakker (1988), sheep are grazers and goats are browsers. According to Reynolds (1987b), however, the primitive sheep of Soay in Butser Farm prefer browsing leaves to eating grass.

Van Wijngaarden-Bakker further stated that sheep are reasonably well adapted to damp soils. However, the liver-fluke mainly occurs in damp environments, so dry (or saline) places are much more favourable to sheep. Goats are highly sensitive to damp conditions.

IJzereef assumed the meat weight to be 30% of the live weight. He estimated live weights from the bone weights of his Bronze Age material. For sheep, he arrived at a weight of 20-34 kg, with an average of 27.4 kg. One goat meta-tarsus corresponded to an animal with a live weight of 33.3 kg. In modelling Bronze Age economy, IJzereef sub-sequently assumed a live weight of 30 kg for both sheep and goats. Reichstein (1984) assumed a live weight of 30-50 kg for sheep in northern Germany during the Iron Age and Roman Period. Prummel (*in press*) calculated with a meat supply of 20 kg for adult sheep.

IJzereef assumed 2930 kcal/kg for both sheep and goat meat. Apart from meat, IJzereef also included fat in his calculations; for sheep/goats fat is set at two-thirds of the meat weight, with a calorific value of 6000 kcal/kg. IJzereef estimated all the other edible components at 10% of the body weight, with 2000 kcal/kg. Thus a sheep/goat of 30 kg yields 9 kg of meat (2930 kcal/kg), 6 kg of fat (6000 kcal/kg) and 3 kg of other edible components (2000 kcal/kg). The total amount of calories thus is 68,370 per slaughtered sheep/goat. It is assumed here that a lamb yields 30% of the calories of an adult, as in cows. Thus, one lamb yields 20,500 kcal. The proteins amount to 190 g/kg for lamb, so one lamb yields 0.5 kg of proteins.

According to Gregg, the lactation for unimproved breeds is ca. 135 days for sheep and ca. 210 days for goats. An average daily production of 0.33 l for sheep and 0.38 l for goats (during the lactation period) is based on data from sheep of 40 kg and goats of 35 kg. Gregg assumed that milk productivity varies in proportion to body weight. If IJzereef's 30 kg is assumed, the yearly milk production totals 34 l for sheep and 69 l for goats. The lesser produc-tion of milk by sheep is partly offset by the calorific content; sheep milk contains ca. 1000 kcal/kg, goat milk only ca. 700

kcal/kg. Prummel assumed a milk production of 50 litres for Iron Age sheep.

The grazing and fodder requirements for three mature sheep or goats is equal to that of one present-day cow (Oosterveld *pers. comm.*). The live weights of sheep and goats do not differ strongly between Neolithic and Iron Age or Roman individuals. In view of the fact that sheep most probably were kept outside throughout the winter, the requirements per head may have been 0.7-1.7 ha for grazing. Sheep probably could not graze in wet, natural reedlands surrounding the farms. When cattle, which are rough grazers, graze in such reedlands, vegetation becomes more suitable for grazing by sheep, which are fine grazers. This situation is directly comparable to the situation in the Serengeti in Africa. The migration routes of the fine grazers, in this case gazelles follow that of rough grazers (zebras).

In salt marsh environments, three sheep require 1 ha for six months of grazing (Oosterveld *pers. comm.*).

Since sheep can winter outside, their role in the diet is difficult to assess. The subordinate role of sheep/goat bones relative to those of cattle, however, indicates their smaller dietary importance.

6.3.3   PIGS (SUS DOMESTICUS)
Although pigs in contrast to cattle and caprovids do not provide the renewable resource of milk, they have another value as well as providing pork. As Gregg stated, by consuming rotting vegetables, crop wastes, stable scraps and carrion as well as human and animal excrements, pigs provide some means of controlling refuse in settlements. That they convert this debris into pork is an added bonus (Gregg 1988: 118). Due to their high reproductive rate, pigs are a very elastic resource, in times of shortage many pigs may be slaughtered, whereas in years of plenty, slaughtering may have been much less.

The following data for pig's a life cycle have been provided by Gregg. Breeding mainly occurs in late October to early November, farrowing is in early spring. A litter size of five or six is the norm. Sows usually farrow for the first time when they are one year old and they can continue to breed for another six years. IJzereef (1981) also assumed a litter size of six, but Prummel (*in press*) based her calculations for Iron Age pigs on a litter size of only two. The low share of pig bones indicates its small importance, and this low estimate will be followed here. It cannot be excluded that more piglets were slaughtered than is suggested by the faunal remains, as their less calcified bones may decompose more easily. The estimates published by Prummel thus provide minimum values.

According to Van Wijngaarden-Bakker (1988), the pig is very well adapted to damp soil conditions.

Pigs attain much of their body weight after the second summer. The weight of mature Neolithic pigs is assumed to be 30 kg (Gregg 1988). A significantly higher weight is estimated by IJzereef for Bronze Age pigs, viz. 75 kg. He assumed a meat yield of 30% of the live weight, i.e. 22.5 kg. Prummel (*in press*) based her calculations on a meat yield of 20 kg for adult pigs and 10 kg for piglets. Reichstein (1984) assumed a live weight of 40-60 kg for mature pigs during the Iron Age and Roman Period.

According to Gregg, the energy content of pork is 2450 kcal/kg, IJzereef assumed 2800 kcal/kg. IJzereef further assumed a fat yield as high as the meat yield, with an energy content of 6000 kcal/kg. Other edible parts in pig are supposed by him to amount to 20% of the live weight with 2000 kcal/kg. Thus an adult pig according to IJzereef yields 22.5 kg of meat (2800 kcal/kg), 22.5 kg of fat (6000 kcal/kg) and 15 kg of other edible components (2000 kcal/kg), totalling 228,000 kcal. Gregg's data suggest a total energy yield of only 36,750 kcal (16% of IJzereef's pigs). Gregg's data seem too low and IJzereef's data will be used here. Unfortunately, IJzereef does not provide data for piglets, which according to Prummel (*in press*) constituted ten percent of the slaughtered pigs on the sites on Voorne-Putten. In the present study, a live weight of 20 kg is assumed, and a meat yield of 40% (analogous to calves), with 72.5% of the calorific value of adult meat, as in IJzereef's cattle, i.e. 2000 kcal/kg. Thus, meat provides 16,000 kcal per piglet. IJzereef assumed that calves provide half the fat yield of adult cattle, for piglets this would correspond to 15% of the body weight, with an energetic value of 6000 kcal/kg. This results in a fat yield per piglet of 18,000 kcal. The remaining edible components may be set at 20% as in adult pigs. With an energy content of 2000 kcal/kg, this yields another 8000 kcal. Thus, one piglet may be equivalent to an energy supply of 42,000 kcal.

The pigs most likely did not need straw/reed or hay on a large scale as they will usually have been fed domestic waste.

The above-mentioned data are necessary for calculating the total area of land required by the inhabitants on Voorne-Putten during the Iron Age and the Roman Period if the total food supply was obtained from the area itself. A comparison with the available area may subsequently give insight into the possibility of such a food supply. The area needed and the feasibility of these calculations will be included in the following paragraphs.

6.4   The evidence for the cultivation of crops on Voorne-Putten during the Iron Age and the Roman Period

6.4.1   THE LOCATION OF THE ARABLE FIELDS
The palynological investigations (see *ch. 2*) have revealed that relatively dry, mineral soils with riverbank forests (German: *Auenwälder*) were present along the Meuse. Clearings occurred in these forests during the Early Iron Age. Particularly oaks declined considerably. The analysis of

wood remains from the excavated sites on Voorne-Putten revealed that these oaks were not extensively used for building purposes (see *ch. 3*). For what reason could these clearings on the levees have occurred? The macroremains of the investigated sites offer clues to this problem. All are typical for summercrops, while weeds characteristic of wintercrops are completely absent. Although Groenman-van Waateringe (1979) claimed that wintercrop weeds do not occur before the Roman Period, later investigations have demonstrated these wintercrop weeds for the Iron Age. The exclusive occurrence of summercrop weeds seems to be limited to the coastal area. Wintercrop weeds occur very regularly in samples analysed from at least six Iron Age sites on Pleistocene soils (unpublished data obtained in the palaeo-botanical laboratory of the *Instituut voor Prehistorie, Leiden*). Thus, the exclusive occurrence of summercrop weeds on Voorne-Putten is rather significant. Cultivation of crops on the deforested levees along the Meuse may explain this exclusiveness of summercrop weeds. The flooding of the levees during winter, which will have been a normal occurrence, prevented the cultivation of wintercrops. Thus, only summercrops could be cultivated, and only summercrop weeds could develop. Bannink *et al.* (1974), however, observed that on rich clayey soils in the coastal area, no wintercrop weeds occur in winter-sown crops due to the richness of the soil (see also Van Haaster 1985). Therefore, the cultivation of wintercrops cannot be ruled out completely, but the import of crops from sandy Pleistocene soils can be excluded, as the associated wintercrop weeds would have been imported too.

Among the cultivated crops found on Voorne-Putten, wheat and barley are the main cereals, whereas linseed and gold of pleasure are important crops with oil-rich seeds. Leguminous crops, like pea and Celtic bean, have not been demonstrated for the Iron Age. This must probably be attributed to the very small possibility of these seeds becoming carbonized and the fast decomposition of the uncarbonized seeds (see further *4.4.7*).

The cultivation of crops on the levees along the Meuse has been made plausible above but any cultivation of crops on the peaty soils around the settlements must also be considered. An important question is whether some of the crops could be cultivated on the peaty soils which surrounded the farms, at least those of the Early and Middle Iron Age, or whether they would require the mineral soils such as found on the levees. On the basis of agricultural information (see *6.1*), the following deductions can be made about cultivation on peaty soils. The cultivation of barley on artificially drained peat during medieval times in the western part of the Netherlands demonstrates that growing of barley on peat cannot be excluded. The other important cereal, wheat, was not cultivated on drained peat in medieval times (see also Thirsk 1965: 36). The third cereal,

broomcorn millet, can be cultivated on peat. Most significantly, however, this cereal is only found in one sample from Spijkenisse 17-30.

The oil-rich seeds of linseed cannot be grown on marshy or very acid soils (Seegeler 1983). The peat around the sites thus probably was unsuitable for growing linseed. Gold of pleasure can be grown on most soils, but again peaty soils are not recommended (Plessers *et al.* 1962). Whether rapeseed can be cultivated on peaty soils is not certain. Thus, when these considerations are reviewed, it can be concluded that probably only barley and millet were suitable for cultivation on peat in the vicinity of the Early and Middle Iron Age sites.

During the Late Iron Age and the Roman Period, the environmental conditions differed to a considerable extent (see *1.2.1*). The presence of clayey sediments deposited during the Dunkirk I transgression phase will certainly have offered better opportunities for arable farming. Unfortunately, palynological data concerning these periods are virtually absent so that any environmental reconstruction for these periods on the basis of such data is impossible.

Shortly after deposition, the clay will have been saline. Desalination, however, may occur after the inundations ceased. In the Dutch Grevelingen, just south of Voorne-Putten, desalination took place after damming up of the area by dikes. Already within one year, desalination occurred locally, and after eight years, large parts of the area were desalinated (Buth 1984: 969). In the sixteenth century, desalination of salt marshes in the British coastal area of Lincolnshire took about ten years (Thirsk 1965: 14).

The sea maintained its influence in the coastal area near Rockanje. In this salt marsh environment, barley could have been cultivated, but emmer could not. Of oil crops, gold of pleasure is the one most suited for cultivation in salt marshes, while linseed may also be cultivated successfully.

Some caution is needed in extrapolating the present agricultural criteria to the past. It is possible that less than optimal soils were well-suited to former requirements. It would be safest to provide botanical evidence for the possible local cultivation of crops. Firstly, clues may be provided by the remains of the crops themselves, secondly, the weeds may also be indicative of the conditions on the arable soils.

Cereals and the remaining crops are treated separately here in the discussion of crop plants, in view of the different interpretations that may be drawn from these crops.

6.4.2   EVIDENCE FOR LOCAL CULTIVATION PROVIDED BY THE CEREAL REMAINS

On all the Iron Age sites in the present study, wheat has been demonstrated, while it occurs much less frequent in the native Roman settlements. Barley plays a major role on nearly all the sites, with Spijkenisse 17-30 as an important

exception. Chaff-remains always considerably outnumber the amount of grain kernels. This is not surprising, since kernels provide the edible product and chaff is the discarded waste. A review of the interpretation of the occurrence of grain kernels and chaff through the development of palaeo-ethno-botany is appropriate to estimate the occurrence of grain and chaff on its merits.

In early publications, the possibility of import of a veget-able crop into a (prehistoric) settlement site was not con-sidered. Grain species found on a site were presumed to have been cultivated by its inhabitants. Later, the occurrence of grains without chaff was seen as evidence that the grain might not have been grown locally (cf. Knörzer 1970 for barley). The chaff was seen as providing proof of local production. The occurrence of Cerealia pollen has also often been interpreted as proof of local cultivation (e.g. Grohne 1957b: 242; Behre 1983: 184; 2.4.1).

Körber-Grohne (1967) made a considerable contribution to the development of studies in the coastal area in her investigations of the Feddersen Wierde in the northern Ger-man salt marsh area. She did not accept the list of crop plants as given, but she explored the possibility of cultiv-ating them in an extant, similar environment. In doing so, she could demonstrate that barley, gold of pleasure and Celtic bean were indeed the crops most suited for cultivation in a salt marsh environment, and that it was not coincidence that they were the predominant species in her subfossil material.

Another landmark in the discussion on the cultivation of crop plants was reached by Hillman (1981) and G. Jones (1984). By analysing the products and by-products in recent processing of cereal crops in Turkey, Hillman could con-struct flow-diagrams of the different steps involved in crop-processing of glume wheats and of free-threshing cereals. G. Jones (1984) presented a flow-diagram for processing of free-threshing cereals in Greece. As Hillman noticed, there are few non-mechanized possibilities in processing a crop, both in the overall sequence as well as in operations. Thus, the use of ethnographic models for the interpretation of prehistoric finds seems justified.

On the basis of these diagrams, Hillman was able to draw valuable conclusions, also strongly influencing the inter-pretation of prehistoric finds of remains of cereals, especially those of glume wheats (see also Bakels 1985: 195).

The most important conclusion regarding prehistoric eco-nomies is the fact that in humid areas emmer grains are stored and transported when they are still enclosed by their glumes. The separation of grains and glumes (chaff) occurs at the final processing, which takes place meal-wise, just prior to consumption. One of the main advantages of this method of storage is that the grains are less susceptible to rotting.

The extrapolation of these recent observations to the pre-historic situation is supported by the find of grains with glumes of emmer in pre- and early historic granaries and silos, in the Netherlands for instance in native Roman Schagen-Muggenburg (Pals/ Troostheide cited in Pals et al. 1989) and in Iron Age Colmschate (Buurman 1986).

At first sight the grains found in silos in Colmschate appeared to be threshed completely as the glumes were absent. However, Buurman did find pairs of grains still attached to each other with their ventral sides, as in their position in glumes. By artificially carbonizing complete (recent) ears, including all chaff, she found that under cer-tain circumstances the chaff burnt to ashes and only the naked grains remained. Thus, it is risky to interpret a car-bonized amount of naked grains of glume wheats as being completely threshed[2].

Furthermore, Sigaut (1988) reasoned that the Portugese word Espigueiro and the German word Speicher both derived from the medieval latin spicarium, which would mean "granary for spikes". According to him, this suggests a wide distribution of grain storage in ears in Europe in early and medieval times. This would also apply to the Dutch equivalent spieker. Varro also described storage of hulled wheat (i.c. spelt) in its chaff (cf. Hooper 1936: 299). Another hint for the storage of glume wheats in spikelets is offered by Plinius, who described the sowing of spelt and emmer in the chaff (cf. Van der Poel 1960-61), which also requires such storage.

The important conclusion from this observation is that the occurrence of chaff of glume wheats on a particular site does not necessarily imply local cultivation, provided that Hillman's model is valid for the prehistoric situation. Ac-cording to his model, the only remains that do exclusively occur on production sites and are discarded during the first stages of crop processing, are cereal stems and larger stem fragments (see Hillman 1984). Theoretically, these would provide the unambiguous proof of local production. It seems illogical to assume that complete sheaves were traded in prehistoric times, when transport of large bulks will have provided logistic problems.

It is highly remarkable, however, that stems of cereals are very seldom found in archaeological material. Körber-Grohne (1967: 136) for instance stated that although the dwelling mound layers in Feddersen Wierde were thoroughly searched for cereal straw, only a few carbonized culm frag-ments could be found. Uncarbonized straw could not be attested at all, despite the excellent preservation of other waterlogged material. M. Jones (1985: 117) and Van der Veen (1991: 353) also observed that straw debris tends to occur in very low quantities in Iron Age assemblages from Britain. Similar observations are very common in palaeo-ethnobotanical literature.

In view of the frequent occurrence of reed stems (Phrag-mites australis) in the sites on Voorne-Putten, it is question-
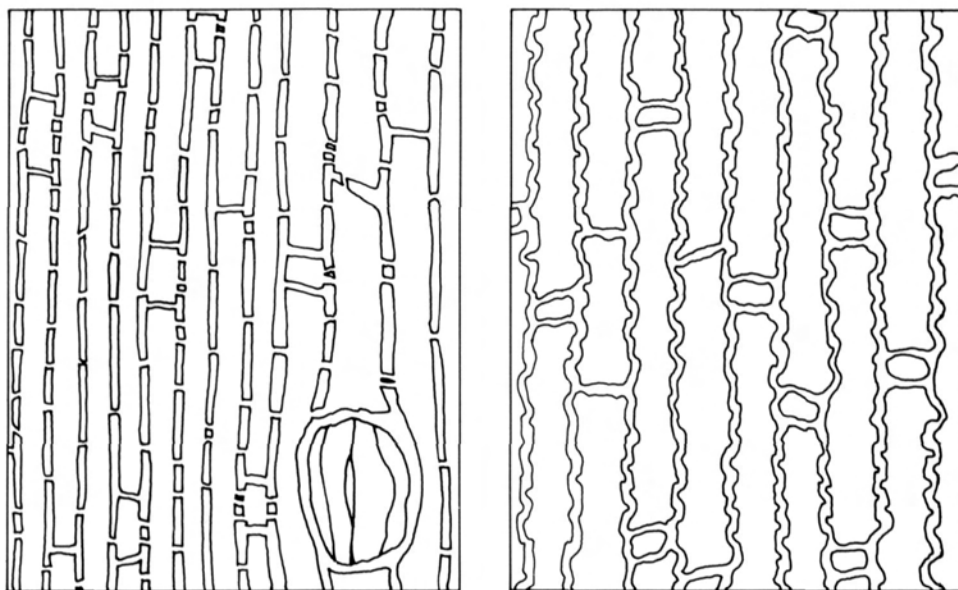
Fig. 60 Epidermis cell pattern of reed and cereals (ca. 600x).

able whether there is cereal straw present among these stems. According to Körber-Grohne (1967: 136) reed stems can be distinguished from those cereal stems by the presence of an adventive bud above the culm nodes, which is absent in cereals. To assure that this feature also applies to pre-historic cereals, I tried to find a second distinguishing characteristic. It appeared that the epidermis cell pattern (see *fig. 60*) strongly differed between recent specimens of these taxa (see also Brinkkemper 1991). According to this criterion, the subfossil stems with adventive buds did indeed belong to reed.

In the macroremains from Rockanje II and Spijkenisse 17-30, some grass stems were found among many stems belonging to reed, that did lack the adventive bud which characterizes *Phragmites*. The epidermes of these stems, however, appeared to have two short cells alternating with one long cell, which does neither occur in cereals nor in reed. The pattern is that of *Molinia* described by Grosse-Brauckmann (1972). Since it cannot be excluded that other grasses also have this epidermis pattern, the stems have been listed as *Molinia*-type. In conclusion, even in the few cases that the absence of the adventive bud points to cereal stems being involved, *it does not necessarily have to be cereal*.

Cereal stems have not been found in the present study, and the few finds reported elsewhere might belong to other grasses than cereals. Thus, the presence of cereal stems seems a most unreliable criterion to demonstrate local grain production. Most probably, the straw was not harvested at all (see *6.4.3*).

For the extrapolation of Hillman's data onto the pre- and protohistoric situation, still another point must be stressed

here. Botanical investigations have demonstrated that hulled cereals were not always transported in their chaff, at least not in the Roman world. This is clearly illustrated by the data obtained from a Roman grain ship found near Woerden (the Netherlands) by Pals and Hakbijl (*in press*). The cargo consisted of emmer wheat and the destination was most probably the nearby Roman military fort (*castellum Laurium*). The amount of chaff is only a fraction of a percent of the amount of grains. All the remains are water-logged, so carbonization cannot have caused the disappearance of the glumes. It is thought that transport occurred in the form of a completely processed crop, which saves up to 20% of the space needed by emmer in glumes (see *6.6.3.2*).

The contents of a so-called *horreum* in the Roman *castellum Praetorium Agrippinae* near Valkenburg with bread (club-)wheat and hulled barley (Pals *et al.* 1989) and of a granary with the glume wheat spelt in the Roman *villa* near Voerendaal (Willems/ Kooistra 1988) both revealed almost pure grain with very few chaff remains. This once more is evidence of storage of completely threshed grain in a Roman military context, provided that the chaff did not disappear during carbonization. However, the finding of emmer, spelt and barley in their chaff in the Roman *castellum* of Valkenburg by Van Zeist (1970) illustrates that this storage method was also in use in *castella*.

Hillman's ethnographic model is not the only one that can be applied to trace production and import of cereals. M. Jones (1985) used archaeobotanical data to derive statements on production and "consumption". Since consumption also occurs on a grain producing site, I prefer to use the expression "import" instead of "consumption".

Jones studied the botanical macroremains from four sites along the Thames, where the glume wheats emmer and spelt also appeared to be the predominating cereals. Two sites were located on the drier second gravel terrace, on free-draining, reasonably fertile land well suited to cereal production. Two other sites were situated on the first gravel terrace, in a wet environment in which open pasture seems a key element. On the basis of the numbers of macroremains, Jones constructed triangular diagrams, in which he plotted the percentages of grain, chaff and weed seeds for each sample on the three axes. It appeared that samples with high percentages of grain all had come from the drier locations on the second terrace. On these sites, the percentage of grain very rarely dropped below 30%. In the samples from the sites on the first terrace, chaff and/or weed seeds attained high percentages, while grain remained below 50% on one site and below 15% on the other. Jones explained these differences as follows (Jones 1985: 120):

"The most likely place for this unlikely event [the deposition of grain as debris] to occur is at its place of production. With further processing and transportation, the perceived unit value of the crop accrues, while its quantity at any single point lessens. The chance of the prime product itself being discarded into a fire consequently drops. A non-producer site receiving the harvest product through exchange is likely to allow only the waste material from any final processing to be discarded into the settlement fires".

Interestingly, clusters of pits (for grain storage?) occur on the sites on the second gravel terrace and not in those on the first, which instead show larger numbers of ditched enclosures (for control of animals?). Robinson (1981) demonstrated that beetle remains (Coleoptera) found on a site on the floodplain provided "overwhelming evidence for the importance of pasture". This floodplain is still closer to the river bed than the first terrace. Apparently, the inhabitants of one group of sites are mainly arable farmers and those from another group of sites pastoralists.

When Jones' model is confronted with the ethnographic data provided by Hillman, some discrepancies are significant. In Hillman's model, grain kernels occur as waste on "import" sites during several stages of crop processing. This contradicts with Jones' assumption that these kernels are mainly to be found on production sites. Furthermore, in Jones' model, weed seeds play a major role on consumption sites, whereas in Hillman's flow diagram they are also important on the production side. As far as the first point is concerned, it can be remarked that Hillman's diagram does not provide quantitative information. The absolute numbers of grains discarded on both sides of the transportation phase may differ considerably, which theoretically may result in high percentages of discarded grain on production sites. A weak point in Jones' model, in my opinion, is the lumping together of all the non-cereal remains as "weed seeds". As a result, the percentages of grains (and chaff) are

reduced by species that are not connected with the cultivation or import of crops.

In conclusion, Hillman's crop processing diagram for glume wheats cannot be applied to demonstrate production of glume wheats in every case where the straw was not harvested. It is also regrettable that this diagram does not provide quantitative information. Jones' model does provide such quantitative data, but the subordinate role of weed seeds on production sites is in strong contrast to Hillman's observations, and the indiscriminate use of all weed species, irrespective of their ecology, is debatable. On sites such as those described by Jones, where only carbonized material has survived, the use of all the weeds may not be of too great an influence. On wetland sites, however, weed species which are not arable weeds are much more important. This can be explained by the fact that their chances of carbonization are relatively low. Furthermore, Jones' production and "consumption" sites are in fact both ends of a continuum, from surplus production through self-support and import of part of the crops needed to complete import. This is also put forward by Van der Veen (1987), who constructed a triangular diagram based on macroremains of the British Iron Age settlement at Thorpe Thewles. This diagram is intermediate between Jones' two types of diagrams, possibly indicative of a self-supporting cereal production. Van der Veen (1991: 357) suggested four broad categories: subsistence production, production for a surplus, small consumer sites and large urban complexes, which also are arbitrary levels in a continuum.

Both Hillman's and M. Jones' models discussed above apply to glume wheat species. This is only one of the two major cereal crops found on Voorne-Putten, the other one being hulled barley. Notably, G. Jones (1984) and Hillman (1981, 1984) conceive hulled barley as a free-threshing cereal. In free-threshing cereals, storage does not take place before grains and rachis internodes have been separated, which can simply be achieved by threshing and winnowing. In Hillman's (1981) model for free-threshing cereals, the paleas and lemmas ("hulls" according to G. Jones *pers. comm.*) still have to be removed. This removal is mostly done with loosely-set rotary-querns or by pounding. However, in contrast to the situation in glume wheats in humid climates, storage takes place after separation of the rachis internodes (and straw) from the grains plus hulls by flailing and winnowing. According to this model for free-threshing cereals, the occurrence of rachis internodes of barley is restricted to production sites, just as those of the free-threshing bread wheat. This concurs with an important observation put forward by Behre (1983). In his comparison of the German medieval sites of Elisenhof (rural) and Haithabu (trade centre), he found that the ratio of rachis internodes to grains in hulled barley was 149.3% in Elisenhof and 0.24% in Haithabu. He attributed this difference to

local production in Elisenhof and import from farms outside in Haithabu. Knörzer (1970) found 98,000 grains and 61 internodes of barley in the Roman *castellum Novaesium*, which he interpreted as evidence for import too. It seems most likely that this applies to the prehistoric situation as well. The relatively simple methods of flailing and winnowing considerably reduced the volume and weight of any traded amount of hulled barley.

The remaining cereal crop found on Voorne-Putten, *Panicum* is stored in its chaff which is, however, easily lost after carbonization.

6.4.3   HARVESTING METHODS

Strictly following Hillman's models, the virtual absence of cereal straw in the samples studied seems to imply that all the archaeological sites investigated on Voorne-Putten are grain importing sites. However, the presence of straw fragments requires that part of the stems are harvested together with the grain ears. Such a harvesting method is obligatory in Hillman's model.

In this respect, the height at which the plant is cut is of relevance. This height can be reconstructed by means of the heights of cropweeds harvested together with the crop. In the present study, nearly all stenoecious crop weeds (with a narrow ecological amplitude) are tall species. Stenoecious summercrop weeds that remain close to the ground do exist. In the present study, only one specimen of these low weeds has been found, viz. one single seed of *Anagallis arvensis*. Besides, this seed occurred in a sample from Geervliet 17-55 in which *Camelina sativa* is a major component. Körber-Grohne (1967) found stems and roots of *Camelina* in the refuse layers in Feddersen Wierde (northern Germany), and so demonstrated convincingly that this crop was harvested by uprooting. Thus, the single *Anagallis* seed is likely to have come from a plant in a *Camelina* crop, and not in a cereal crop. Similarly, the occurrence of low-growing weeds on other sites, which has been interpreted as evidence for harvesting close to the ground (e.g. Körber-Grohne 1967; Knörzer 1971b) might (partly) have belonged to crops other than cereals. Behre (1983) for instance found much larger amounts of low-growing weeds in samples predominated by *Linum* than in remains of cereal crops. Willerding (1971) concluded that in the case of cereals, ears were harvested during the Neolithic, Bronze- and Iron Age, since the crop weeds mentioned in a range of publications are practically always tall species. Kroll (1987) did find low growing weed species in preserved Iron Age arable field soils on the island of Sylt (e.g. *Rumex acetosella* and *Spergula arvensis*). On the site connected with these fields, however, almost exclusively tall species were found, which is a clear example of the effect of the harvesting method on the selection of seeds that find their way to a settlement site.

For the harvesting method used on Voorne-Putten, an observation made by Reynolds (1981a) is of relevance. He indicated that in harvesting ears by hand-picking, the transitions from stem to internodes are not represented in the harvested material, whereas they are after harvesting with sickles, irrespective whether low or high on the straw. In the material from Voorne-Putten, only one such transition has been found in a carbonized state in Nieuwenhoorn (Roman Period). Uncarbonized transitions were not found, notwithstanding the fact that uncarbonized chaff is as common as carbonized. The single transition found is much less than might be expected if harvesting occurred with sickles. From this it can be concluded that harvesting by means of hand-picking was practised. Even today this is a widespread method of harvesting in poorly mechanized agricultural systems.

Harvesting by picking of ears may also account for the relatively low amount of crop weeds, which does not only occur on the present sites, but has also been observed by Dennell (1974) and Knörzer (1971a). Varro described this practice to save labour (cf. Hooper 1936: 287). This also implies that cereal straw cannot be expected to occur abundantly on the sites (see 6.4.2). In consequence, the absence of straw does not provide a reliable clue to local production or import of the cereals concerned.

Most probably the straw remained on the fields. One possibility is that it was ploughed into the soil (cf. Enklaar 1837), which would improve the texture, but the decomposition would withdraw nitrogen. This could have been overcome by burning the straw on the fields before ploughing. The use of an ard for ploughing might not have been sufficient to plough the straw into the soil. However, from the Middle Iron Age onwards, a mouldboard plough appears to have been used throughout the entire coastal region (Van Heeringen 1992: 319). With this implement the straw probably could be ploughed under. An alternative possibility is that the straw was fed to cattle or other domesticates directly on the arable fields (cf. Knörzer 1971a). Reynolds (1981b, 1987b) stated that the straw of prehistoric cereals is quite palatable to livestock. Spahr van der Hoek (1952) also mentioned the use of straw to feed cattle during the 18th century. This practice is still in use. Whether or not prehistoric straw could serve as fodder for cattle when still on the fields must remain uncertain. However, it would be a very efficient way of dunging.

A last possibility is that the straw was harvested separately from the ears, as is indirectly mentioned by the Roman author Varro. According to him, the straw should be cut within 30 days after the ears were cut (cf. Skydsgaard 1968: 53). In areas where reed was less abundant, straw could have been used for thatching. Slicher van Bath (1987: 207) also described a separate harvesting of the straw during medieval times, to be used for thatching. Straw could also have been used as winter fodder or as litter. However, straw

was not used on the sites dealt with here, as it would have been found among the botanical macroremains.

6.4.4   THE EVIDENCE FOR LOCAL CULTIVATION PROVIDED BY NON-CEREAL CROP REMAINS

In the present study, the most important crops next to cereals are linseed and gold of pleasure. Ethnographic studies of the processing of these crops for seeds are unknown to me. However, anyone separating seeds and chaff of *Linum* or *Camelina* for a reference collection will experience the great ease of this task. These crops are undoubtedly comparable to free-threshing, naked cereals.

Dewilde (1984) mentions that the oldest and most primitive method of freeing flax seeds from their capsules will have been by hitting well-dried and ripe seed capsules against a wall or a floor. In analogy to Hillman's and G. Jones' models (see above), it can be expected that bulk storage and transport occur in the stage of seeds. Therkorn *et al.* (1984: 32) found ca. 200 *Linum* seeds and no capsules or stems in the Iron Age site of Assendelft-Q. They concluded that linseed was imported occasionally for consumption. Only *Linum* is cultivated locally are capsule segments to be expected. Behre (1983) even goes one step further when he states that if linseed is traded, this would be as oil pressed from the seeds to facilitate transport.

In the case of *Camelina sativa* it may also be expected that local cultivation results in the presence of silicles on the site. *Camelina* has been found abundantly on site Q of the Assendelver Polders. In view of the numerous threshing remains, Therkorn *et al.* (1984) conclude that this crop was produced by the inhabitants of the site themselves. This site is situated on a (drained) raised bog. Apparently, *Camelina* could be grown in the surroundings of the site, whereas *Linum* could not.

The suggestion that *Camelina* may have been cultivated on peaty soils around Assendelft is of relevance for the Early and Middle Iron Age situation on Voorne-Putten. This crop could probably have been grown near the sites, although the actual cultivation of this crop does not confirm this suggestion. Agricultural experiments on peaty soils could demonstrate the reality of growing *Camelina* there.

Next to cereals and crops cultivated for their oil-rich seeds, leguminous crops form a third category. For all leguminous crops it is extremely difficult to assess their importance for the economy of a site as uncarbonized leguminous seeds are highly perishable and thus very rare (cf. Willerding 1971). Moreover, the chances of their seeds becoming carbonized are much smaller than in hulled cereals. Körber-Grohne and Kroll (1984) stated that even in the German coastal settlements where great amounts of waterlogged straw of Celtic beans occur, the carbonized seeds of this species are still rare. Behre (1983) concluded that *Vicia faba* was not cultivated locally by the inhabitants of Haithabu's

trade centre, seeing the absence of straw, roots and pods. The presence of straw, roots and pods is considered to point towards local production. However, the fact that no bean straw was found in the present study must not immediately be interpreted in the same sense. According to Van Zeist (1970: 164), pods or stems of Celtic bean have never been encountered in Dutch sites. It could be that bean straw is highly perishable. According to Behre (*pers. comm.*), however, the straw of Celtic bean is as resistant to decay as reed stems. The fact that bean straw was found in several German dwelling mounds may be due to deliberate collecting of this straw to be used as material to raise the level of the mound. On Voorne-Putten, the settlements were not raised as much as in the northern German salt marsh area so the need for heightening material may have been considerably lower. This may explain why bean straw was not transported to the sites. The threshing, by flailing or suchlike after drying of the plants, may very well have taken place on the fields, after which the seeds could simply be collected. Cattle may have been fed the nutritious bean straw directly on the arable fields.

6.5   Implications of the botanical investigations on the reconstruction of agricultural economies of the sites.

To be able to include both arable farming and stock breeding in one interpretative model, it is appropriate to review the results that were obtained through the analyses of botanical remains (pollen, wood and macroremains) from the sites on Voorne-Putten. This review is presented in the following paragraphs, table 33 provides a summary of the crop plants found in the various sites.

6.5.1   THE EARLY IRON AGE

Three Early Iron Age sites have yielded data about botanical macroremains. Rotterdam-Hartelkanaal 10-69 produced cereal imprints in pottery which were all identified as barley (*Hordeum vulgare*). Not a single crop plant, nor a crop weed could be attested in the refuse layers of this site. All plant remains belonged to species of reed vegetations, which presumably grew close to the site. Van Trierum (*in press*) furthermore observed that only a very thin refuse layer, with little domestic waste like sherds, had developed on this site. The poor durability of the alder wood used for building this house would not allow a long inhabitation.

In Spijkenisse 17-30, a remarkable set of crops was found. The cluster analysis based on these crop plants also showed this site to be different from all others (see *4.7.3*). *Brassica rapa* appeared to be numerous, but it cannot be ascertained whether this was a true crop plant or whether the seeds were gathered from wild plants. *Panicum miliaceum*, millet, was present exclusively on this site. Emmer (*Triticum dicoccum*) was also regularly found. Barley (*Hordeum vulgare*), gold of

Table 33. Frequency of crop plants on Voorne-Putten. * = impressions present.

site period	RH.10-69 E.I.A.	Sp.17-30 E.I.A.	Sp.17-35 E.I.A.	Sp.17-35 M.I.A.	Sp.17-34 M.I.A.	Gv.17-55 M.I.A.	Ab.17-22 L.I.A.	Zl.16-15 L.I.A.	Zl.17-27 L.I.A.	Ro.08-52 L.I.A.	Nh.09-89 R.P.	Rock. R.P.
Hordeum vulgare	—*	—	2/5	1/3	13/19	3/3	—	1/1	2/2	7/12	10/27	12/23
Triticum dicoccum	—	3/9	—	1/3	13/19	3/3	1/1	1/1	2/2	6/12	7/27	2/23
Panicum miliaceum	—	1/9	—	—	—	—	—	—	—	—	—	—
Linum usitatissimum	—	—	1/5	1/3	9/19	3/3	1/1	1/1	2/2	6/12	3/27	—
Camelina sativa	—	—	1/5	1/3	1/19	3/3*	1/1	—	2/2	3/12	1/27	—
Brassica rapa	—	8/9	—	2/3	4/19	1/3	1/1	—	2/2	—	—	—
Vicia faba	—	—	—	—	—	—	—	—	—	—	4/27	—

pleasure (*Camelina sativa*) and linseed (*Linum usitatissimum*) are conspicuous by their absence. Stenoecious crop weeds are completely absent on this site. Moreover, cereal chaff is scarcely represented on this site (see *4.6.3*).

The Early Iron Age samples from Spijkenisse 17-35 did reveal low amounts of barley, linseed and gold of pleasure. Wheats are absent in the Early Iron Age samples from this site. The sparse presence of barley internodes and *Linum* capsules may demonstrate the cultivation of these crops by the inhabitants of Spijkenisse 17-35. This site is the only Early Iron Age site where stenoecious crop weeds could be demonstrated, despite the fact that in the case of Spijkenisse 17-30 more samples were analysed which also yielded more crop plant remains, even if *Brassica rapa* is excluded.

Palynological data could only be obtained from Spijkenisse 17-30. Peat apparently grew here through to the Middle Iron Age. Despite the fact that the pollen section was situated 6 m outside the wall of the farm, not one single pollen grain of a crop plant could be found. The threshing of cereals in quantity normally produces a considerable contribution of Cerealia-type pollen to the local pollen rain. Particularly grains of emmer wheat can be identified with relatively great certainty as belonging to Cerealia-type. This does not apply to barley, since the *Hordeum*-type includes a whole range of wild, especially coastal, grasses. None the less, the emmer wheat found in the macroremains of Spijkenisse 17-30 could not be attested in the pollen spectra, which according to the ^{14}C dates are synchronous with the habitation. One possible explanation may be that no peat formation occurred during the habitation. This would not be surprising, seeing the close distance of the pollen section to the house wall. Nevertheless, a standstill of one or two decades would produce an oxidation horizon in the peat. This could not be observed in the section. Furthermore, the regularity of the cumulative pollen influx curve and the good fit of the ^{14}C dates to this curve also are in sharp contrast with a standstill in peat formation. If it is indeed assumed that the peat formation continued during habitation of the site, it must be concluded that large scale threshing of cereals in the open air cannot have taken place in Spijkenisse 17-30.

At first sight, this observation seems to be in sharp contrast to the occurrence of emmer glume bases, which is the chaff discarded during crop processing. However, the previously discussed ethnographical investigation by Hillman (see 6.4.2) demonstrated that chaff of glume wheats also may occur on sites where import of these glume wheats occurred. The final processing of this crop also results in the separation of pollen grains. Their absence in Spijkenisse 17-30 can only be explained by small-scale, indoor processing of emmer.

To further explore the cultivation of emmer, the possible location of the arable fields must be reconstructed.

The palynological investigation revealed the presence of levees along the Meuse. During the Early and Middle Iron Age, the primary forest trees showed a considerable decline. These observations are explained by human intervention in the natural forest to produce arable fields. The absence of wintercrop weeds on the sites studied indicates that crops were most probably grown on these levees. The regular flooding of these levees in winter will have prevented the cultivation of wintercrops.

Groenman-van Waateringe (1979) stated that along coasts and riversides, where annual sedimentation of fertile soil took place, permanent cultivation without manuring or fallow was probably possible. Heresbach, describing the 16th century situation, also stated that regions that are regularly flooded by rivers may be cultivated permanently, without a fallow period (cf. Dreitzel 1970).

Whether the levees were farmed by the inhabitants of the sites near Spijkenisse themselves cannot be concluded from the botanical macroremains. If the inhabitants of Spijkenisse 17-30 had grown their own crops there, they would also have processed it. The first steps in crop processing might have occurred directly on the fields, after which transport (over water?) of semi-cleaned spikelets to the site may have taken place. Thus, the absence of Cerealia-pollen in the pollen section next to the farm does not necessarily attest that the crop was obtained from the inhabitants of other farms, viz. those on the levees.

Still, the location of arable fields at three to four km distance from the site has considerable implications. Firstly,

protection of the crops becomes problematic. Although the glume wheats are relatively resistant to predation by birds, deer species also occurred in the area (see *ch. 5*). With unprotected fields, they may have caused great damage to the crops. Besides, human beings might also have been interested in the crops.

Secondly, the excavated Iron Age farms have never revealed evidence of granaries accompanying the buildings. Storage pits can be excluded in the wet Holocene part of the Netherlands. This concurs with the fact that silos are restricted to the Pleistocene sand and löss soils (Roymans 1985). Thus, storage of crops can only have taken place inside the house. In the case of Spijkenisse 17-30, such a storage place might have existed in the central part of the building between the byre and the living quarters (Van Trierum *in press*). Kroll (1987: 53) described a 10 cm thick layer of carbonized grain in the byre area of a burnt down farmstead on Sylt (northern Germany), dating to the 3rd century AD. This indicates that the crop was stored in the house, most probably on a loft. Another observation of grain storage inside a house has been provided by one burnt-down farm on Feddersen Wierde, which also dates from the Roman Period (Haarnagel 1979: 119). However, the large scale excavations near Oss on the Pleistocene sandy soils along the Meuse did nearly always reveal some granaries accompanying Iron Age farms (K. Schinkel *pers. comm.*). Iron Age settlements on mineral soils in the coastal area often did reveal granaries as well (Van Heeringen 1992). These arguments seem to plead against a large-scale cereal production by the Early Iron Age inhabitants of Voorne-Putten.

However, Chisholm (1968: 48) observed that

"the average distance to the cultivated land is commonly of the order of one kilometre or more and very frequently rises to three or four".

It is impossible to judge this observation in view of the objections mentioned above.

The alternative to the model of cereal cultivation on fields at a relatively great distance is the following situation. The levees along the Meuse might also have been inhabited. The people living there grew crops on these levees and had a considerable over-production. This surplus is exchanged with the peat-dwellers, who specialized in rearing livestock. This model would predict the absence of relatively large byres with stalls in the farms on the levees, while the occurrence of granaries would be expected.

Unfortunately, the levees along the Meuse have been eroded and therefore these predictions cannot be tested on Voorne-Putten. However, of significance is the fact that on IJsselmonde and the Hoekse Waard, just upstream of Voorne-Putten, Iron Age traces were found on levees along smaller tributaries of the Meuse, which have not been

eroded (cf. Van Trierum *in press*). There, the model could be tested.

This model of exchange was introduced by Brandt and Van Gijn (1986) to explain the situation in the Assendelver Polders during the Iron Age. This area is highly comparable to Voorne-Putten as far as the Iron Age habitation is concerned. Some farmsteads were located in a peaty environment (e.g. site Q). In this area also some sites on relatively small levees accompanying creeks could be excavated. Indeed, most Iron Age and Roman farms found on these levees did not show traces of stalls (Brandt/Van Gijn 1986: 69).

The exchange-model was incorporated in a model explaining the sequence of events in the colonization of the Assendelver Polders by Brandt *et al.* (1984). The first step is thought to be occasional and seasonal visits of the area, mainly for reconnaissance trips and subsequently to provide a grazing territory for cattle. During these seasonal visits, the agricultural potential of the formerly uninhabited area could be assessed.

The following phase according to Brandt *et al.* is the foundation of permanent inhabitation, which still completely specialized in cattle breeding. For the supply of crop plants, an exchange with relatives living in drier areas is suggested. The last phase in this model is the return of a predominantly self-supporting, autarkic economy, with the cultivation of crop plants by the descendants of the colonists. Brandt *et al.* were of the opinion that desiccation of the peat owing to a transgression could trigger the above-mentioned sequence. Recovery of the peat growth may cause the termination of the occupation. The relation between natural conditions and habitation has been presented as a cyclic sequence by Brandt *et al.* (see *fig. 61*). It can be asked how much time is required for the total sequence. Brandt *et al.* do not indicate any time span thought to be involved in their model. They do state, however, (1984: 4) that the peaty area was drained adequately for c. 75 years during the Early Iron Age.

The pattern of this colonization in three steps compared to the data provided by Early Iron Age sites on Voorne-Putten shows many remarkable similarities. Voorne-Putten was uninhabited during the later part of the Bronze Age. The Early Iron Age inhabitants thus colonized the area. The
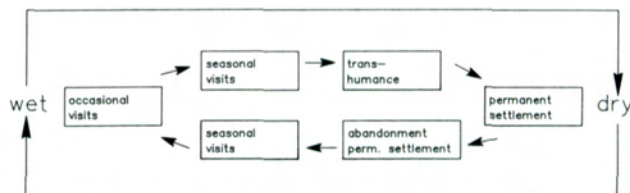
Fig. 61 Cyclical model for colonization of a peaty area (according to Brandt *et al.* 1984).

site of Rotterdam-Hartelkanaal 10-69 seems to have been
inhabited relatively shortly, the construction cannot have
stood for more than a decade considering the poor durabil-
ity of the alder wood used. This site may very well be an
equivalent of the pioneering transhumant stage. The absence
of crop plants and their weeds in the thin refuse layer of
Rotterdam-Hartelkanaal would fit in well with this assump-
tion, but the quantity and quality of the samples is too low
for well-founded statements.

The second -exchange- stage could be represented by Spij-
kenisse 17-30. The farm is made of a better quality wood,
the uprights being mainly constructed of elm and sycamore.
The deviating spectrum of crop plants, the absence of
stenoecious crop weeds (see *table 30*) and the relatively high
importance of grassland plants (see *table 28* and *30*) all may
indicate a specialization in stock-raising and the import of
crops. However, as stated above, the botanical data cannot
be used as definite evidence against the cultivation of crops
by the inhabitants themselves at a relatively great distance
from the site. The absence of granaries near the site, the
absence of Cerealia-type pollen in the peat next to the site
and the difficulty in protecting the crops sufficiently in fields
at several kilometres distance are all in favour of the
exchange model for Spijkenisse 17-30.

Spijkenisse 17-35 is the only excavated Iron Age site on
Voorne-Putten where habitation during two phases could be
demonstrated, viz. Early and Middle Iron Age. The spec-
trum of crop plants differs considerably from that of Spijke-
nisse 17-30 and does agree more closely with the crops
found on the later Iron Age sites. Furthermore, the presence
of several stenoecious summer crop weeds may indicate a
greater role for arable farming in comparison to Spijkenisse

17-30. The presence of internodes of the free-threshing
hulled barley and the processing by-products of *Linum* also
give an indication for the cultivation of these crops by the
inhabitants themselves. None the less, Spijkenisse 17-35 is
also located at a distance of 3-4 km from the levees along
the Meuse. No granaries were discovered at the site either,
so the objections against crop farming for Spijkenisse 17-30
also apply to this site. However, the fact that barley, the
main cereal in the Early Iron Age samples of Spijkenisse 17-
35, could probably have been cultivated on peat near the
settlement, is of great relevance. Local cultivation of barley
on peat may have made the inhabitants of Spijkenisse 17-35
more independant in their food supply.

According to Van Trierum (*pers. comm.*), the pottery of
the three Early Iron Age sites does not provide any clues on
the time sequence of these three sites. ^{14}C dates obtained
from wood of the three sites do not reveal a time sequence
either (see *fig. 62*), mainly as a result of the huge wiggles in
this part of the calibration curve (cf. Baillie/ Pilcher 1983).

6.5.2   THE MIDDLE IRON AGE

Although the Middle Iron Age is the phase of the Iron Age
about which most sites are known on Voorne-Putten, Spij-
kenisse 10-28, 17-34 and 18-50 are the only sites that yielded
partial house plans from this phase. From these, only Spij-
kenisse 17-34 has been investigated for botanical macro-
remains. Both other sites were excavated at a time when it
was not common practice to sample for botanical macro-
remains. In Spijkenisse 17-35, one single row of posts was
found. Geervliet 17-55, the third Middle Iron Age site
studied has not been excavated (see *4.1.1*).

In Spijkenisse 17-34, barley, emmer and linseed occur
frequently, while one gold of pleasure seed and some rape
seeds were recorded. This spectrum of crop plants and the
occurrence of some stenoecious summercrop weeds resemble
the data obtained from the Early Iron Age site of Spijke-
nisse 17-35. The numerous rachis internodes of barley and
the (few) capsule segments from linseed point to the cultiva-
tion of these crops by the inhabitants of Spijkenisse 17-34.
The occurrence of numerous carbonized manna-grass
remains in Spijkenisse indicates the gathering of this species
(see *4.5.5*). Apparently, the demand for carbohydrates could
not be satisfied by crop plants in one or more years.

The Middle Iron Age samples from Spijkenisse 17-35
revealed barley, emmer, linseed and gold of pleasure. The
presence of rachis internodes of barley and of capsules resp.
silicles of linseed and gold of pleasure demonstrate that
these crops were grown by the inhabitants themselves. For
emmer, this cannot be ascertained in view of the absence of
straw.

The macroremains from Geervliet 17-55 show the greatest
share of crop plant remains of all sites studied. Especially
gold of pleasure and linseed remains are abundant. The
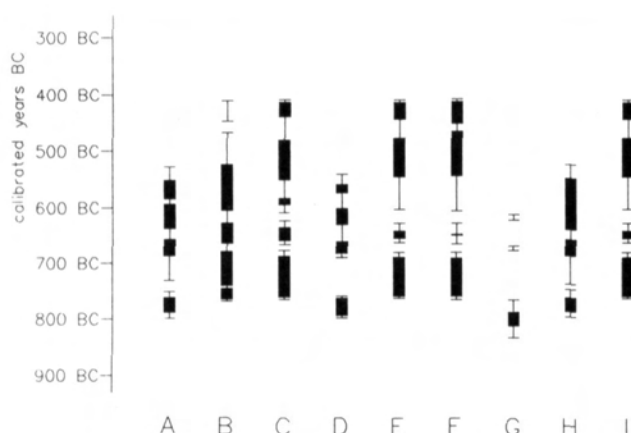
Fig. 62 Calibration of ^{14}C dates obtained from wood of Early Iron
Age settlements (A-C = Rotterdam-Hartelkanaal; D-F = Spijke-
nisse 17-30; G-I = Spijkenisse 17-35). Black = 1σ interval; line-
= 2σ interval.

ubiquity of threshing waste (silicles and capsule segments) again may be conceived as evidence for local production of these crops. Unfortunately, none of these sites have yielded pollen data from deposits close to the site. The diagram from Spijkenisse 17-30 did show peat formation during the Middle Iron Age, but no pollen of crop plants could be recognized. This cannot be taken as firm evidence that no crops were grown near the sites. The fact that crops with anemophilous (wind dispersed) pollen do not occur among the Iron Age crops may explain their absence.

The presence of numerous crop-processing by-products is a strong indication for the permanence of the Middle Iron Age inhabitation, since cultivation of crops in a non-permanent settlement is highly improbable.

According to Van Trierum (1986: 69), there is a gap of one century in the habitation on Voorne-Putten during the Early and the Middle Iron Age, caused by renewed peat growth in the period in between. ^{14}C dates support this statement. The model presented by Brandt et al. (see fig. 61) predicts that colonization would start again with transhumance visits, followed by specialized cattle breeding before a self-supporting economy can develop again.

The Middle Iron Age counterparts of the Early Iron Age sites of Rotterdam-Hartelkanaal and Spijkenisse 17-30, with little habitational refuse and the absence of specific crop weeds, apparently are not present on Voorne-Putten. This may simply be attributed to the small number of sites investigated. If the absence of sites belonging to the first two phases of settling, however, still holds after investigation of more Middle Iron Age sites, it must be assumed that the potential of the area, discovered during the Early Iron Age, was still known during the Middle Iron Age, even after a habitation gap of one century.

6.5.3   THE LATE IRON AGE

According to Van Trierum (1986: 69), the clear gap that divides the habitation of the Early and Middle Iron Ages is not present between the Middle and Late Iron Ages. The Dunkirk I deposits that separate both phases is not an absolute time boundary, as has clearly been demonstrated by the Late Iron Age site near Rockanje, which lies stratigraphically below Dunkirk I sediments, while the Late Iron Age sites near the Bernisse lie on top of these deposits. Thus, the inhabitants probably were not forced to leave Voorne-Putten entirely, since there were always areas that were inhabitable notwithstanding the marine influence.

Of the known Late Iron Age sites on Putten, around the Bernisse, none has yet been excavated. Three sites were sampled in outcrops of settlement layers in slopes of ditches. The site of Zuidland 17-27 yielded most crop plant remains. As in the Early and Middle Iron Ages, both barley and wheat are important cereals. Linseed is also conspicuously represented, gold of pleasure only to a lesser extent. Evid-

ently, this spectrum closely connects to those from the earlier sites.

The Late Iron Age site near Rockanje showed a much stronger focus on barley than on wheat. The numerous internodes of barley found suggest the local cultivation of this crop. Linseed and gold of pleasure are also well represented by threshing remains, also suggesting a local cultivation. The environment of the site is much more influenced by salinity than that around the Bernisse. The fact that barley, linseed and gold of pleasure can all be cultivated in salt marsh surroundings (see 6.1) indicates that these crops found in Rockanje indeed could have been grown by the inhabitants themselves. Whether this also applies to the scarce wheat remains must still be questioned.

The steady increase of the sizes of the farms through the Iron Age indicates that the importance of pastoralism was certainly not declining. Exchange may still have been practised in the Late Iron Age. The abundance of pottery connected with salt production in the Late Iron Age site of Rockanje can be seen as an indication of export of salt (cf. Van den Broeke 1986, 1987). Import most likely concerned non-food products, seeing the considerable potential local production of animal and vegetable food products.

The numerous crop processing by-products found in the Late Iron Age sites do attest to the permanence of the inhabitation on Voorne-Putten during this period.

6.5.4   THE ROMAN PERIOD

The two Roman settlements that could be investigated for botanical macroremains, Nieuwenhoorn and Rockanje, are both situated on Voorne. On both sites, the crop plant remains are dominated by barley. Wheat plays a very subordinate role and linseed and gold of pleasure are of little or no importance. The few Celtic beans found in Nieuwenhoorn may point to a much greater role for this crop, considering the low chance of preservation. The fact that Celtic beans can be grown on peaty soils (see 6.2.8) fits in well with the assumption that this crop was cultivated near Nieuwenhoorn. However, the bean straw that would unambiguously evidence local cultivation, was not found.

In Rockanje, the abundance of barley internodes, the ubiquity of crop weeds and the presence of a large granary must be interpreted as evidence for the local production of barley near this site. The Roman site near Rockanje must have been situated in a salt marsh environment, in view of the importance of plants from such habitats among the macroremains. The fact that barley is the predominating crop found on this site agrees well with a local production in such a salt marsh environment. In view of the experiments in the salt marshes near Groningen and Cappelersiel, and the ubiquity of Camelina sativa and Vicia faba in other coastal settlements, these crops could also be expected in Rockanje. Their absence might indicate a stronger focus on

barley on this site. It may be concluded that in Rockanje indeed only a small part of the potential spectrum of crop plants was cultivated. This indicates a kind of specialization as far as arable products are concerned. The fact that the house plans in Rockanje are considerably smaller than those in Nieuwenhoorn indicates a differentiation in the importance of stockbreeding during the Roman Period.

Several authors have discussed the consumption of barley by Roman soldiers. According to Davies (1971: 123), barley was destined for the horses in the Roman army. Usually, barley was given to man only as a punishment, while normally wheat was consumed. Groenman-van Waateringe (1989) also stressed the importance of wheat for the Roman military diet. The predominance of barley over wheat in the native Roman settlements is therefore remarkable. In the salt marsh area near Rockanje, wheat could not be cultivated successfully, as is evidenced by recent agricultural experiments, nor could it be cultivated on the peat around Nieuwenhoorn. Barley may have been exported to the Roman *castella* as food for horses. One such *castellum* may even have been present near Oostvoorne (see *1.3.1.4*). Alternatively, the inhabitants of Rockanje may have been horse breeders themselves. Unfortunately, the faunal investigations on this site are very scanty. The horse skeletons in the well may reflect the importance of horse breeding, but an unambiguous proof is not provided by this probably non-representative evidence.

6.6   The consumption side of the economy

In an autarkic subsistence economy, the inhabitants of a particular site are the consumers of the agricultural products produced by themselves. Production and consumption are in balance with each other. Whether this type of economy existed on Voorne-Putten during the Iron Age and the Roman Period must be assessed through comparison of estimates both of production and of consumption. A large complication is that prehistoric consumption is even more difficult to estimate than production (cf. Dennell 1979).

The usual way to estimate consumption is via the extant nutritional needs of man, mostly in terms of energy requirements and the amount of essential amino-acids needed. The energy and protein requirements most often cited are those published by the World Health Organization (Passmore *et al.* 1974). These data are separated by sex and age-group (see *table 34*). Unfortunately, the calorific requirements can be fulfilled by a virtually endless list of possible combinations of food products. Energy may be provided by any foodstuff and a shortage will result in a so-called quantitative malnutrition.

Essential amino-acids are those amino-acids that cannot be synthesized by man. They have to be acquired through food. Animal products provide all the essential amino-acids, whereas vegetable products are deficient in some. In this

Table 34. Energy and protein requirements according to the W.H.O. (Passmore *et al.* 1974).

	Energy (kcal)	Protein (gr)
Children		
<1 yr	820	14
1-3 yr	1360	16
4-6 yr	1830	20
7-9 yr	2190	25
Male		
10-12 yr	2600	30
13-15 yr	2900	37
16-19 yr	3070	38
adult (moderately active)	3000	37
adult (very active)	3500	37
Female		
10-12 yr	2350	29
13-15 yr	2490	31
16-19 yr	2310	30
adult (moderately active)	2200	29
adult (very active)	2600	29
pregnant females	+350	38
lactating females	+550	46

respect, cereals and leguminous seeds supplement each other. Regular consumption of both is needed in a vegetarian diet. A shortage of one or more essential amino-acids results in qualitative malnutrition.

For the provision of energy, grain would have been the most important plant food. So as to be able to estimate the total amount of energy required by one household and by the total population in the Voorne-Putten area during the three phases of the Iron Age and during the Roman Period, the number of inhabitants per household and the total number of synchronous households in each phase/period must be assessed. These calculations are shown in paragraph 6.6.1.

6.6.1   SIZES OF HOUSEHOLDS AND POPULATION DENSITY
The number of inhabitants per household can only be estimated. A number used frequently for the later prehistoric and the Roman Period is six persons (Brandt 1976; Bloemers 1978), Haarnagel (1979) assumed 6-8 persons per household.

Prummel (*in press*) assumed a relationship between the number of stalls present in a farmstead and the number of human inhabitants. However, differences in status are well-known from the Iron Age onwards and the differences in the numbers of stalls and thus in the number of cattle, in my opinion, may also be a reflection of the status of the inhabitants.

A different approach to establish the number of inhabitants was explored by Kossack *et al.* (1975: 307; see also Harck 1984). They counted the number of items of types of

Table 35. Areas of the living quarters and total areas of the excavated farms on Voorne-Putten and the inferred number of inhabitants.

Site	Area living quarters (m^2)	Total area (m^2)	Share living area (%)	Inhabitants Naroll	Inhabitants Cook & Heizer
R.H. 10-69	27.1	46.7	58.1	3	2
Sp. 17-30	43.7	81.5	53.6	4	3
Sp. 17-35	31.4	73.1	43.0	3	2
Sp. 17-34	≤41.2	≤110	37.4	4	3
Ro. 08-52	57.3	121.8	47.0	6	4
Si. 17-24 (1)		79.1			
Si. 17-24 (2)		141.7			
Nh. 09-89 (1)	81.4	152.4	53.4	8	6
Nh. 09-89 (2)		129.6			
Nh. 09-89 (3)	87.7	194.6	45.1	9	6
Rock. II (2a)	?	42	100?	≤4	≤3
Rock. II (2b)		120			
Rock. II (3)	?	66	100?	≤6	≤5

pottery that have an individual character (e.g. cups, plates) for a burnt-down farm on Archsum on Sylt (northern Germany), which dates from the Roman Iron Age. It appeared that all the types were represented by six or seven specimens. They concluded that this house was inhabited by seven persons. Apparently, this family was not considered to be hospitable to visitors!

A third way to estimate the number of inhabitants of a farm relates the number of persons (P) to the area (A) that they would require. Bakels (1978) reviews the relationship between P and A that have been proposed in the literature. For farms, the equation of Naroll (1962) and the model published by Cook and Heizer (1968) can be applied. Naroll assumed that each person requires 10 m^2, so P = A/10. Cook and Heizer stated that the first six inhabitants of a house require 150 sq. feet each (13.93 m^2), every following person would need another 100 sq. feet (9.28 m^2). When these data are applied to the living area of the excavated farms on Voorne-Putten, the number of inhabitants can be estimated. The results are presented in table 35.

It is interesting to note that the number of inhabitants of the Early and Middle Iron Age farms is lower than six. The numbers according to Cook and Heizer's model seem unrealistically small. The numbers of inhabitants according to Naroll's model seem more realistic. Therefore, four and six inhabitants will be used as alternatives for the number of inhabitants of Iron Age farms. The number of inhabitants of the larger Roman farms in Nieuwenhoorn may well have amounted to eight. The size of these farms are in the upper range of what Haarnagel (1979) published for Feddersen Wierde. The smaller farms in Simonshaven and Rockanje probably had considerably fewer stalls. For the Roman Period, six and eight inhabitants will be used as alternatives.

The population density is the product of the number of inhabitants per household and the number of synchronous households. The number of synchronous households is very difficult to quantify. Van Trierum (*in press*) presented an overview of all the sites known on Voorne-Putten up to and including 1991. He stated that some of these sites cannot be interpreted as former settlements with certainty. His criteria for a settlement are that at least five "find-units[3]" must have been found. In consequence, two redeposited sherds in a Dunkirk III gully do not represent a settlement, nor do the Roman culverts.

According to Van Trierum's criteria, five Early Iron Age settlements are known to date. All are situated in the area around the Bernisse. From the Middle Iron Age, 25 settlements are known from the Bernisse-area, seven are situated along the Meuse and three on the western part of Voorne. One settlement near the Bernisse belongs either to the Early or to the Middle Iron Age.

The Late Iron Age yielded fifteen settlements in the area around the Bernisse and eight on western Voorne. Furthermore, one settlement near the Bernisse and three on western Voorne belong either to the Middle or to the Late Iron Age. To date, the Roman Period settlements amount to 29 in the Bernisse area, 46 on western Voorne and 4 along the Meuse. Figure 8 shows the locations of these settlements per phase/period.

The number of known settlements, of course, is only part of the number of settlements that really existed. The fact that new sites are still being discovered clearly illustrates this. From 1976 onwards, the intensity of surveys and excavations has increased considerably. In figure 63, the yearly increase in known numbers of sites (*not only settlements*) between 1976 and 1990 is presented, based on the publication of Van Trierum *et al.* (1988) and Döbken *et al.* (*in press*).

The curve for the Early Iron Age seemingly shows a saturation, the increase stops in 1986. However, the archaeological visibility of the Early Iron Age is lower than

Early Iron Age
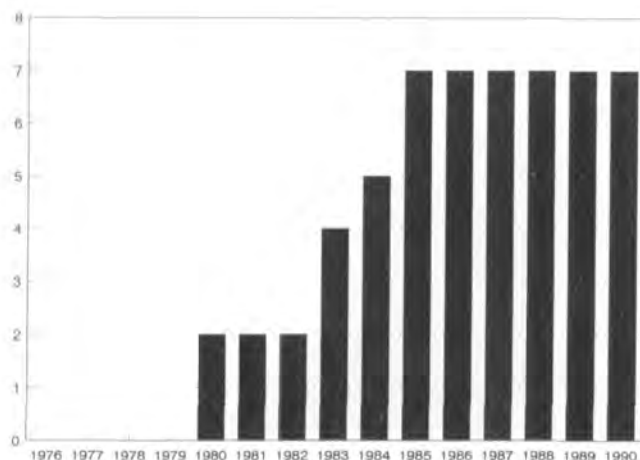
Fig. 63a Yearly increase in number of sites known from the Early Iron Age.

Late Iron Age
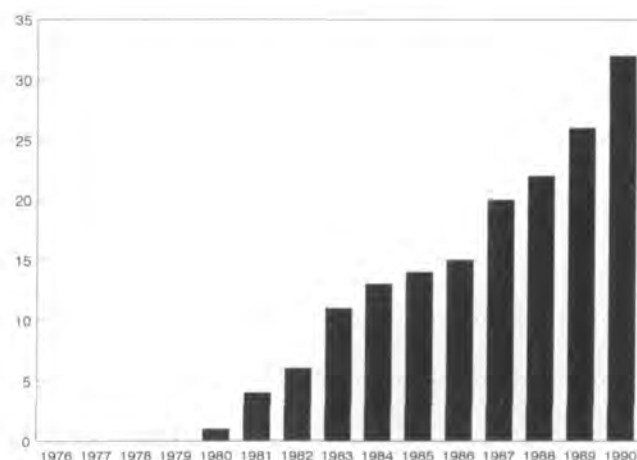
Fig. 63c Yearly increase in number of sites known from the Late Iron Age.

Middle Iron Age
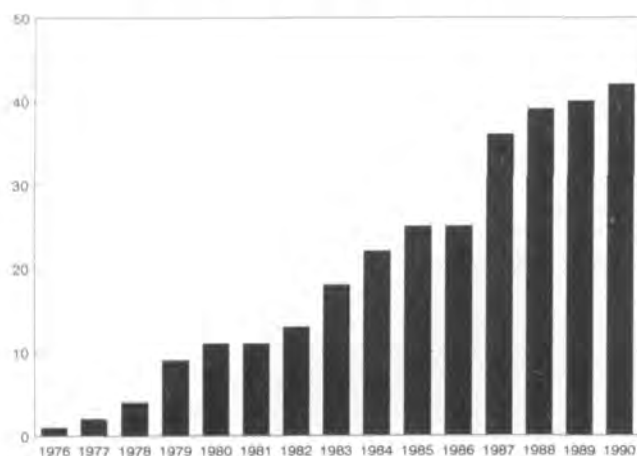
Fig. 63b Yearly increase in number of sites known from the Middle Iron Age.

Roman Period
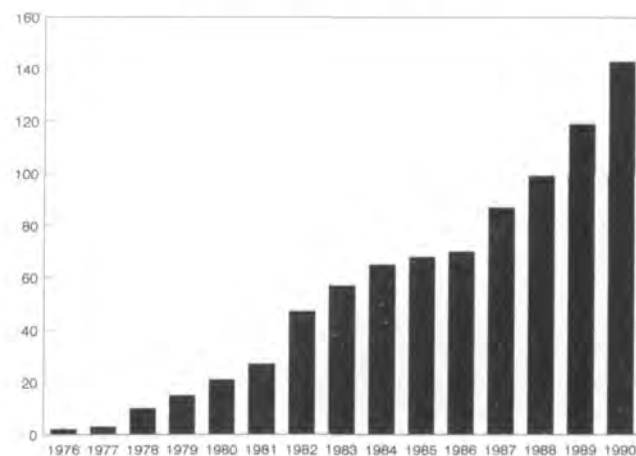
Fig. 63d Yearly increase in number of sites known from the Roman Period.

that of the later phases due to the thin habitation layers that have developed on these sites. The discovery of new sites is very much dependant of large-scale activities, such as house-building, which became less after 1986 in the area around the Bernisse. For the remaining phases of the Iron Age as well as for the Roman Period, it seems clear that the increase is so regular that the curve does not show any sign

of saturation. The discovery of new sites will mainly depend upon such factors as the intensity of surveys and corings (which also yields new sites), the occurrence of reallotments, etc. Besides, some areas have not been subjected to surveys to date, e.g. the area west of Brielle (cf. Van Trierum *in press*). Even intensive surveys may only yield a fraction of the sites found during large-scale construction work, as was

demonstrated by Van den Broeke (1991) for the Iron Age habitation in the peaty area in Midden-Delfland, just north of the Meuse estuary. According to Van Trierum (*pers. comm.*), the known number of sites on Voorne-Putten should probably be multiplied by three to five to give an estimate of the true number.

Within each phase, settlements are not necessarily synchronous. The number of synchronous households may be assessed with the aid of the total duration of each period and an estimation of for how long each settlement was inhabited. According to Van Trierum (1986), the Early Iron Age habitation occurred between 725 BC and 525 BC, so this phase lasted ca. 200 years. The Middle Iron Age, from 425 BC to 200 BC, lasted ca. 225 years and the Late Iron Age, from 200 BC to 25 BC, lasted ca. 175 years. The Roman habitation on Voorne-Putten presumably started around 50 AD and ended between 200 and 260 AD, so it lasted 150-210 years.

It is of further relevance that the Iron Age settlements consisted of single farmsteads. In view of the thin habitation layers found on the Early Iron Age settlements, they were inhabited for a shorter period than their Middle Iron Age counterparts (see *ch. 1*). The durability of the building wood suggests that the farms could not survive longer than ca. twelve years, probably even less than five years. This implies that 200/12 = 16.7 or even 200/5 = 40 sites may have occurred during the Early Iron Age without any of them being contemporaneous. The five settlements known to date are considerably less. Even a multiplication of this number by three to five, as suggested by Van Trierum, still does not necessarily imply synchronous sites.

The duration of the Middle Iron Age farms is hardly supported by wood identifications. The only excavated Middle Iron Age site also studied for wood remains, Spijkenisse 17-34, mainly yielded wood from the wall. Central roof-supporting elements, which on other sites were made of relatively durable wood species (see *ch. 3*), are hardly present. However, it does seem probable that oak wood was not used commonly, since it does not occur among the wood remains studied from Spijkenisse 17-34. In view of the preservation of waterlogged organic material, the environment will have been wet. Therefore, it seems highly probable that the Middle Iron Age site of Spijkenisse 17-34 did not last significantly longer than 10 years. Taking into account a duration of 225 years for the Middle Iron Age, the 25 known settlements in the area of the Bernisse just cannot be all asynchronous. If the number of sites is multiplied by three to five, three to six sites may have occurred synchronously in the area around the Bernisse. The three settlements on western Voorne, probably representing nine to fifteen settlements, may all have been asynchronous. This also applies to the seven (probably representing 21-35) sites

along the Meuse. According to Van Heeringen (1992: 231), six to twelve synchronous settlements may have occurred on Voorne-Putten during the Middle Iron Age.

The durability of wood in Late Iron Age settlements cannot be assessed. However, a preliminary wood research of the Late Iron Age site of Rockanje 08-52 demonstrated that ash predominates among the crucial construction elements. Besides, even birch was sometimes used for roof supports. A durability of ten years at the very best seems likely. The fifteen known settlements near the Bernisse may all be asynchronous, as the Late Iron Age lasted 175 years. If this number of settlements is multiplied by three to five, two to four settlements would have been synchronous. The eight settlements known from western Voorne may represent two or three synchronous households in that area.

The duration of the Roman settlements may have differed considerably from the Iron Age ones. Firstly, oak wood was more regularly used as building material. Secondly, the excavated sites near Nieuwenhoorn and Simonshaven revealed houses one on top of the other, which considerably increases the duration of the settlements at these sites. Thirdly, in Rockanje, houses were built next to each other. Of the three houses studied for botanical macroremains, one seems to be asynchronous, but the remaining two probably were occupied simultaneously. These data indicate that the duration of Roman sites may well have been between 50 and 100 years. Without evidence for the other settlements, which mostly have not been excavated, an average duration of 50 years is assumed for the Roman settlements. As the Roman habitation lasted 150-210 years, the 29 known settlements in the area around the Bernisse represent seven to ten synchronous settlements, which may be three to five times as many when corrected for unknown settlements. The 46 known settlements on western Voorne similarly may represent 15 or 45-75 simultaneously inhabited houses. The four sites along the Meuse may represent one or four to six synchronous households. The large increase in the number of settlements between the Late Iron Age and the Roman Period is striking. Archaeological visibility cannot be the only explanation, as the Late Iron Age sites around the Bernisse are located upon the same Dunkirk I deposits as the Roman ones, while the increase occurs in this area as well. An ecological explanation does not appear from the present study either. The large-scale relocation of autochthonous inhabitants during the start of the Roman occupation (see *1.3*) might provide an archaeological explanation.

6.6.2　THE AREA AVAILABLE FOR ARABLE AND PASTORAL FARMING

The levees along the Meuse had the soils best suited for arable farming on Voorne-Putten during the Early and Middle Iron Age. The width of the Meuse levees can be set at 100 m. This may seem rather narrow for a large river as

the Meuse. The levees along the Ems are several kilometres wide (see *2.5.3*). In the Meuse basin, however, there is not enough space for such wide levees. The Dunkirk III gully, which completely eroded the Iron Age Meuse with its levees, had a width of 600 m. The river plus its levees should fit into this width. Thus, the width of the levees cannot have been far in excess of 100 m. The palynological investigations demonstrated that the transition from fresh to brackish conditions was near Heenvliet (see *2.5.3*). The levees east of this transition are in a fresh water environment, covering 10 km on Voorne-Putten. West of this transition levees lay in a brackish to saline environment, which covered ca. 25 km. At a width of 100 m, the 10 km stretch of levees in the freshwater area provides 100 ha of arable land, the 25 km in the brackish or salt area covers 250 ha. The total area covered by these levees thus amounted to ca. 3.5 km², a very small part of the ca. 193 km² of Voorne-Putten.

The peaty area on Voorne-Putten during the Early and Middle Iron Age will mainly have been used for pasture (if used anyway). The area covered by the Holland peat has been assessed by digitized maps (see *fig. 4*). Unfortunately, the total area of peat during the Early and Middle Iron Age cannot be assessed. The Holland peat occupies ca. 124 km² of the 149 km² represented on the geological map 37 West (see also *fig. 4*).

The situation during the Late Iron Age and the Roman Period is very different owing to the deposition of Dunkirk I sediments (see *fig. 5*). Clayey deposits, which are favourable for arable farming, cover ca. 41 km² on western Voorne and 7.2 km² in the area around the Bernisse. Peat covers 77.8 km² during the Roman Period.

6.6.3   THE SUBSISTENCE PATTERN OF THE SINGLE FARMS
The requirements of a single household in terms of calorific and protein consumption will have been fulfilled by a combination of animal and vegetable sources. The mutual share of these sources is extremely difficult to quantify through archaeological data. Estimates are therefore often used. However, as Fokkens (1991) indicated, such estimates may range from 90% to 40% vegetable products.

The arable/pastoral ratios on the basis of palynological data do not offer a reliable alternative for estimating the importance of these components. The more sophisticated pollen-ratios indicate over 90% of pastoral products, which is extreme. These ratios are most probably influenced by taxa that are of small relevance (see *ch. 2*). Both render these percentages doubtful.

The ratios on the basis of botanical macroremains, proposed in chapter 4, seem to indicate differences between the sites. The precise values cannot be expected to represent the factual importance of arable and pasture for the sites investigated, but the trend in the data is remarkable (see *table 30*). The frequency ratios indicate that stenoecious arable

weeds are absent in Spijkenisse 17-30. The role of arable farming was probably less important than in the other sites. Unfortunately, the Early Iron Age site of Rotterdam-Hartelkanaal yielded too few data to allow calculation of a reliable ratio. The Late Iron Age sites show higher frequency ratios than their earlier counterparts, which can be seen as an indication for the increased possibilities for arable farming on the Dunkirk I sediments. The ratio of Rockanje 08-52 does not differ markedly from that of the Late Iron Age sites around the Bernisse. The fact that Dunkirk I sediments had not yet been deposited during the Late Iron Age habitation in Rockanje is apparently not of great influence in the roles of arable and pastoral farming.

The Roman site near Nieuwenhoorn shows a much lower ratio than the Late Iron Age sites and the Roman site of Rockanje. The latter site shows the highest ratios of all sites investigated. The large farms, probably with many stalls, in Nieuwenhoorn and the much smaller house plans in Rockanje do agree with this observation. Both point to differences in the agricultural economies of these native Roman settlements.

For quantification of past economies, it seems best to work with the only reliable quantitative information, the number of stalls in the farms. These provide information about the number of animals kept, although this may be a minimum number since not all the animals necessarily had to be housed. On the basis of this number, the meat supplied by these animals can be assessed, as Prummel did for hypothetical Iron Age farms on Voorne-Putten (see *ch. 5*). The proteins and calories supplied by these animal sources may subsequently be evaluated in terms of remaining needs to be fulfilled by vegetable products. The area needed for keeping the animals involved and for growing the vegetable products can then be calculated and compared with the available area. A similar sequence of analysis was conducted by Gross *et al.* (1990) for Neolithic lakeside villages in Switzerland. However, these authors did not use the number of stalls but the Minimum Number of Individuals for the domesticated animals based on bones found. For Voorne-Putten, this method cannot be applied due to the decay of bone in the mainly peaty sediments.

In view of the differences in archaeological data from the Iron Age and the Roman Period, they will be discussed separately in the following sections.

6.6.3.1   *The Iron Age*
Prummel (*in press*) has drawn up a table to estimate the yearly meat supply for Iron Age farms on Voorne-Putten (see *table 32*). She assumed that the larger farm, with ten stalls, was inhabited by eight people. The data discussed in *6.6.1* indicate that this number is probably too high. Hereafter, the number of inhabitants will be set at four and six as alternative variables in the assessment of the dietary

Table 36. Provision of energy and proteins in model Iron Age farms.

Number of stalls	6	6	10	10
Number of inhabitants	4	6	4	6
Energy provided by animal products ($\times 10^6$ Kcal))	1.5-2.1	1.5-2.1	1.8-2.6	1.8-2.6
Energy required per year ($\times 10^6$ Kcal)	3.1	4.8	3.1	4.8
Share covered by animal products	47-67%	31-44%	58-84%	38-54%
Proteins provided by animal products (kg)	34-48.5	34-48.5	47.5-69	47.5-69
Proteins required per year (kg)	37	64	37	64
Share covered by animal products	91-100%	53-76%	100%	74-100%
Required amount of grain (kg)	300-455	850-1030	150-395	665-910
Required area in ha (yield 1:7)	0.8-1.3	2.4-2.9	0.4-1.1	1.8-2.5

needs. The main variables discussed below have been assembled in table 36.

First, these dietary needs of inhabitants of a small hypothetical farm, with six stalls, will be estimated. According to Prummel, two to three head of cattle could be slaughtered yearly. Each head may have provided 478,200 kcal. The protein content amounts to 10 kg for the 60 kg of meat with 168 g protein/kg. Sheep will also have provided meat. Prummel stated that one sheep may have been slaughtered yearly. This would have yielded ca. 68,370 kcal, proteins would amount to 1.5 kg (9 kg of meat, 170 g of proteins/kg; cf. *Voorlichtingsbureau voor de Voeding* 1980). Prummel further estimated that one or two piglets were slaughtered yearly. She based this estimate on a litter size of only two. In view of IJzereef's estimated litter size of six, the number of slaughtered pigs and piglets may have been higher. However, the proportion of pig bones does not suggest a greater importance of pig relative to sheep. The age of slaughter of pig indicates that adult pigs were consumed as well, so the slaughter of one pig and one piglet per year will be assumed here. These probably provide a minimal estimate. These animals will provide 270,000 kcal. The 30.5 kg of meat provides ca. 5 kg of proteins.

In total, these animals may have provided the inhabitants of the smaller farm with 1.3-1.8 million kcal, and with 25-36.5 kg of proteins. The role of milk in the diet of our household is also estimated by Prummel. She arrived at a yearly net yield of 300-400 kg milk from cows and 50 kg milk from sheep. The milk-yield of 100 kg per cow per year used by Prummel is low, but will be followed here to assess a minimum value. The 300-400 kg correspond to 180,000-240,000 kcal and to 9-12 kg protein. The 50 kg of milk of sheep corresponds to 50,000 kcal and 1.5 kg protein.

The dietary demands of the inhabitants depends upon their age and sex. A low level and a high level of requirements will be used here, to explore the limits of the agricultural system. A low level is needed by four inhabitants. To provide a base for calculations, it will be assumed that this hypothetical family consisted of one moderately active male plus one female, one child of 1-3 years old and one of 4-6

years old. According to data of the World Health Organization (W.H.O.; see *table 34*), the daily requirements of this household amounts to 8390 kcal and 102 g protein. This corresponds to yearly figures of 3.1 million kcal and 37 kg protein. If the farm was inhabited by a model family of six persons plus one baby, one moderately active male plus a lactating female, and two other children of 1-3 and 7-9 and a subadult male of 13-15 years old respectively, the daily requirements amount to 13,020 kcal and 175 g proteins, or 4.8 million kcal and 64 kg protein per year.

These data indicate that the protein requirements of four inhabitants could be provided by meat and milk alone. The 1.5-2.1 million kcal provided by meat and milk are ca. 1-1.5 million kcal below the needs. Thus, in this case meat plus milk may have provided 47-67% of all the energy required. The remaining 1-1.5 million kcal must have been obtained through vegetable products. This amount corresponds to 300-455 kg of grain (3300 kcal/kg). This yield can be obtained from ca. 1 ha of arable. If 60 kg/ha is sown in rows, a yield of 1:6 to 1:8.5 is sufficient (including grain for sowing next year). If 200 kg/ha is sown broadcast, a yield of 1:2.5 to 1:3.3 is sufficient.

The protein requirements of six inhabitants plus a baby, 63.9 kg per year, cannot have been provided by animal products alone. The 35.5-50 kg protein fall 13.9-28.4 kg short. The 1.5-2.1 million kcal produced by meat and milk are ca. 2.7-3.3 million kcal below the needs. In this model, meat plus milk may have provided 31-44 % of the total calorific needs. If the remaining calories are to be provided by grain, ca. 850-1030 kg is needed. This amount of grain would provide 76-216 kg protein (barley at least 9%; emmer at most 21% of protein) so that this requirement is also covered. At a yield of 1:7 and planting in rows, 2.4-2.9 ha are required to produce these calories, in broadcast sowing and a yield of 1:3.5, a maximum of 2.1 ha will be sufficient.

After the above calculation for a farm with six stalls, the food production of a larger farm, with ten stalls, will be estimated, again for the above-mentioned model households of four and six persons plus a baby.

According to Prummel (*in press*), three to five adult head

of cattle could have been slaughtered yearly. However, her age-class distribution for cattle demonstrates that 35% of the cattle was slaughtered between the ages of 1-3.5 years. Thus, the three to five head of cattle are here assumed to have been two to three adults and one to two heifers.

The number of sheep slaughtered per year probably amounted to one adult and one lamb per year (Prummel *in press*). As far as pigs are concerned, Prummel assumed that one adult pig and one piglet were slaughtered per year on a farm with ten stalls. In view of the low litter size assumed by Prummel, this will be used as a minimum value here. The energy provided by these two animals amounts to 270,000 kcal. The proteins amount to 5 kg.

In total, meat may have provided the inhabitants of the larger farm with 1.5-2.1 million kcal and with 32.5-48 kg proteins per year. The quantity of milk on this larger farm, as indicated by Prummel, may have been 400-500 kg from cows and 100-200 kg from ewes. Again, these may represent conservative estimations. This corresponds to 240.000-300.000 kcal and 12-15 kg protein for cows milk and to 100,000-200,000 kcal and 3-6 kg proteins for ewes milk.

The 47.5-69 kg protein provided in total by milk and meat are sufficient for four inhabitants, while the upper range may also have been sufficient for six inhabitants plus a baby, who probably need 64 kg protein per year.

The 1.8-2.6 million kcal are 0.5-1.3 million kcal below the requirements of four inhabitants. Animal products in this case may have provided 58-84% of the total calorific needs. The remaining calories are equivalent to 150-395 kg of grain, which of course requires even lower yields as calculated for the four persons in a house with six stalls. If six persons and a baby inhabited the farm with ten stalls, the calories derived from animal products would be 2.2-3.0 million kcal short of their requirements. Therefore, animal products constitute 38-54% of the total calorific requirements. To supply the remaining calories by grain, an amount of 665-910 kg of grain is needed. If 60 kg/ha is sown in rows on one ha, a yield of 1:12 to 1:16 must be reached. Broadcast sowing of 200 kg/ha requires a yield of 1:4.3 to 1:5.5 if one ha is sown. As yields above 1:7 in sowing in rows and above 1:4 in broadcast sowing (see Sigaut 1992: 403) may not have been feasible, a greater area had to be sown. If three ha are sown, ratios of are 1:4.7 to 1:6 and 1:2.1 to 1:2.5, respectively, are appropriate.

The feasibility of the required yields is mainly determined by the time needed for planting and harvesting the crops and the area required for arable fields. These aspects will be discussed in the following paragraph (*6.6.5*).

When applied to the site of Rotterdam-Hartelkanaal, which had six stalls, these calculations demonstrate that the calorific requirements cannot have been fulfilled by animal products alone, neither for six nor for four inhabitants. If it is maintained that the inhabitants of this site did not grow

their own cereals, it follows that they must have imported calories, which may well have been in the form of cereals. It implies that the inhabitants had to develop an obligatory relationship for the import of food products, for instance with cultivators of cereals. Even if the peat dwellers exported some of their products, this relationship remained asymmetric in terms of calories, as cereal-growers export more calories than they import.

The very low population density in the peaty area during the Iron Age is of relevance in this context. The number of people is far too low to form a separate, independant population (marriage group). According to Hassan (1981: 61), a mating pool must have at least 175 individuals to be able to subsist independently. Birdsell (1973) mentioned a group size of ca. 500 persons needed for independant existance, Kosse (1990: 280) arrived at group sizes around 350-400 individuals. Waterbolk (1979: 4) assumed a minimum group size of a few hundred persons. Thus, ties of the peat-dwellers on Voorne-Putten with inhabitants in adjacent areas, such as the levees and/or the dunes, were a necessity from this point of view too.

Pottery does not provide evidence for relationships with the Pleistocene hinterland. According to Van Heeringen (1992: 302)

"the similarities in the pottery suggest that the occupants of these areas [i.e. the peaty areas along the Meuse] maintained close social contacts with the occupants of the Older Dunes".

The second excavated Early Iron Age site, Spijkenisse 17-30, also has six stalls, so the inhabitants again could not fulfil their own calorific requirements with animal products alone. Thus, they must either have grown their own crops or had to import them. In contrast to Spijkenisse 17-35, cultivation of crops by the inhabitants of Spijkenisse 17-30 could not be ascertained.

The Early Iron Age inhabitants of Spijkenisse 17-35, a farm with ten to twelve stalls, were probably self-sufficient. Barley and linseed were grown by the inhabitants themselves, in view of the threshing remains that only occur on production sites. Emmer does not occur in the Early Iron Age samples from this site. This is also the crop least likely to grow on peaty soils. Whether or not barley and linseed can indeed be grown on drained fen peat, however, does deserve experimental cultivation on such soils. The presence of exclusively summercrop weeds in the samples suggests that the rich soils of the levees along the Meuse are more likely candidates for the Early Iron Age arable fields. Cultivation of crops on peat does not necessarily demand cultivation as a summercrop. Moreover, weeds of acid soils, e.g. *Spergula arvensis*, would be expected if cultivation of crops on peat was practised.

The Middle Iron Age materials from Spijkenisse 17-34 and 17-35 and from Geervliet 17-55 all suggest cultivation of

several crops by the inhabitants themselves. All sites seem to have been autarkic in their food production. Again, cultivation of crops on the mineral soils along the Meuse is most likely.

Interestingly, according to Van Heeringen (1992) and Van Trierum (*pers. comm.*), the Middle Iron Age pottery from Voorne-Putten seems to stand on its own. There are no clear relations with other areas. This would also plead for a self-supporting system during the Middle Iron Age, but the population density still will have been far too small to form a separate marriage-group.

The only excavated Late Iron Age farm, near Rockanje, has twelve stalls. Emmer, barley, gold of pleasure and linseed all occur frequently in the samples for macroremains. Again, by-products characteristic for production sites have been found of barley, gold of pleasure and linseed. Emmer does again not provide conclusive evidence.

In the samples from the unexcavated Late Iron Age sites near the Bernisse, local production of the first three mentioned crops is also demonstrated. In view of the improved agricultural conditions during the Late Iron Age, as a result of Dunkirk I deposits, self-sufficiency during this period can be concluded. Even more so than in the Middle Iron Age, however, the population in this area is too small to be independent. Contacts with inhabitants of the levees along the Meuse and the dune area must have persisted throughout the Iron Age.

6.6.3.2   The Roman Period
The Roman settlements lack some of the crucial information used for the Iron Age sites discussed above. Firstly, the excavated farms do not show the well-defined stalls. One possibility to reconstruct the byre-parts of these farms is by measuring the distances of the roof supports. It has often been noticed that these distances are smaller in byre-parts (e.g. Haarnagel 1979). The plans of the settlement of Nieuwenhoorn 09-89 are the only native Roman ones on Voorne-Putten that can be used in this respect. In the first phase farm, the posts in the byre area are 3 m apart, in the third building phase this distance is 3.20 m. These distances are considerably wider than the distances for "double" stalls reported by Waterbolk (1975) for Roman farms. One possibility is that the byres in Nieuwenhoorn were not for cattle, but for caprovids. This may explain the absence of clear partitions too. Unfortunately, any support for this assumption, based on the importance of sheep/goat remains among the bones is wanting. The investigation of the bone remains from Nieuwenhoorn may in the future provide important information. The faunal remains from Roman sites studied by Van Mensch do indicate an increased importance of sheep/goats, but cattle is still predominant.

Secondly, the fact that slaughter ages of bones from Roman sites have not been established, poses further limita-

tions when compared to the Iron Age situation. As a result, the role of animals in the diet of the inhabitants of Voorne-Putten during the Roman Period is very uncertain. In view of the sizes of the farms it will be assumed here that the herds were not smaller than those of the hypothetical farm with ten stalls in the Iron Age. The amount of livestock that could be housed in this farm will be used for the Roman situation. The importance of sheep will not be assumed to have been higher here, as the increased number of finds may have been caused by better preservation conditions.

Thus, as in the Iron Age farm with ten stalls, meat and milk may have provided 1.8-2.6 million kcal and 47.5-69 kg protein.

In view of the larger sizes of the native Roman farms, the number of inhabitants will have been between six and eight rather than four. These six inhabitants and a baby required 4.8 million kcal and 64 kg protein per year. In consequence, the amount of proteins derived from meat and milk would have been more or less sufficient. The calorific content of meat and milk may again have provided 38-54% of the needs.

A household with eight inhabitants may have consisted of two adult males and one pregnant female, a fourteen year old male, a twelve and a ten year old female and two children of seven and three years of age. They will have needed ca. 7.2 million kcal and 91 kg protein per year. The proteins from animal products could have covered 52-76% of the requirements, the calories 25-36%.

Granaries from the Roman period were discovered at Rockanje and Simonshaven. If we assume that these granaries did serve for storage of grain, the storage capacity can be assessed. The potential amount of grain that can be stored, and the amount of calories it represents, may give an insight into the grain production.

In order to calculate the amount that could be stored, it is assumed that in the Iron Age and Roman Period, storage took place in the chaff (see 6.4.2)., probably with the exception of military Roman contexts, which are not of relevance here. My own measurements showed that barley grains have a density of 837 kg/m^3, of which ca. 1% is chaff (the more voluminous internodes would have been discarded before storage), leaving ca. 829 kg available for consumption. In the case of wheat, grains have a density of 852 kg/m^3. The glumes of emmer are much denser than the hulls of barley. Measurements demonstrated the share of emmer glumes plus internodes on basis of weight to be 20%. Thus, 710 kg/m^3 remains for consumption. Evidently, the better preservation of hulled wheats stored in chaff is at the expense of the storage capacity.

Davies (1971 citing Haverfield 1920) stated that one ton (2240 lb = 1017 kg) of (unspecified) grain required a storage capacity of 1.5 yd^3 = ca. 1.1 m^3, corresponding to a density of 925 kg/m^3. Reynolds (1974 cited in Mercer

1981) found that in a silo of 1.2 m³ an amount of 1120 kg of threshed, modern barley could be stored, corresponding to 933 kg/m³. The difference with my measurements is probably caused by a difference in moisture content of the grains. As calorific contents are measured on dry seeds, my measurements will be used in the following.

The granary of Rockanje has a floor area of 16 m², the one in Simonshaven of 15 m². It will be assumed here that grain was not stored in sacks or bins, but in bulk. Stored bulks of grain form a cone with an angle of inclination of 30°. A wall surrounding the floor of the granaries would appreciably increase the storage capacity, but cannot be demonstrated archaeologically. Every height of 6.25 or 6.7 cm for Rockanje and Simonshaven, respectively, would increase the capacity by 1 m³. Without wall, the capacity of the granary of Rockanje (4 × 4 m) is 4.82 m³, the height of the cone is $2 \times \tan 30° = 1.15$ m. The granary of Simonshaven measures 5 × 3 m and has a capacity of 4.64 m³. Both these capacities are minimum values.

The storage of grain probably took place in the form of hulled grain. In view of the data presented above, ca. 837 kg of unthreshed barley and 852 kg of emmer could be stored per m³. The granary of Rockanje could contain ca. 4034 kg of unthreshed barley, that of Simonshaven 3884 kg of barley or 3953 kg of emmer. These data are for granaries without walls on the floor. If a yield ratio of 1:7 is assumed, 1/7 part of the crop must be reserved for sowing in the next year.

After subtraction of the chaff and the required amount of seed grain, 3490 kg of barley remains for consumption in Rockanje, in Simonshaven 3365 kg of barley or 2880 kg of emmer. The amount of calories provided by the amounts of grain available for consumption can be used to estimate whether or not this stored crop exceeds the requirements of a household. In the case of Rockanje, the amount of barley that can be used for consumption in the granary without a wall equals to 11.1 million kcal. For Simonshaven, this value is 10.7 million kcal for barley or 9.5 million kcal for emmer.

The requirements of eight inhabitants remaining after subtraction of the calories provided by meat and milk are 4.6-5.4 million kcal. The potential overproduction is therefore considerable. If the floor had a wall of only ca. 6.5 cm height, the granaries would provide an additional capacity of 1 m³. A wall of ca. 35 cm would increase the storage capacity by 5 m³, which corresponds to 3620 kg of pure barley for consumption or 3105 kg of emmer. In that case, the surplus in Rockanje may have been amounted to ca. 17.3-18 million kcal, or over 5400 kg of pure grain. If we assume with Davies (1971: 123) that a Roman soldier consumed one third of a ton of grain per year, corresponding to ca. 3000 kcal/day, the surplus produced by a farm with probably eight inhabitants may have been sufficient for sixteen soldiers. In the following paragraph, it will be calcu-

lated whether this overproduction is feasible in terms of land and labour required.

6.6.4   The feasibility of the models for food consumption

The calculations presented in the previous paragraphs are not informative until it is assessed whether the areas of grain required to fulfil the requirements in the Iron Age or to fill the granaries in the Roman Period are feasible. Both the available amount of arable land in the wetland area of Voorne-Putten and the available amount of labour may have been limiting factors. The area of land needed for pastoral farming must also be assessed.

6.6.4.1   The area of land required

The area of land that is required for the farms must comprise of both arable and pastoral land. During the Early Iron Age, probably not more than one single farm existed any one time in the peaty area. They are situated in the surroundings of the present Bernisse as other parts of Voorne-Putten have not yielded any traces of Early Iron Age habitation. If the worse archaeological visibility of the Early Iron Age is compensated, few synchronous households may have existed.

In the model, the inhabitants of a large Early Iron Age farm had fourteen head of cattle, two horses, four sheep and two pigs in winter. This number of housed animals had to be provided with fodder. If we assume that 200-225 kg of reed hay per month is needed per head of cattle or horse (see 6.3.1), 3200-3600 kg of reed is required for winter fodder per month. If the animals were housed for four months, the amount required would be 12,800-14,400 kg.

The amount of hay that can be harvested from one ha is estimated by Gregg. The lowest recent hay yields are from natural meadows on low-lying damp soils, where hay yields are 1470 kg/ha (Gregg 1988: 108). However, this estimate is very low. Drost (1986) stated that in reedlands, 7000-12,000 kg of dry matter is produced per ha. Near the Lauwerszee, a production up to 13,000 ka of dry matter was measured in reedlands (Drost et al. 1983). These vegetations are better comparable to the ruderalised reed vegetations on Voorne-Putten during the Iron Age and the Roman Period. Since the reedlands cannot have been turned into hay completely, a yield of 3500 kg of reed per ha will be used next to Gregg's hay yield. For the amount of reed hay needed in our Early Iron Age farm with ten stalls, ca. 8.7-9.8 ha are required if Gregg's estimate is used, whereas 3.7-4.1 ha are appropriate if 3500 kg of reed is harvested from 1 ha. The storage of this large amount of reed hay must have required special structures, such as hay-stacks. Their traces would be difficult to recognize in excavations.

For the eight months that cattle and horses fed on pastures, 2-5 ha per individual would have been needed, sheep

require 0.7-1.7 ha of pasture for one year. The 4-7 calves and 2-3 lambs also required pasture. It is assumed here that they required half the amount of adult cattle and sheep, respectively. Therefore, another 4-7.5 ha may have been required for the calves and 0.7-1 ha for the lambs. The total area for grazing for domesticates would amount to 27-70 ha. For grazing plus hay 31-80 ha would be required in the Early Iron Age farm with ten stalls.

The amount of grain needed by six inhabitants and a baby to supplement the calories provided by meat and milk in a farm with ten stalls is 665-910 kg (see *6.6.3.1*), while four inhabitants would need 152-394 kg of grain. If we again assume a yield ratio of 1:7 in fields planted in rows with 60 kg/ha of sowing grain, the net yield per ha is 360 kg. For 910 kg, ca. 2.5 ha of arable land are required. Although the levees have a fertile soil, for reasons of certainty a fallow period may be assumed. If allowance is made for a fallow every other year, 5 ha of arable land are needed.

The predominating cereal crops during the Early Iron Age are wheat and barley. Barley may have been cultivated on desiccated peat around the settlement, but this is not very likely in view of the crop weeds found. It will be assumed here that the 5 ha of arable land is to be sought on the deforested levees along the Meuse. The 5 ha of arable land provided roughly the same amount of calories as the 31-80 ha needed for domesticates.

Of the levees of the Meuse, a stretch of ten km length in the northern part of Voorne-Putten lies in the sphere of influence of fresh water, while 25 km lies in the brackish to salt zone. These levees were probably also exploited by settlements on the levees themselves. The fact that the pollen influx diagram of Spijkenisse 17-30 shows a decrease in oak pollen depostion of ca. 80% indicates that a considerable proportion of the *Hartholz-Aue* forest had been felled. As the remaining oaks will have profited from the improved light conditions, the deforested area might even have been more than 80% of the area covered by oaks. This quantity of felling cannot possibly have been achieved by one single Iron Age farm in the peaty area.

Since 5 ha of arable are required for a large Early Iron Age household, the levees along the Meuse (350 ha, see *6.6.3*) may have provided arable land for dozens of such farms. Since probably no more than a few farms existed at any one time in the peaty area, the area available will most probably not have been a limiting factor during the Early Iron Age. The amount of reedland available was very large, so this will not have imposed limits.

During the Middle Iron Age, three to four synchronous sites may have occurred in the peaty area, one on western Voorne and one near the Meuse. The available land will have been similar to that during the Early Iron Age. The five or six synchronous households may have had dozens of

counterparts on the levees without the area for arable and pastoral farming becoming scarce.

The number of Late Iron Age farms may have amounted to two to three synchronous farms in the Bernisse area and to two on western Voorne. The area of arable land available is considerably enlarged by 720 ha of Dunkirk I sediments around the Bernisse and 4100 ha on western Voorne. Hundreds of autarkic settlements could have been founded in this area.

The Roman Period shows the densest habitation on Voorne-Putten, with 30 synchronous settlements in the area around the Bernisse, 45 on western Voorne and 4 along the Meuse. Not only reedlands were available for grazing, but for the sites on western Voorne, the salt marsh could also have provided grazing territory.

The amount of animals kept in the Roman Period is assumed to be similar to that in a large Iron Age farm with ten stalls. In the reedlands, 31-80 ha were needed for the domesticates for grazing and winter fodder. Since the grazing density is higher in salt marshes (compare *6.3*), the area needed will have been smaller than in reedlands.

If we assume that the granaries were filled each year with grain grown by the inhabitants of the Roman farms, a yield of 2880 kg of pure emmer in Simonshaven or 3495 resp. 3365 kg of barley in Rockanje and Simonshaven (granaries without walls) to 5985-7120 kg of pure grain (granaries with walls of ca. 35 cm) would be required. If grain was planted in rows (60 kg/ha) and the yield ratio was 1:7, each ha would yield 420 kg. In that case, 14.3-17.0 ha of arable fields must have been available to fill a granary with walls. If it is assumed that a fallow was required every other year, which is a very cautious estimate, the area needed for cereals is 29-34 ha.

In the reedland situation, the total area needed in this model amounts to 31-80 ha for animals and to 28.6-34 ha for arable products. The 720 ha of Dunkirk I deposits near the Bernisse, if used for arable fields only, could have supported 21 to 25 farms. If these clayey sediments also were used for pasture, at least six farms could exploit this area. The much larger Dunkirk I sediments on western Voorne (4100 ha), where the salt marsh could have provided part of the grazing territory, could have supported at least 36 synchronous farms.

The estimated 30 farms that were present near the Bernisse thus probably could not all produce the amount of grain needed to fill granaries of the size found in Rockanje and Simonshaven. Besides, they had to reserve the Dunkirk I deposits around the Bernisse for arable fields. The drained peat that covered 7780 ha during the Roman Period must have been used for pasture, an area larger than required.

In contrast, the number of settlements on western Voorne remained far below the carrying capacity of the area for arable and pastoral farming.

6.6.4.2   The amount of labour required

In the production of food products, the severest time stress will have been posed by arable farming. Although the management of livestock will have required time spent every day, the large-scale events connected with the cultivation of crops have in many publications been regarded as bottlenecks (e.g. Brandt 1976; IJzereef 1981; Gregg 1988; Gross *et al.* 1990). The amount of reed with forbs to be harvested for hay in late summer may also have required a considerable investment of time.

For hay, it is best to harvest before the seeds ripen, as ripening of seeds lowers the quality of the hay. The presence of many unripe seeds in carbonized hay remains in a Roman horse stable confirms this practice (cf. Knörzer 1979). Most likely, hay was harvested shortly after cereals were.

Beranova (1989) described experimental harvesting of hay with replicas of Iron Age scythes from Bohemia. She calculated that harvesting one ha would require 47.5-62.5 hours. These data agree well with those provided by Steensberg (1979), who experienced that 1750 m^2 of barley could be harvested in 10 hours with a scythe. This corresponds to 57.5 hours per ha. This figure will be used for reed hay here. The 8.7-9.8 ha needed (according to Gregg) to feed livestock in a farm with ten stalls thus required 50-56 working days of ten hours for harvesting. The 3.7-4.1 ha suggested by Drost's data require 21-24 working days. Since the hay had to be transported and stored as well, the amount of labour required according to Gregg's data is most likely not feasible.

The time needed for ploughing has been assessed by several authors. According to Hansen (1969), ploughing with an ard (Døstrup type) with two trained oxen took place at a speed of 3.6-4.3 km/hr. The prehistoric ard marks found in excavations are ca. 25 cm apart (cf. Zimmermann 1984). This leads to 40 km of furrows for one ha. This means that ploughing and cross-ploughing of one ha requires ca. twenty hours or two working days of continuous ploughing.

According to Steensberg (1986: 143) and Reynolds (1987b), it takes about one day to plough and cross-plough one acre (4050 m^2), corresponding to 2.5 days per ha with an ard. Varisco (1982) observed that ploughing with an ard in Yemen took 3.3 days per ha with a span of two oxen. These data may be more realistic than those of Hansen, as turning the oxen and removing large objects were not included in his measurements. Ploughing with a mouldboard plough will have been slightly faster than with an ard. Cross-ploughing with a mouldboard plough is not necessary, but the field cannot be sown in rows after ploughing with this kind of plough. In that case, a drilling-ard would still be required. Alternatively, broadcast sowing and covering the seeds (for instance by raking or harrowing) is possible after mouldboard ploughing.

Ploughing can be carried out over a greater time-span than sowing or harvesting, so it will not have presented a limiting factor in the total area that could have been cultivated.

The time needed for sowing heavily depends on the method used (see *6.2.2*). Planting in rows implies that a distance of 40 km must be walked for every ha sown, whereas in broadcast sowing this may have been 2 km. If a speed of 1 km/hr is assumed, 1 ha would require four working days when planted in rows. Sigaut (1992) stated that sowing one ha in rows costs five working days. Moreover, according to him, a whole family has to be involved. A drilling ard would require 1.25 days (it is unidirectional!), but may also replace the cross-ploughing. 0.2 working days are required when 1 ha is sown broadcast. Sigaut (1992) stated that broadcast sowing of one ha takes 0.25 days. Raking, to cover the seeds, may have required another 0.5 days per ha. It is often assumed than one month is available for sowing and one for harvesting. In one month, one person could plant ca. 6.7 ha in rows (or 17.1 ha with a drilling ard), while 42.8 ha could be sown broadcast. As Sigaut (1992: 402) observed, the only advantage of sowing in rows is a saving on seed grain. The method of broadcast sowing seems primitive, however, it is actually a more advanced technique, which is only used in communities were the price of labour is relatively high.

It is not certain whether cereal fields were weeded. The yields in Butser Farm were obtained in fields that were usually weeded three times (Reynolds 1987b); this will be assumed for the Iron Age and Roman Period too. Weeding can be done more efficiently in fields that have been planted in rows. Weeds in the spaces between the rows can be eradicated rapidly. However, sowing in rows will also create more favourable light conditions for weeds than broadcast sowing. The time necessary for weeding is unknown. Weeding will probably not have been a limiting factor, since this could be spread over a relatively large time-span of several months.

Harvesting is the remaining process that will be considered here. The speed of harvesting is strongly influenced by the tools available. Steensberg (1979) assessed harvesting times required with different types of sickles. With modern, balanced sickles, 1000 m^2 could be harvested in 10 hours, which corresponds to 100 hours or 10 working days for one ha. With bronze sickles, ca. 500 m^2 could be harvested in 10 hours, or 20 working days for one ha. With flint sickles, ca. 400 m^2 was harvested in 10 hours, or 25 working days for one ha. Steensberg further cited Columella, who reported that harvesting 2500 m^2 of barley and 1600 m^2 of wheat with iron sickles required one working day (of unknown length). One ha of wheat would require six working days. Since harvesting was done by picking ears, as shown in 6.4.3, the experiments by Steensberg are of limited relevance.

Reynolds (1981a) stated that hand-picking was far more efficient than harvesting with flint sickles. Harvesting 2.5 ha could probably have been achieved within one month by one person. The data provided by Columella suggest that 15 working days might have been appropriate[4].

In conclusion, the maximum of 3 ha of arable land needed during the Iron Age can have been sown well within one month by a single person. Another 10 days will have been required for ploughing. If a conservative harvesting speed of 20 working days per ha is assumed, it would require about one months' labour for two persons. If instead the harvesting speed indicated by Columella is assumed, 15 working days are required to harvest this area. In view of the data provided by Steensberg for modern sickles (10 days per ha), Columella's data will not be used here as they may be too optimistic. Hand-picking of 2.5 ha may be estimated to have taken ca. one month for two persons. It can be concluded that harvesting produced the greatest bottle neck as far as available time is concerned.

These calculations may be compared to the situation in the Celtic fields. These are the Iron Age arable soils found on Pleistocene soils. The fields measure 30 × 30 m. It is assumed that the size of a Celtic field was chosen so that one field could be ploughed, sown and harvested in one day (Reynolds pers. comm). Harvesting of 0.09 ha in that case would last one day, corresponding to 2.7 ha in one month. This is within the range of the 2.5-3 ha in one month assumed above.

It is worth noting that this amount of labour is required for inhabitants of a site on Voorne-Putten where pastoral farming was an important element. This observation is of great interest in view of the Early Iron Age economy. If the inhabitants of the excavated farms did not grow their own cereals, they had to obtain them from inhabitants of the levees. However, these inhabitants also had to harvest cereals for their own consumption. If the inhabitants of the peaty area were specialized cattle breeders, the amount of cereal calories required by the inhabitants of the levees will have been higher. In consequence, they had to invest considerably more than one month for two persons in harvesting. In view of the small family sizes and the fact that harvesting was not the only task, these inhabitants would probably not have time to harvest cereals for their own demands and the extra amount required by the peat dwellers.

Gregg (1988: 161-162) assumed that sowing was the bottle-neck during Neolithic times. She pointed to the possibility that hunter/gatherers probably aided farmers in return for part of the yield. This mutualistic behaviour, according to her, is more favourable than competition, which is

"detrimental to interacting populations, [while] a mutualistic relationship is beneficial to both".

The same might apply to the relationship between Iron Age inhabitants of the levees and the peat, especially for harvesting. However, the difference with purely autarkic peat inhabitants that cultivated crops on the levees themselves, becomes very small, at least from an archaeological or palaeobotanical point of view. In conclusion, the inhabitants of the peaty area during the Iron Age lived in the grey zone between exchange and aid in harvesting, and own crop cultivation at a considerable distance.

For the Roman Period, 14.3-17 ha of grain was to be sown in rows and harvested to fill the a granary. If the time estimated above is correct, planting in rows would have cost 57-68 working days. Two people would probably not manage planting within one month. With a drilling ard, the amount of labour could be reduced to 18-22 days. Broadcast sowing would save even more time. This, however, will certainly have lowered the yield ratio. If a yield ratio of 1:4 is assumed for broadcast sowing of 200 kg/ha, 7.5-8.9 ha had to be sown to fill a granary with walls. However, the amount of grain to be saved for sowing the next year would amount to 1500-1780 kg. The potential overproduction of 5400 kg of grain (see 6.6.3.2) is considerably reduced. Not sixteen, but eleven soldiers could have been provided with grain for one year.

For harvesting the 14.3-17 ha of grain planted in rows, 286-340 working days may have been required (20 days per ha). This would necessitate seven to eleven persons, while a farm probably was inhabited by six or eight, of which five or six at a maximum could have been involved efficiently with harvesting. There is a probability that a granary was used by more than one household. However, in that case the surplus production would be considerably reduced. It is far more probable that broadcast sowing was practized to save labour.

In the case of broadcast sown grain, harvesting the 7.5-8.9 ha would still need 150-180 working days. This is at the upper limit of the feasibility for the inhabitants of one farm, as five to six harvesters would be needed. A higher yield ratio would lower the area to be harvested. However, in broadcast sowing, a yield ratio of more than 1:4 may be unrealistic (see also Sigaut 1992: 403).

The considerable difference between broadcast sowing and planting in rows has much less effect for the Iron Age situation. The area sown during the Iron Age was much smaller, and therefore also the amount of grain to be saved for sowing the next year would be smaller. The acceptance of broadcast sowing during the Roman Period would imply that the area available for arable farming around the Bernisse was a less limiting factor than in the case of planting or rows, since for each farm 17.8 ha at maximum would be needed instead of 29-34 ha (compare 6.6.3.1). It can be questioned whether the sowing method will leave any traces

in an archaeological context. The rake found in the Roman settlement of Nieuwenhoorn (cf. Van Trierum *et al.* 1988) may have served to cover the seeds after broadcast sowing. Significantly, Zimmermann (1984: 257) stated that the first rakes in northern Germany and the Netherlands are also of Roman age. This implement may have had other functions as well (e.g. hay-making), but raking of broadcast sown grain (first necessary during the Roman Period) is an appealing function.

In conclusion, the native Roman farms had the storage capacity, the area of land and the amount of labour to produce an amount of grain per farm, which was appropriate to feed ca. eleven soldiers. The production of this large amount of grain will have posed a considerable time stress upon the inhabitants.

6.7   The influence of the Roman occupation

6.7.1   INTRODUCTION

To be able to assess the influence of the Roman occupation of Voorne-Putten, it is first necessary to know the situation before the Roman occupation. In the previous paragraphs, an attempt was made to reconstruct the economy of the Iron Age sites, which were single farmsteads. A picture of regional or even local autarky seems the most probable on the basis of the investigations of botanical macroremains, pollen and wood. The absence of granaries near the Iron Age settlements on Voorne-Putten and their presence in coastal sites on mineral soils (Van Heeringen 1992: 313-318) may indicate that the emphasis lies on pastoral farming in the former and on arable farming in the latter environment. Apparently, the subsistence economy was not necessarily uniform, but rather differed with the environmental setting.

This picture closely resembles to the reconstructions of Roymans (1983) of the North Belgic tribes in the Late Iron Age. This area lies immediately south of Voorne-Putten. According to him (1983: 52),

"the economy is poorly integrated but rather characterized by a large degree of local and regional autarky. All traces are lacking of centralization and storage of tribute flows in regional and supra-regional centres. More or less urbanized oppida are unknown in the North Belgic area".

According to Roymans (1983: 53), there were hardly any contacts with the Roman world during the final part of the Late Iron Age. Besides,

"the infrastructure appears to be less developed in the area of the North Belgic tribes. Caesar frequently mentions almost impassible roads and hardly accessible forests and swamps. Bridges over larger rivers are not mentioned. This all indicates that the information and communication network was simple and weakly developed".

Slofstra (1983) also stressed the poor infrastructure of northern Gallia Belgica at the start of the Roman occupation.

In the same volume, Groenman-van Waateringe (1983)

reviews the drastic modification of the economy of natives in the Dutch East Indies and in East Africa after the advent of colonialism, as a reference for the situation during the expansion of the Roman Empire. These modifications are:
1. the native agricultural systems are disrupted in favour of production for an overseas market.
2. there is a move away from a small-scale mixed economy to large-scale monocultures.
3. the existing market and exchange patterns are dismantled, partly in order to exercise increased control.
4. a trading network is transferred into a taxation network.

Groenman-van Waateringe (1989: 101) distinguished three periods in the provision of food for the Roman army by the native people on the northwestern fringes of the Roman Empire. The first was during the campaigns, when the Roman army had to keep its supply lines continually in mind. The quality and quantity of food produced by the natives did not meet the army's demands. The Roman army is thought to have mainly requested wheat, whereas the Late Iron Age farmers, according to her, mainly cultivated barley on the poor Pleistocene sands and the more or less saline coastal areas. Davies (1971: 140) in this respect stated that barley was normally given to soldiers as a punishment.

The second period she distinguished was during the early phase of occupation, from the middle of the first to the early second centuries AD. In this period, because of the qualitative and quantitative differences between the Roman demands and the local production,

"something entirely new had to be constructed and that took time".

During this period, the Roman soldiers were forced to cultivate the military land around the forts themselves. Only during the second to the third centuries was a local food supply guaranteed according to Groenman-van Waateringe. This is also the period in which the large agrarian buildings in Roman style (*villae*) flourished.

According to Davies (1971), a major source of food for the Roman army in peace-time was provided by civilians of the provinces; this could take the form of requisitions or compulsory purchases at a fixed price.

The third period was towards the end of the Roman occupation in the second half of the third century and the fourth century. In this period, arable farming would have become less attractive to the native population because of soil exhaustion and erosion caused by over-exploitation on the poorer soils. Besides, the more fertile soils best suited for wheat cultivation were adversely affected by changes in the water level in marine, perimarine and riverine areas. As a result, grain had to be imported from Britain by ship, as is attested by historical sources.

In the light of all this, it is interesting to examine the results produced by the Roman sites on Voorne-Putten. This will be carried out in the following paragraphs.

6.7.2   NIEUWENHOORN 09-89: A NATIVE ROMAN SETTLE-
           MENT DURING THE EARLY PHASE OF THE ROMAN
           OCCUPATION

The four subsequent farms on this site could be dated by
means of dendrochronology (see *3.1.6*). The phases started
at 57 AD, 63 AD, 84 AD and 107 AD respectively, precisely
corresponding to Groenman-van Waateringe's phase 2 (see
6.7.1). She called this a period of change from subsistence
production, mainly of barley, to a surplus production of
wheat.

It is tempting to suggest that the absence of a granary on
this site may indicate a still relatively small-scale grain pro-
duction. Unfortunately, such a structure may well have been
missed, since the excavation trench stopped just outside the
house walls.

The crop plant remains of Nieuwenhoorn are dominated
by barley, while emmer occurs rather scarcely. At first sight,
the spectrum of crop plants seems to plead against an arable
overproduction for the Roman occupants, as this seems to
require wheat.

Interestingly, Groenman-van Waateringe and Pals (1983)
described similar abundant occurrences of barley in the
native Roman farmsteads in Assendelft, where again emmer
occurred scarcely. Palynological investigations on these same
sites, however, did yield dominant *Triticum* pollen grains.
Groenman-van Waateringe (1989: 100) interpreted these
data by assuming that wheat (*Triticum*) was produced, but
only to export it to the Roman army. Barley was kept for
own consumption. The fact that, according to Groenman-
van Waateringe, barley is the dominant crop in the Late
Iron Age fits in with this hypothesis. The export of wheat
may have occurred in Nieuwenhoorn too.

Some observations, however, plead against this hypo-
thesis. Firstly, large amounts of grain for the Roman army
seem to have been transported and stored as completely
cleaned grain. If all crop processing is indeed conducted on
the site of production, this would leave glume remains of
wheat on the site.

Secondly, Groenman-van Waateringe and Pals (1983: 154)
reported the regular occurrence of *Triticum*-pollen in the
Iron Age site of Assendelft site Q, where emmer grains and
spikelet forks were scarce. *Hordeum* pollen was absent on
site Q, but numerous barley grains and internodes were
found. Export of wheat from this site, where emmer is
thought to have been imported (cf. Therkorn *et al.* 1984:
368) seems out of the question. One might question the
certain identification of *Triticum* pollen grains, but the
elaborate documentation by Groenman-van Waateringe and
Pals (1983: 144-146) makes it rather undisputable. In
conclusion, the occurrence of *Triticum* pollen grains on a
site apparently may not coincide with its local cultivation.
Redeposition could be an explanation, but has been ex-
cluded by Groenman-van Waateringe and Pals.

Besides, in an environment which can be considered
unsuited to the cultivation of wheat, such as the peaty
environment of Nieuwenhoorn, barley could have been
grown for the Roman army. In view of the regular occur-
rence of barley in Roman castella (Neuß: Knörzer 1970;
Valkenburg: Van Zeist 1970) the avoidance of barley for
human consumption may have been not as strong as Davies
and Groenman-van Waatering suggested.

Pals *et al.* (1989: 129) in this respect concluded that

"the Roman influence in the Netherlands was not characterized by
a shift from barley to wheat, but merely by a diversification in
cereal types".

Furthermore, not the soldiers, but their horses may have
been the main consumers of barley. The large farms in
Nieuwenhoorn point towards a greater role for stock-
breeding on these farms as compared to those in Rockanje
and Simonshaven. The considerably higher share of grass-
land plants in Nieuwenhoorn as compared with Rockanje
(see *table 30*) also indicates a greater importance of stock-
breeding in the former settlement. Animal products could
have served as payment of the Roman tributes as well. Since
the botanical information mainly concerns the first two
building phases, it may also be possible that the economy
had not yet changed to the production of a surplus.

6.7.3   ROCKANJE II: A NATIVE ROMAN SETTLEMENT
           DURING THE CONSOLIDATION PHASE OF THE ROMAN
           OCCUPATION

This site dates from the second half of the second and the
first half of the third century AD. It is the period in which,
according to Groenman-van Waateringe, the local food
supply for the Roman army was more or less guaranteed.
The native economy had changed into an economy involv-
ing surplus production.

Most remarkably, the botanical macroremains of
Rockanje did reveal hardly any trace of wheat, barley is
practically the only crop attested. The fact that the settle-
ments are located in a salt marsh environment explains the
virtual absence of wheat, at least among cereals cultivated
locally. Furthermore, the farms in Rockanje were much
smaller than those in Nieuwenhoorn. If we interpret this as
evidence for a subordinate role of stockbreeding, what was
exported to meet the Roman demands? Several options can
be put forward. Firstly, salt making may have been an
important economic activity for the inhabitants of
Rockanje. In the Late Iron Age site of Rockanje pottery,
which is related to salt production is of considerable impor-
tance (Van Trierum *in press*). However, this pottery has not
been found in the Roman site of Rockanje (Hallewas *pers.
comm.*).

Secondly, barley may have been produced in surplus,
which is corroborated by the large granary on this site. The

Roman army may have used barley for its own consumption (see 6.7.2) or for feeding its horses. The fact that in the Dutch castella cavalries played an important role (Willems 1986), demonstrates the need for food for horses.

Thirdly, the farmers may have been horse breeders themselves. According to Thirsk (1965), a salt marsh provides excellent pasture for horses as well as for sheep. The surplus of barley produced could have served as winter food for these horses as well as serving as food for the humans. Two of the excavated houses in Rockanje are of such a size, that part of them could have served for housing livestock. Besides, it cannot be excluded that horses were kept outside in winter, so large farms with byres were probably not necessary.

In conclusion, the influence of the Roman occupation of Voorne-Putten is not clearly expressed. Only the appearance of large granaries and the diversification of house plans indicate that economic conditions did change quantitatively. Qualitative changes cannot be demonstrated. The fact that the investigated site of Rockanje may have been located close to a military settlement near Oostvoorne (see 1.2) is apparently of no influence.

6.8 Summary

In the small Iron Age farms on Voorne-Putten, with six stalls, livestock provided most or all of the proteins required by the inhabitants. If the farm was inhabited by four persons, ca. 47-67% of the yearly energy requirements was provided by animal products, in case of six inhabitants plus a baby, this figure corresponds to 31-44%. The remaining calories will have been provided by crops. Cereals will have constituted the main suppliers of vegetable calories, mainly in the form of carbohydrates. To supply the remaining calories, the four inhabitants needed 300-455 kg of grain per year, the six inhabitants plus a baby 850-1030 kg. These amounts of grain could have been grown on 1-3 ha if moderate yields are assumed.

In larger farms, with ten stalls, the protein requirements of six inhabitants will largely have been provided by animal products. The calories provided will have covered 58-84% of the needs of four inhabitants and 38-54% for six inhabitants and a baby. The grain needed to supplement the energy is 150-394 kg and 665-910 kg per year respectively. This amount can be obtained from 1-2.5 ha, assuming moderate yields.

One month of labour may be conceived as the maximum possible time for sowing and one month for harvesting the cereals. The time required to sow and harvest 1-3 ha is well below one month of labour for two persons. The land required will have been ca. 13-22 ha for the domesticated animals. This land could be found in the immediate surroundings of the site. If allowance is made for a fallow every year, 5 ha of arable land is the maximum requirement for

one farm. The levees along the Meuse provided enough arable land for dozens of Iron Age farms. This is much more than the probable number of synchronous farms, which in the peaty area may not have exceeded six (during the Middle Iron Age).

The point that can be raised against autarkic production of agricultural products is the 3-4 km distance between the levees along the Meuse and the Iron Age settlements. However, Chisholm (1968: 48) stated that

"the average distance to the cultivated land is commonly of the order of one kilometre or more and very frequently rises to three or four".

The alternative is that the inhabitants of the farms in the peaty area imported their cereals. An exchange of cereals for animal products during the Iron Age has been suggested by Van Gijn and Waterbolk (1984) and by Brandt and Van Gijn (1986). However, the amount of labour required to harvest cereals by any inhabitants of the levees for their own demands as well as for trade is too large to be feasible. They would have needed the assistance of the peat dwellers for harvesting and probably also for sowing. The difference between exchange and aid versus production by the peat inhabitants themselves is thus small, that it most probably cannot be traced archaeologically. Anyhow, at least on a microregional level, the society was autarkic.

The situation during the Late Iron Age was more favourable for arable farming, due to the Dunkirk I sediments that were deposited prior to the Late Iron Age. The settlements are located in the vicinity of or directly upon these clayey sediments. An autarkic subsistence economy is not hampered by the distance of the arable fields away from the homesteads.

The situation during the Roman Period differs in that a surplus production of agricultural products for the Roman army must be considered. The large farms in Nieuwenhoorn suggest a comparatively large importance of stockbreeding. It is assumed that livestock was equivalent to that in an Iron Age farm with ten stalls.

The amount of proteins provided by animal products will more or less have been sufficient for the needs of six inhabitants plus a baby. The energy requirements will have been covered for 38-54% by animal products. In cases of eight inhabitants, animal products will have covered 52-76% of the demands for protein and 25-36% for calories.

Granaries have been demonstrated near two of the three excavated Roman settlements on Voorne-Putten. The absence of a granary near Nieuwenhoorn is not conclusive, since the trenches hardly reached beyond the house walls on this site. The storage capacity of the granaries is large enough to store a surplus of ca. 5400 kg of grain.

The area of arable land required to grow this surplus of grain and to feed livestock will have been sufficient on

Voorne. Around the Bernisse, the carrying capacity of the area for crop raising was probably exceeded. If sowing was in rows, 16-22 ha would be required to produce this surplus. This could not have been harvested within one month by the inhabitants. If sowing was broadcast, 7.5-8.9 ha would be required if the yield amounted to 1:4. This is at the upper limit of the feasibility for the inhabitants. In this case, a larger part of the surplus must be reserved for sowing the next year. The remaining surplus of 3645-3900 kg could feed at least eleven Roman soldiers. The harvest will have been a period of enormous time stress for the family that had to produce this surplus.

The local inhabitants on Voorne-Putten had enough land to produce a surplus for the Roman army, the labour requirement may have been appropriate to reach a surplus production to feed at least eleven soldiers.

notes

1 In *A. fatua*, the glumes of the two grains in one spikelet both have awns, while in *A. sativa* only the lower grain may have an awn (cf. Körber-Grohne/ Bickelmann/ Leist 1988).

2 The recovery of samples of grain without chaff does pose some additional problems, as is clearly illustrated by Behre (1990b). He described a sample from Iron Age Rullstorf, which mainly consisted of carbonized naked *Avena* spec. grains (95.2%). The sample had been sieved on the site during the excavation. Kroll also took a sample on this site and sieved it himself. He found 99% *Avena sativa* in its chaff. Apparently, the carbonized seeds were "threshed" by sieving in Behre's material!

3 "Find-units" are pottery sherds, wooden posts and other artefacts (each specimen counting as one). The presence of dung also counts as one find-unit.

4 Gregg (1988: 161) stated that the figures provided by Steensberg (1979) suggest a harvesting time of 32.1 hours for harvesting one ha of wheat with flint sickles. However, Steensberg's data (cf. his table 12) yield figures of ca. 250-333 hours per ha (10,000 m^2) for flint sickles. On the basis of her erroneous calculations, Gregg concluded that the time needed for harvesting was no bottle-neck at all. Gross *et al.* (1990: 95), who based themselves on Gregg's publication, came to the same conclusion for Neolithic farmers.

Identification criteria of botanical macroremains occurring in the investigated sites

An exhaustive description of all the taxa encountered is not considered useful at the present state of palaeo-ethno-botanical research. In the past, many taxa from a great number of sites have been recorded and described by many authors. When palaeo-ethnobotany was still in its infancy, this proved very useful. Nowadays, however, it may be assumed that common species do not present identification problems, largely because of the thorough descriptions published earlier. Of course, the taxa included below represent a personal choice of the available material, based on the number of already existing descriptions known to me.

The material is stored in the palaeo-ethnobotanical laboratory of the *Instituut voor Prehistorie, Rijksuniversiteit Leiden*, and this material is available for examination.

The taxa are grouped per family, different families are treated alphabetically, as are the species per family. Measurements have an accuracy of 0.03 mm, except for seeds and fruits exceeding 3.6 mm, in which case the unit of measurement is 0.06 mm. Unless otherwise stated, measurements and descriptions concern waterlogged (uncarbonized) material.

Alismataceae
Sagittaria sagittifolia
Sp.17-35:598 (n = 1): 2.22 × 1.25 mm.

As far as I know (and this applies to all following descriptions), the embryo of *Sagittaria* has only been described by Wieserowa (1979: 146). Its U-shape (see *fig. 64*) is strongly reminiscent of the embryo of *Alisma plantago-aquatica*. The size, however, is larger, whereas this never exceeds 1.8 mm in *Alisma*. The size and shape of the *Sagittaria* embryo correspond closely to Wieserowa's description (2.4 × 1.3 mm) and to recent ones in our reference collection.

Callitrichaceae
Callitriche spec.
Sp.17-34:266 (n = 25): 1.18 (1.09-1.31) × 0.61 (0.48-0.70) mm.

The fruits of the *Callitriche* species offer the most reliable criteria in identifying recent species. Some are clearly winged, others are not. The preservation of the material in the samples containing *Callitriche* fruits is excellent without exception. The present fruits are clearly unwinged. *Callitriche obtusangula* is the only unwinged species, whereas the more common species *Callitriche platycarpa* has a small wing. It is, however, not clear whether the absence of the wing is an original feature in the subfossil material or whether it is caused by (unobserved) corrosion. The fruits have therefore not been attributed to a species.

Caprifoliaceae
Sambucus cf. *nigra*
Sp.17-35:598 (n = 1): 3.32 × 1.68 mm.

The seeds of *Sambucus nigra* are larger than those of *S. racemosa* and *S. ebulus* (cf. Knörzer 1970). However, Fredskild (1978) showed that there is a considerable overlap between these species, *S. ebulus* measuring up to 3.7 mm and *S. racemosa* up to 4.1 mm, while in *S. nigra* the length ranges from 2.7 to 4.7 mm. The width ranges also largely overlap, *S. ebulus*, however, is too wide for the present seed. Since the seed from Spijkenisse does not exceed the sizes of *S. racemosa*, it is presented only with reservation. The commonness of *S. nigra* and the present-day absence of *S. racemosa* in the Holocene part of the Netherlands are circumstantial evidence pointing to *Sambucus nigra*.

Caryophyllaceae
For the measurements of Caryophyllaceae, the length of the seeds is taken as the largest diameter and the width as the diameter perpendicular to it.

Arenaria serpyllifolia ssp *macrocarpa*
Nh.09-89:3039 (n = 1): 0.75 × 0.59 mm

The kidney-shaped seeds have blunt warts, in contrast to the similar small seeds of *Lychnis flos-cuculi*. The size normally reported for this species is up to 0.6 mm (cf. Körber-Grohne 1967; Knörzer 1967, 1970, 1973, 1975, 1981; Van Zeist 1974; Körber-Grohne/ Wilmanns 1977; Wasylikowa 1978; Wieserowa 1979; Pals 1987; Jacquat 1988; Jacomet et al. 1989). Only Dickson et al. (1970: 58) mention seeds ranging from 0.65 to 0.8 mm. They are attributed to ssp. *macrocarpa*, which occurs near the British coasts. Van der Meijden

et al. (1983) also mention this subspecies from coastal dunes in the Netherlands. The seeds of one specimen of this subspecies in our reference collection from the dune area near The Hague (the Netherlands, from *Rijksherbarium*, Leiden) measured 0.63 (0.58-0.69) × 0.50 (0.43-0.54) mm (n = 10). This size range thus shows an overlap with ssp. *serpyllifolia*. The taxonomic value of the two subspecies is at present being examined at the *Rijksherbarium* (F. Adema *pers. comm.*) and is beyond the scope of the present publication.

Moehringia trinervia
Sp.17-35:600 (n = 26): 1.11 (0.90-1.21) x 0.88 (0.74-0.98) mm.

The average size and the range of this sample are practically identical to the recent data mentioned by Knörzer (1971a). Furthermore, the lustrous, smooth seeds with faint, radial grooves on the edge are clearly different from all other Caryophyllaceae.

Stellaria aquatica and *Stellaria media*

Stellaria aquatica seeds resemble those of *Stellaria media*, although on average they are somewhat smaller. The criterion given by Wieserowa (1979) and Jacomet (1986) proved very useful in case of doubt; *Stellaria media* has small spines superimposed on the warts, the warts of *Stellaria aquatica* are bare.

Sagina species.

The very small seeds of *Sagina* were mostly found on the 1/4 mm sieve. According to Behre (1983), further identification of these species does not seem possible. Pals (1987), however, distinguishes a *Sagina apetala/procumbens*-type. Its

Table 37. Sizes of *Sagina* species.

Sagina apetala	
Hortus Genève: Genève, Switzerland	0.27-0.30 mm
Hortus Glasnevin: Bunclady, Ireland	0.29-0.35 mm
Rijksherbarium: Den Haag, Netherlands	0.26-0.32 mm
Hortus Helsingborg: Helsingborg, Sweden	0.28-0.35 mm
Sagina procumbens	
Botanische Garten Marburg: Marburg, Germany	0.26-0.32 mm
L.U. Wageningen: Wageningen, Netherlands	0.30-0.36 mm
Sagina maritima	
Rijksherbarium: Schiermonnikoog, Netherlands	0.40-0.49 mm
Hortus Helsingborg: Helsingborg, Sweden	0.37-0.42 mm
Sagina subulata	
Rijksherbarium: Harlingen, Netherlands	0.38-0.46 mm
Sagina nodosa	
Hortus Oslo: Bærum, Norway	0.37-0.48 mm
Hortus Helsinki: Kotka, Finland	0.45-0.55 mm

largest diameter is ca. 0.35 mm, and therefore smaller than *S. nodosa*, *S. subulata* and *S. maritima* (see also Kulpa 1974). Measurements of ripe seeds in our reference collection have largely confirmed these observations. In table 37, the largest diameters for 10 recent specimens per sample are given. (Measuring units are 0.016 mm).

Based on these data, two taxa within subfossil *Sagina* seeds were distinguished, i.e. *Sagina apetala/procumbens* with a largest diameter of ca. 0.35 mm and *Sagina nodosa*-type which measure at least 0.40 mm.

Sagina apetala/procumbens
Sp.17-34:279 (n = 11): 0.35 (0.32-0.38) × 0.26 (0.24-0.29) mm
Sp.17-35:612 (n = 6): 0.35 (0.34-0.38) × 0.27 (0.24-0.30) mm

This type is clearly more common than *Sagina nodosa*-type and in most, if not all cases, *Sagina procumbens* will be represented, which is a very common, tread-resistant species.

Sagina nodosa-type
Sp.17-34:515 (n = 2): 0.48 × 0.36; 0.57 × 0.46 mm
Gv.17-55:2 (n = 1): 0.56 × 0.43 mm

This type was found in four samples, in two cases occurring in combination with dominant *Sagina apetala/procumbens* seeds, in the other two cases only *Sagina nodosa*-type was present. It seems unlikely that we are dealing with extraordinary large *S. apetala/procumbens*.

Silene vulgaris
Sp.17-34:279 (n = 1): 1.60 × 1.38 mm.

The size of these seeds is somewhat larger than in the other *Silene* (including *Melandrium*) species in our region (see also Jacomet *et al.* 1989). Furthermore, the criterion given by Knörzer (1981: 49) proved valuable, *Silene vulgaris* having 4-5 rows of warts in lateral view, the *Melandrium* species showing 7 of these rows in lateral view. This is also apparent in our reference collection.

Stellaria palustris
Div. (n = 5): 1.60 (1.54-1.64) × 1.19 (1.10-1.29) mm

The oblong seeds have protracted warts, as in *Stellaria graminea*, which has a more rounded appearance and does not exceed 1.3 mm.

Chenopodiaceae
Atriplex littoralis-type
Div. samples (n = 5): 2.64 (2.54-2.85) × 2.35 (2.02-2.66) mm
Nh.09-89:3035 (n = 5): 2.57 (2.02-3.41) × 2.39 (1.98-3.07) mm

Table 38. Sizes of *Cirsium* species.

C. vulgare	
Eupen, Belgium: IPL, Leiden	3.66 (3.58-3.78) × 1.49 (1.41-1.60) mm
Hienheim, Germany: IPL, Leiden	3.69 (3.52-3.90) × 1.43 (1.28-1.60) mm
C. oleraceum	
Neustadt, Germany: IPL, Leiden	3.96 (3.46-4.29) × 1.59 (1.41-1.79) mm
Hienheim, Germany: IPL, Leiden	3.61 (3.26-3.90) × 1.52 (1.41-1.73) mm
C. palustre	
Helsingborg, Sweden: Bot. Garden Heslingborg	3.05 (2.69-3.26) × 1.22 (1.15-1.31) mm
München, Germany: Botanical Garden München	3.30 (3.07-3.46) × 1.29 (1.22-1.34) mm
C. arvense	
Heemstede, Netherlands: IPL, Leiden	3.09 (2.82-3.26) × 1.15 (1.09-1.22) mm
Amersfoort, Netherlands: IPL, Leiden	3.60 (3.20-3.84) × 1.24 (1.09-1.34) mm

For this type Van Zeist (1974) has been followed. He distinguishes this type having a largest diameter exceeding 2 mm, it includes *A. littoralis* and *A. prostrata (hastata)* var. *salina*. It has a distinct reticulate pattern on the surface.

Chenopodium glaucum
Rock.1-0-6 (n = 10): largest diam 0.98 (0.90-1.06) mm

Chenopodiaceae seeds without visible hilum and smaller than 1.2 mm (and with a smooth surface in contrast to unripe *Atriplex* seeds) belong to *C. glaucum* or *C. rubrum*. On the basis of our reference material it proved possible to distinguish the two species. *Chenopodium glaucum* has a circular outline and is on average larger (0.8-1.2 mm) than the elongated seeds of *Chenopodium rubrum*, which usually do not exceed 0.9 mm (see also Guinet 1959). In some cases, a few questionable seeds occurred in samples with many *Chenopodium rubrum* seeds. Only in Rockanje could *Chenopodium glaucum* be demonstrated unambiguously.

Chenopodium polyspermum
Sp.17-34:289 (n = 1): largest diam. 1.15 mm, thickness 0.61 mm

Only one seed of this species was found in the present study. It corresponds exactly to the descriptions in the literature consulted. It has a radial pattern on both sides of the seed, in contrast to *Chenopodium ficifolium*.

Salicornia europaea s.l.
Sp.17-30:309 (n = 8) 0.76 (0.68-0.86) × 0.54 (0.47-0.67) mm

According to Van der Meijden (1990), this taxon can be divided into three species, *S. disarticulata*, *S. europaea* s.s. (= *S. brachystachya*) and *S. procumbens* (= *S. dolichostachya*). The latter species has 1.0-1.7 mm long seeds compared to 0.6-1.4 mm long seeds in the first two species. Apparently, *S. procumbens* is absent in the present material. This species occurs mostly below mean sea level, while *S.*

europaea s.s. is mainly restricted to places above this level. *S. disarticulata* occurs on still higher places and is very rare, which renders *S. europaea* s.s. as the most likely species in our material.

Compositae
Artemisia cf. *vulgaris*
Rock.2-0-12 (n = 18): 1.18 (1.02-1.30) x 0.48 (0.40-0.62) mm

The oblong seeds offer very few characteristics for identification in magnifications up to 50x. Fortunately, in Rockanje, one uncarbonized seed was found to be covered by numerous pollen grains, which could be identified as *Artemisia* spec. (see *fig. 98*). In microscopic view (ca. 100 ×), the seed surface appeared to consist of rows of slightly S-shaped cells (see *fig. 99*). These characteristically shaped cells could also be seen in specimens in other samples which lacked the accompanying pollen grains (see also Jacomet *et al.* 1989). In some specimens, this cell pattern was covered by long, bifurcated projections, which remind one of those found in *Juncus*.

Bidens cernua

Apart from the commonly used criterion based on the number of projections (mostly 4, while 2-3 in *B. tripartita*), the shape also proved to be a reliable criterion. As mentioned by Behre (1983: 169), *B. cernua* fruits taper toward the base, whereas *B. tripartita* has a broader base (see also Katz *et al.* 1965, *fig. 4* and *5*).

Cirsium species

Behre (1976c: 119) presented measurements of recent fruits of the *Cirsium* species. His measurements are based upon 20 fruits per species. In table 38, measurements of another 20 fruits from our reference collection are presented. For each species, two samples from different places were measured, 10 fruits per sample.

On the basis of both data, the length can generally be used to distinguish *C. arvense* and *C. palustre* (average less than 3.6 mm) from *C. vulgare* and *C. oleraceum* (more than 3.6 mm). The width does not seems to be a useful criterion in distinguishing the species within these two groups, in contrast to the suggestion in the data of Behre. In Behre's material, *C. vulgare* has a larger average width than *C. oleraceum*, while the reverse is true in our reference material. Behre also mentions a difference in the collar of these species. *C. vulgare* has an oblique collar, whereas it is straight in *C. oleraceum*. This is also the case in our reference material and seems a better characteristic to distinguish these species than the width.

Concerning *C.palustre* and *C. arvense*, Behre's data reveal that the width of *C. palustre* is larger. In our material they are almost equal. According to Behre, the collar of *C. palustre* is oblique, while only slightly so in *C. arvense*. Unfortunately, this is not confirmed in our reference collection. In both species the two types occur regularly, although in *C. arvense* the majority of the collars are straight. Van Zeist (1974) indicated the presence of longitudinal ribs for seeds of *C. palustre*. In the best preserved specimens this proved to be an additional characteristic of some use. In fruits in a more corroded state, however, these ribs probably cannot be seen.

Cirsium arvense-type
Sp.17-34:div.(n = 2): 2.70 × 0.94 mm; 3.10 × 1.10 mm

Because of the very small width, it seems most likely that we are dealing with *C. arvense* here (see *fig. 65*). Apart from these seeds, seven fruits occurred in sample Sp.17-35:598 within the length range of *C. arvense/palustre*. The width ranged from 0.90-1.56 mm. It proved impossible to demonstrate a clear boundary, so in this sample no separation was made.

Cirsium palustre
Div.(n = 5): 3.33 (3.13-3.68) × 1.48 (1.34-1.66) mm

Because of their longitudinal ribs, the seeds were attributed to *C. palustre*. Owing to flattening the width is probably not representative (see *fig. 66*).

Cirsium vulgare
Rock.10-2-56 (n = 1): 3.52 × 1.92 mm.

All the larger *Cirsium* seeds found have an oblique collar, so they have been attributed to *C. vulgare* (see *fig. 67*).

Senecio aquaticus
Sp.17-35:612 (n = 25): 1.77 (1.41-2.24) × 0.66 (0.48-0.80) mm

The attribution of seeds to this genus is based on the 10-12 faint ribs and the collar-like pappus-base (cf. Knörzer 1981). Our reference material revealed that the small size of the present fruits excludes the larger *S. congestus*, *S. fluviatilis*, *S. fuchsii*, *S. paludosus* and *S. viscosus*, while *S. sylvaticus* and *S. vulgaris* are more slender (see also Knörzer 1970). *S. erucifolius* and *S. jacobaeae* are of comparable size to *S. aquaticus*. In these species, however, the ribs are more pronounced. The present seeds correspond in detail to *S. aquaticus* only (see *fig. 68*).

Xanthium strumarium
Zl.17-27:8 (n = 11): 11.81 (10.61-13.10) × 8.10 (7.07-9.17) mm

The fruits of *Xanthium strumarium* are highly characteristic. Their size, the hooked spines on the surface and the two apical points are of great diagnostic value (see *fig. 69*).

Convolvulaceae
Calystegia sepium
Ro.08-52 (n = 1): 5.0 × 4.1 mm

The large seeds have a conspicuous, more or less triangular hilum (Knörzer 1970). The surface of *Calystegia* is smooth, in contrast to the warty surface of *Convolvulus arvensis* (see *fig. 70*). *Calystegia soldanella* has even larger seeds than *C. sepium* (see also Frank/ Stika 1988).

Cruciferae
Brassica rapa (= *B. campestris*)
Sp.17-30:126 (n = 21): largest diameter 1.85 (1.54-2.30) mm

More or less globular Cruciferae-seeds belong to *Brassica*, *Raphanus* or *Sinapis*. *Raphanus*-seeds are in general larger than *Brassica* and *Sinapis* and the seed wall shows a distinct reticulum. *Sinapis*-seeds have a fainter reticulum than seeds of *Brassica* (cf. Van Zeist et al. 1987).

The identification of *Brassica* seeds posed great difficulties to many authors. Wieserowa (1979) identified all four species (*B. rapa*, *B. napus*, *B. nigra* and *B. oleracea*) from Polish cesspits. The criteria she mentions (which apparently have been overlooked in a range of later publications) were tested on recent material. The shape of the meshes on the seed coat were studied with the use of a Leitz-microscope with incident light, at a magnification of 100x. To avoid incorrect identifications the recent seeds were collected from specimens of the *Rijksherbarium* in Leiden. Dr. R. van der Meijden checked the identifications and subsequently seeds of the clearest examples of each species were sampled. The criteria of Wieserowa allowed to distinguish three of the four species. *Brassica rapa* (= *B. campestris*) has a reticulum with polygonal meshes (honeycomb-shaped). Around the hilum

Table 39. Sizes of *Cochlearia* species.

C. danica Amsterdam, Netherlands: Hortus Vrije Universiteit	1.08 (1.02-1.24) × 0.91 (0.80-0.99) mm
C. officinalis Frankfurt, Germany: Botanical Garden	1.44 (1.27-1.55) × 0.95 (0.90-1.21) mm
C. anglica Schiermonnikoog, Netherlands: Rijksherbarium Leiden	1.75 (1.67-1.86) × 1.28 (1.18-1.40) mm

the meshes become more elongated and less clearly visible. In *Brassica nigra*, polygonal meshes are also present, but they do not change towards the hilum. The reticulum is more conspicuous than in *B. rapa* (see Berggren 1981: 126-127). A very clear, subfossil example of *Brassica nigra* has been published by Vermeeren (1990: 146), although the identification at that time was *Brassica rapa/nigra*. *B. oleracea* has elongated meshes all over the surface. *B. napus* according to Wieserowa has a very indistinct reticulum of subrectangular meshes. However, this was more variable in our material. In some cases, the reticulum was completely absent (even at a magnification of 250x). However, if present, the reticulum did consist of subrectangular meshes all over the surface, thus resembling the reticulum of *B. oleracea*. Our observations concerning *B. napus* more or less parallel the description by Berggren (1981) concerning the meshes. Körber-Grohne's (1967) observation of *B. napus* seeds with polygonal meshes becoming elongated towards the hilum must be due to hybridization with *B. rapa* or misidentification of the material. The sizes Wieserowa mentions seem less reliable, if our reference material is followed.

In view of Wieserowa's criteria (excepting size), the subfossil material from Voorne-Putten could clearly be attributed to *Brassica rapa*, if the area around the hilum was present. If this was absent, the reticulum always was reminiscent of this species, so no other *Brassica* species is present (see *fig. 71*).

Cochlearia officinalis
Rock.08-52:1076 (n=1): 1.40 × 1.00 mm

Cochlearia seeds have very conspicuous papillae. The published sizes of the seeds of the three species are somewhat confusing. According to Berggren (1981), *Cochlearia danica* has smaller seeds (average 1.1 × 0.8 mm) than *C. officinalis* and *C. anglica* (both ca. 1.5 × 1.0 mm). Behre (1976c) stated that *C. anglica* has larger seeds (ca. 1.8 mm long), while he reports that *C. danica* differs from *C. officinalis* in the arrangement of the papillae, but he does not mention a difference in size.

Measurements of specimens in our reference collection revealed averages and ranges as shown in table 39 (n=10).

The ranges for *C. danica* and *C. officinalis* were supported by two resp. three other specimens. The sizes, apparently, can be used to separate these species. Besides, *C. danica*

shows coarser papillae than the other two species. Figure 72 depicts the subfossil specimen.

Erysimum cheiranthoides
Rock.1-0-6 (n=25): 1.62 (1.41-1.82) × 0.91 (0.80-1.09) mm

In Rockanje two samples with large numbers of a cruciferous species were analysed. The seeds have a pointed radicle and small, blunt papillae. They show a close similarity with recent *Erysimum cheiranthoides* seeds. Van Zeist (1974) is the only author who described these seeds, he reported a comparable size-range. According to him, the papillae are spine-like. However, on examination with a transmitted light microscope, the recent seeds show blunt papillae, as do the subfossil ones (see *fig. 74*).

Lepidium ruderale
Rock.10-2-58 (n=4): 1.06 (0.91-1.23) × 0.66 (0.53-0.75) mm

The seeds of this species are small and resemble those of *Capsella bursa-pastoris*. In contrast to the latter species, the radicle is as wide as the cotyledons and both point upwards (see *fig. 73*). In *Capsella*, the tip of the radicle curves above the cotyledons. The seed drawn by Körber-Grohne (1967) as *Lepidium ruderale* in my opinion belongs to *Capsella*. Other finds of *Lepidium ruderale* are unknown to me.

cf. *Sinapis arvensis*
Zl.16-15:1 (n=1): 1.35 × 1.20 mm.

In this sample, one and a half mineralized, globular, cruciferous seeds were found. The reticulate surface pattern is as small as in *Sinapis*. Since the seeds are mineralized, it is uncertain whether this reticulum concerns the same cells as those that can be seen in recent material, only a tentative identification was therefore possible.

Sisymbrium officinale
Rock.1-0-6 (n=4): 1.54 (1.44-1.65) × 0.74 (0.63-0.81) mm
Sp.17-35:612 (n=25): 1.47 (1.22-1.89) × 0.99 (0.74-1.12) mm

The seeds of this species do not have papillae, in contrast to *Erysimum*. The cells are arranged in longitudinal rows. The truncated base and apex are characteristic (see *fig. 75*).
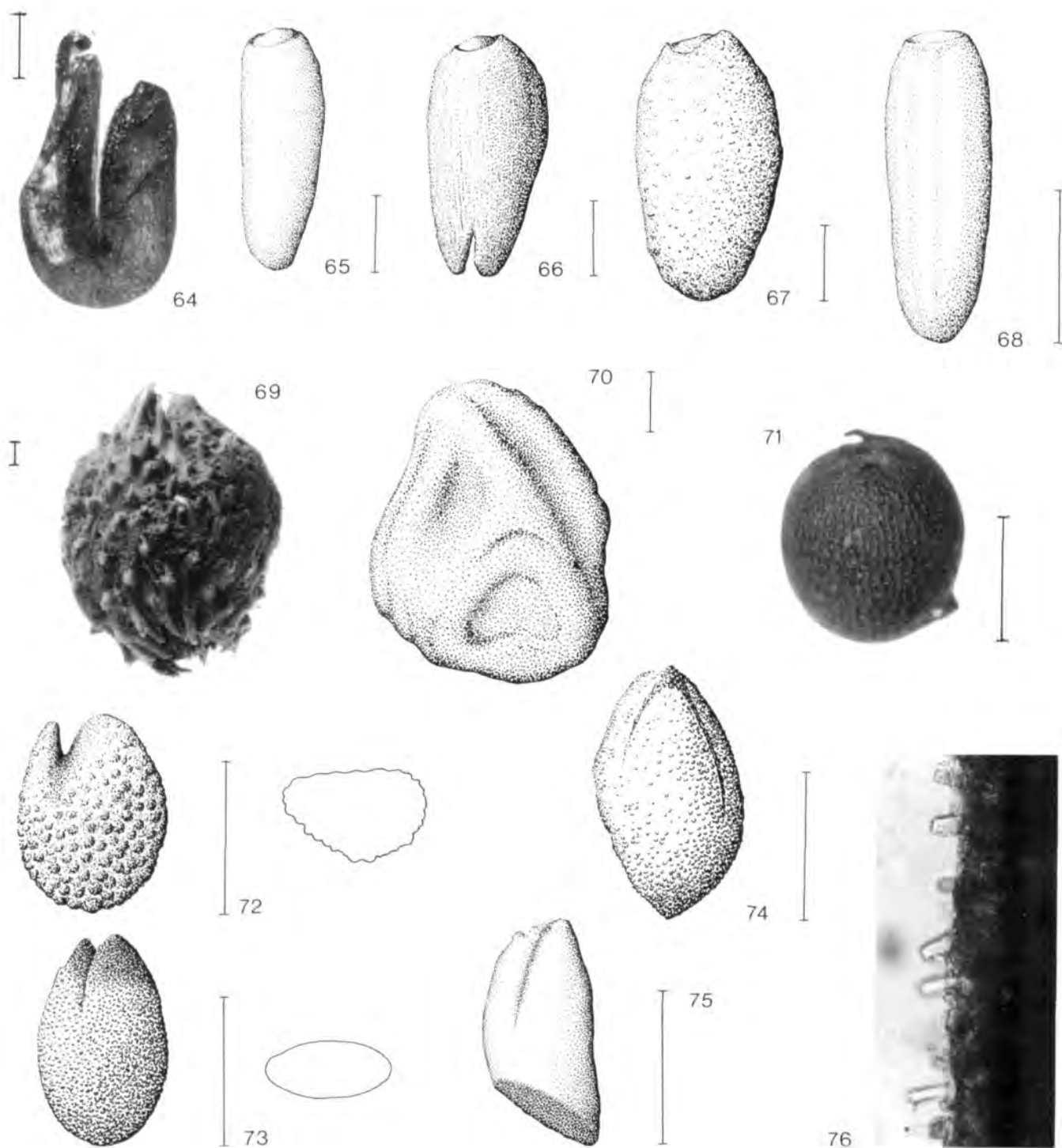
This is caused by the neighbouring seeds in the pods (cf. Kroll 1987). Seeds with more room are less truncate, resulting in a great variation of shape (cf. Kulpa 1974). Seeds of *Cardamine pratensis* are also angular in shape, but are not obliquely truncated.

Cuscutaceae

Cuscuta epilinum
Sp.17-34:311 (n = 1): 1.82 × 1.54 mm
Nh.09-89:3001 (n = 1): 1.50 × 1.10 mm

The seeds of *Cuscuta* species show faint ridges and have a rough, sponge-like surface. The different species can be distinguished on the basis of their largest diameter (cf. Van Ooststroom 1942). *C. europaea* and *C. epithymum* measure around 1 mm, *C. lupuliformis* 2.5-3 mm and *C. epilinum* 1.5-1.75 mm. According to Pals and Van Dierendonck (1988), *C. campestre* has the same size as *C. epilinum*, but it lacks the rough surface. Consequently, the present specimens belong to *Cuscuta epilinum*.

Cyperaceae

Carex

The identification of sedge nutlets is generally considered to be very difficult, not in the least because often only the nutlets (called seeds hereafter) and not the more characteristic utricles (perigynia) are recovered. Therefore, often only a group of species or tentative ("cf.") identifications can be reached. Jacomet *et al.* (1989: 317) published a diagram with lenghts and widths of central European *Carex* species, which is very useful for a first selection.
All measurements of Cyperaceae exclude the beak.

Carex acuta-type
Sp.17-35:600 (n = 32): 2.02 (1.68-2.34) × 1.59 (1.17-1.87) mm
Sp.17-34:337 (n = 4): 1.72 (1.50-1.86) × 1.25 (1.18-1.31) mm

This type has flat seeds characterized by a broad base and distinct epidermis cells (cf. Van Zeist 1974); it includes *C. acuta*, *C. elata* (= *C. hudsonii*), *C. nigra* and *C. trinervis*. The shape is obovate to almost sphaerical. Pals (1987) discusses in detail the different species belonging to this type. He concludes that his material most closely resembles *C.*

nigra, but recent material shows considerable overlap between the species. In the present study, a large range of forms and sizes was found in one sample (Sp.17-35:600), it proved impossible to distinguish distinct types, so it was decided to lump them all together as *Carex acuta*-type (see *fig. 77*).

Carex acutiformis
Sp.17-35:598 (n = 5): 2.02 (1.92-2.08) × 1.24 (1.09-1.34) mm
Sp.17-35:600 (n = 3): 1.79 (1.60-2.10) × 1.12 (0.97-1.29) mm

The seeds are triangular. The greatest width lies in the middle, which results in a more or less elliptic outline (see *fig. 78*). The shape closely resembles that of *C. rostrata*. The latter species, in our reference collection, has a remarkably light colour. This is also apparent in subfossil material. Berggren (1969) mentions the great difference in colour in recent material as well (p.46). *C. rostrata* is also somewhat smaller than *C. acutiformis* (cf. Berggren 1969). *C. vesicaria* is often reported in one and the same breath with *C. rostrata*. According to Berggren, however, *C. vesicaria* has somewhat larger and wider seeds measuring 2.1 × 1.4 mm on average. This is also apparent in our reference collection. Its colour is still lighter than *C. rostrata*.

Carex cuprina-type (= *C. otrubae*-type)
Sp.17-30:123 (n = 16): 2.25 (2.11-2.43) × 1.60 (1.44-1.76) mm
Sp.17-34:311 (n = 3): 2.31 (2.24-2.43) × 1.40 (1.22-1.50) mm
Sp.17-35:598 (n = 5): 2.20 (2.08-2.37) × 1.62 (1.50-1.82) mm

This type has broadly ovate to slightly pear-shaped seeds and the surface has a wart-like appearance when examined at a magnification of 200x (see *fig. 79*). According to Berggren (1969), *C. cuprina* has epidermis cells of 25-30 μm in diameter, while those of *C. vulpina* are 40-50 μm in diameter. In our reference material (which was correctly identified according to the nervation of the utricles), there was no difference in the sizes of the epidermis cells between *C. cuprina* and *C. vulpina*. More or less complete utricles were not found in the present study, so the highly diagnostic criterion of difference in the nervation on the two sides of *C. vulpina* utricles could not be used. Since *Carex cuprina* is by far the more common species in the Netherlands, the type was named after this species here.

Fig. 64 *Sagittaria sagittifolia* (12x). Sp.17-35:598.
Fig. 65 *Cirsium arvense* (12x). Sp.17-34:337.
Fig. 66 *Cirsium palustre* (12x). Sp.17-34:279.
Fig. 67 *Cirsium vulgare* (12x). Rock. 10-2-56.
Fig. 68 *Senecio aquaticus* (25x). Sp.17-34:337.
Fig. 69 *Xanthium strumarium* (4x). Sp.17-35:612.
Fig. 70 *Calystegia sepium* (10x). Ro.08-52:1073.

Fig. 71 *Brassica rapa* (20x). Sp.17-30:126.
Fig. 72 *Cochlearia officinalis* (25x). Ro.08-52:1076.
Fig. 73 *Lepidium ruderale* (25x). Rock. 2-0-12.
Fig. 74 *Erysimum cheiranthoides* (25x). Rock. 1-0-6.
Fig. 75 *Sisymbrium officinale* (25x). Rock. 1-0-6.
Fig. 76 Papillae of *Erysimum cheiranthoides* (600x). Rock. 1-0-6.
Scale bars equal 1 mm.

Carex distans
Rock.10-1-4 (n = 25): 2.13 (1.86-2.37) × 1.24 (1.09-1.50) mm

The slender, triangular seeds have a prominent cell pattern. The greatest width is at or slightly above the middle (see *fig. 80*). The descriptions and figures in Behre (1976c) and Körber-Grohne (1967) are directly comparable. The seeds of *C. extensa* resemble those of *C. distans*, but in *C. extensa* they are more slender, measuring ca. 1 mm in width (see also Kern/ Reichgelt 1954). Furthermore, the cell pattern of *C. extensa* is rather indistinct (Berggren 1969).

Carex disticha
Sp.17-35:600 (n = 25): 1.81 (1.63-2.07) × 1.06 (0.82-1.33) mm

As Körber-Grohne (1967) mentions, this species is extremely variable in the shape of its seed. It is flat, but sometimes so slender that the distinction with *C. elongata* becomes unclear. This led Behre (1983) to conclude that without utricles these two species cannot be separated. In our reference collection, the seeds of *C. disticha* and *C. elongata* showed a slight difference in the stipe. In *C. elongata*, no remains of the stipe adhere to the seeds, while *C. disticha* has a short stipe, which is abruptly truncated (see *fig. 81*). According to Behre (1976c), *C. disticha* has sharply keeled utricles, while *C. elongata* has not. The illustrations in Berggren (1969) show another clear difference. In *C. disticha* the utricles show fine, sawteeth-like projections along most of the sides, in *C. elongata* these are restricted to the upper quarter of the utricles. The characteristic appeared also clearly in our reference collection. On the basis of this criterion, the subfossil utricles proved to belong to *C. disticha* exclusively.

Carex hirta
Sp.17-30:309 (n = 1): 2.76 × 1.50 mm
Sp.17-34:306 (n = 1): 2.82 × 1.50 mm
Rock.10-2-52 (n = 1): 2.50 × 1.60 mm

The triangular seeds of this species are larger than most of the other triangular Carices (see *fig. 82*). Only *C. riparia* has similarly large seeds, these are, however, wider (cf. Knörzer 1970). The rough seed-surface of *C. hirta* also differs from *C. riparia*, which has a smooth surface.

Carex oederi s.l. (= *C. serotina/demissa*)
Rock.10-2-56 (n = 25): 1.36 (1.25-1.54) × 1.05 (0.93-1.38) mm

The small, triangular seeds have their greatest width just below the top, thus resulting in a distinctly shouldered outline (see *fig. 83*). The small size distinguishes them from the

similarly shaped *C. flava* and *C. lepidocarpa*. It is not possible to discriminate between *C. oederi* and *C. tumidicarpa* (cf. Van Zeist 1974; Pals 1987). Both authors give very similar size-ranges for their subfossil material attributed to this type.

Carex cf. *remota*
Sp.17-35:598 (n = 1): 2.07 × 1.29 mm

The flat, pear-shaped seed shows a distinct cell pattern on the surface. The shape reminds one of *C. cuprina/vulpina*, however, *C. remota* is more slender (see *fig. 84*). At a magnification of 200 ×, the cell pattern is clearly reticulate, in contrast to the wart-like surface of *C. cuprina/vulpina*. *C. ovalis* (= *C.leporina*) is of similar shape, but has a very indistinct cell pattern (cf. Berggren 1969).

Carex panicea
Rock.10-2-56 (n = 1): 1.95 × 1.73 mm
Sp.17-34:332 (n = 1): 2.11 × 1.50 mm

This species has seeds that are tapered and concave towards their base (see *fig. 87*). The size is larger than that of *C. paniculata*, which also has a tapered, concave basal outline.

Carex paniculata
Sp.17-35:598 (n = 3): 1.56 (1.44-1.76) × 1.01 (0.90-1.13) mm
Sp.17-34:279 (n = 2): 1.28 × 1.02 mm; 1.60 × 1.06 mm

More or less lozenge-shaped seeds widest in the middle and of a remarkably convex, basal outline (see *fig. 86*) are attributed to this species. The coriaceous utricle is often (partly) preserved, which allows the distinction between this species and *C. appropinquata* and *C. diandra*, with similarly shaped seeds (cf. Behre 1983). *C. paniculata* has only faint veins on the utricle, while *C. appropinquata* shows a very strong venation and *C. diandra* has one unveined side. According to Behre (1983), the seeds of *C. paniculata* are also smaller than those of *C. appropinquata*. However, Nilsson and Hjelmqvist (1967) and Jacomet *et al.* (1989) on the contrary state that *C. paniculata* has the larger seeds of the two. Since the size-ranges of both show a great overlap anyhow, it is considered that only utricles allow a reliable identification. Since only *C. paniculata* utricles were found, the bare seeds are also attributed to this species, which in addition is nowadays far more common in the Netherlands.

Carex pilulifera
Rock.10-2-56 (n = 1): 1.51 × 1.48 mm

The seeds are distinctly shouldered, the width almost equals the length (see *fig. 85*). The cross-section is almost circular, in contrast to the more triangular cross-section of *C. oederi*

s.l. The characteristic light ribs, as present in our reference material, could not be seen in the subfossil specimen, thus the identification remains tentative.

Carex pseudocyperus
Sp.17-34:279 (n = 3): 1.70 (1.63-1.79) × 1.01 (0.90-1.18) mm
Sp.17-34:337 (n = 1): 1.75 × 0.80 mm

The very regular, triangular seed (see *fig. 88*) is smaller than the other triangular and unshouldered Carices. The markedly nerved utricles with long beaks were also found (see *fig. 89*). The combination of these features is very characteristic of this species, thus making it more easily identifiable than most other *Carex* species.

Carex riparia
Sp.17-34:311 (n = 1): 3.04 × 1.92 mm
Sp.17-35:598 (n = 6): 2.94 (2.72-3.17) × 1.72 (1.44-1.98) mm

The large, triangular seeds resemble those of *C. hirta* (cf. Knörzer 1970). However, *C. riparia* seeds are wider, which gives them a plump appearance (see *fig. 90*). Besides, the seed wall is smooth, in contrast to the rough surface of *C. hirta*. According to Kroll (1987) and Körber-Grohne (1967), *C. acutiformis* seeds resemble those of *C. riparia*. In our reference material, however, there is a great difference in size and shape, which is also apparent in Berggren's illustration (1969, plate 36, *fig. 1* and 2). Some utricles were also found. They are dark with faint venation (see *fig. 92*).

Carex spec.
Zl.17-27:8 (n = 1): 1.54 × 0.93 × 0.83 mm

This triangular seed closely resembles *Carex oederi* s.l. However, the seeds are slightly longer and have less pronounced shoulders (see *fig. 91*). The seed most closely resembles recent *Carex flava*. As only one specimen was found and since *Carex flava* is also rare in the Netherlands, it was decided to list this seed, although very well preserved, as *Carex* spec.

Rhynchospora alba
Rock.10-2-52 (n = 1): 1.92 × 1.34 mm.

The seeds are obovate and biconvex. Twelve perianth-bristles are present. They are slightly shorter than the seed length (see *fig. 93*). The seed splits very characteristically, only adhering to its persisting style (cf. Grosse-Brauckmann 1974).

Schoenus nigricans
Sp.17-34:411 (n = 1): 1.57 × 0.93 × 0.90 mm.

Descriptions of this species in palaeo-ethnobotanical literature are unknown to me. The triangular seed has the greatest width just above the middle. The sides are convex with smooth angles. Most striking is the lustrous whitish colour, which is due to a high silicium-content of the seed wall and which does not occur in other Cyperaceae. The size is in accordance with recent seeds (derived from the Botanical Garden, Frankfurt a.M. (n = 10): 1.47 (1.30-1.67) × 0.98 (0.90-1.05) mm). The three to five perianth-bristles are not preserved in the subfossil specimen (see *fig. 94*).

Scirpus spec.

Körber-Grohne (1967) thoroughly discussed three common *Scirpus* species with more or less similar seeds (*S. maritimus, S. lacustris*(s.s.) and *S. (lacustris* ssp.) *tabernaemontani* (= *S. lacustris* ssp *glaucus*). Recent seeds can be distinghuished without much difficulty. *S. maritimus* is clearly shouldered, has seeds with a shiny surface and is the largest of the three. *S. lacustris* ssp. *tabernaemontani* is biconvex and smaller than the other two species. *S. lacustris* resembles *S.maritimus*, but is smaller and has a dull surface. According to Berggren (1969: 14), the average sizes are as follows: *S. maritimus*: 3.1 × 2.2 × 1.2 mm; *S. lacustris*: 2.7 × 1.9 × 1.0 mm; *S. lacustris* ssp *tabernaemontani*: 2.2 × 1.6 × 0.9 mm. Material sampled from specimens of the *Rijksherbarium* was in agreement with these sizes, so it was used to identify the fossil seeds.

Apart from these three species, however, another species must be considered. It concerns *Scirpus triqueter*, up to now neglected in palaeo-ethnobotanical literature. At present, it is a declining species especially occurring in freshwater tidal areas (Van der Meijden 1990). It hardly occurs in brackish environments. It is clear that this species cannot be left out of consideration.

Reichgelt (1956) gives some differences between the seeds of this species and those of the very similar *S. lacustris* ssp. *tabernaemontani*. The seed size is the same, about 2-2.5 mm. The perianth-bristles show some differences. In *S. triqueter*, mostly 4 (up to 6) relatively slender bristles are present, which are usually shorter than the seed length but they can equal this length. *S. lacustris* ssp. *tabernaemontani* has mostly 6 (sometimes 4-5) bristles, which are stouter than those of *S. triqueter* and longer than the seed length. The two specimens of *S. triqueter* in our reference collection supported these criteria. In all cases where perianth-bristles were present in the subfossil specimens, these were of the stout type. Besides, if well preserved, they were longer than the seed. Many, however, were broken. Furthermore, often six bristles (or remains) were noticed. The stoutness, however, is considered conclusive. Since no slender and short perianths were seen, all specimens without perianths were also attributed to *S. lacustris* ssp. *tabernaemontani*.
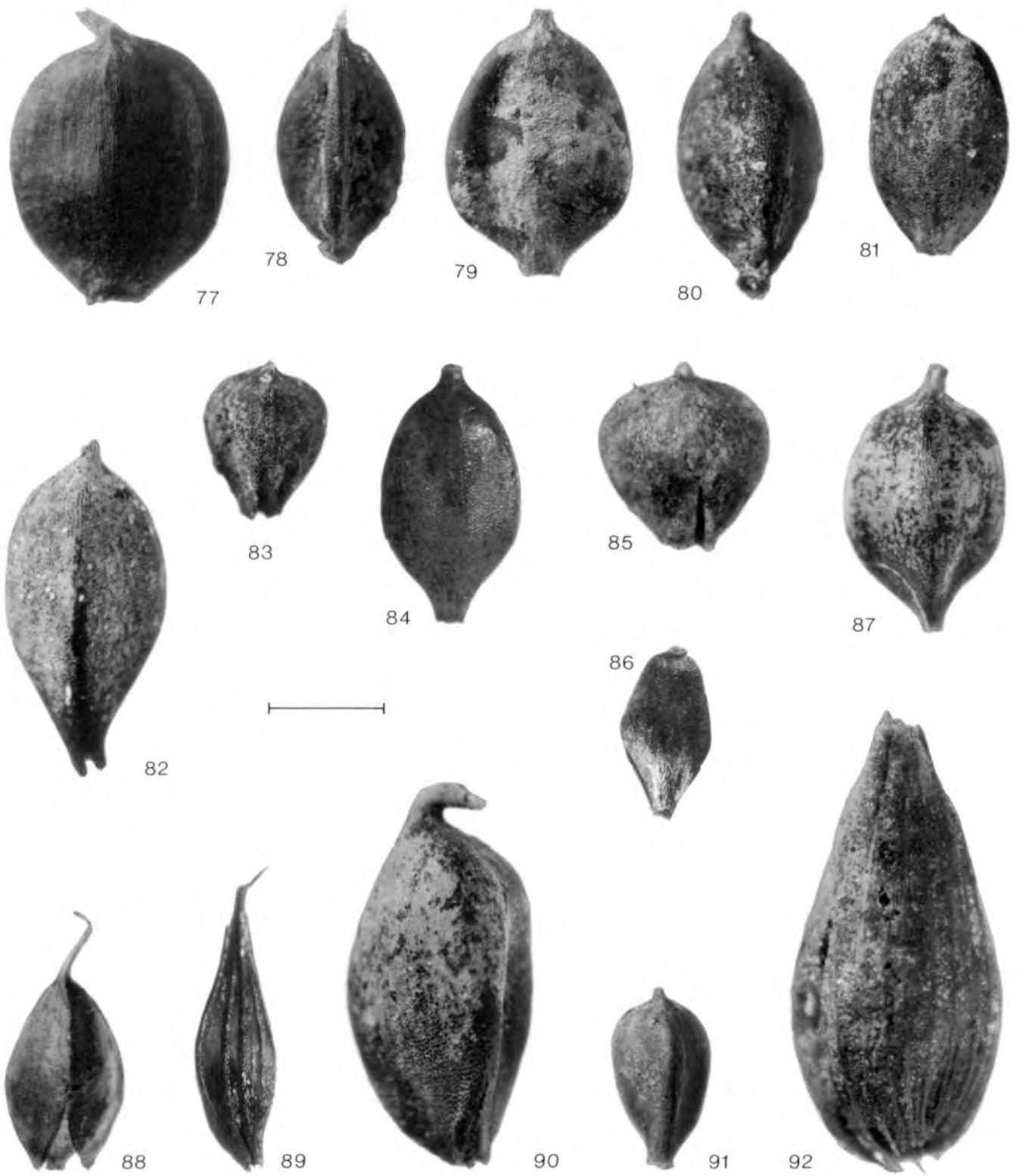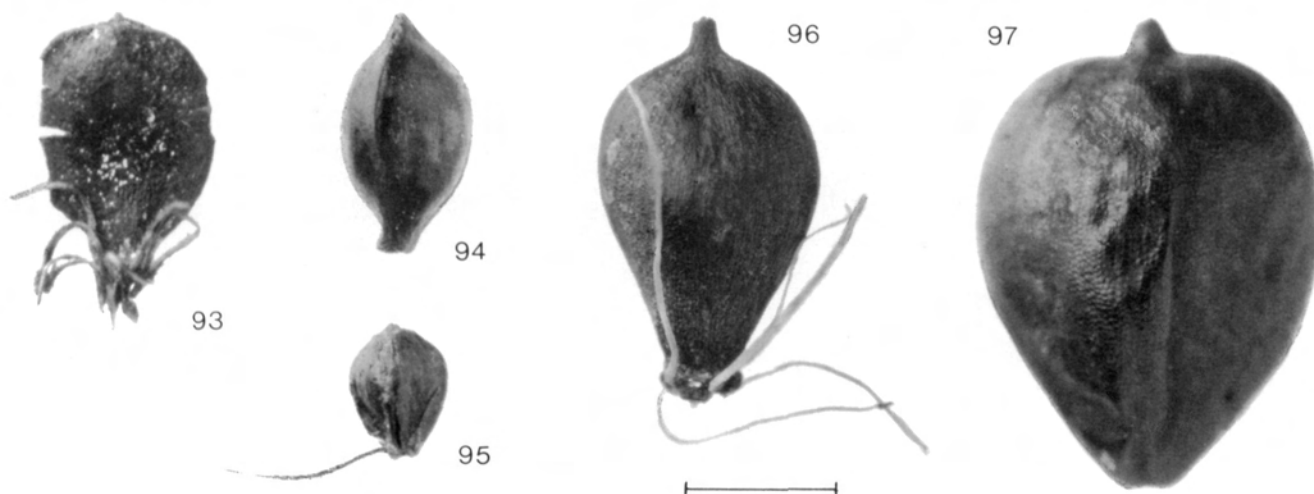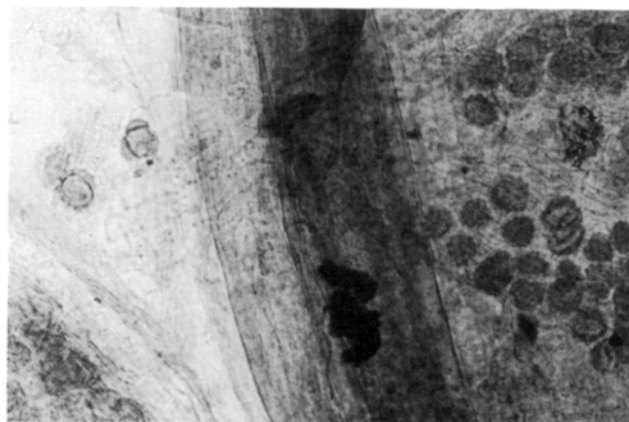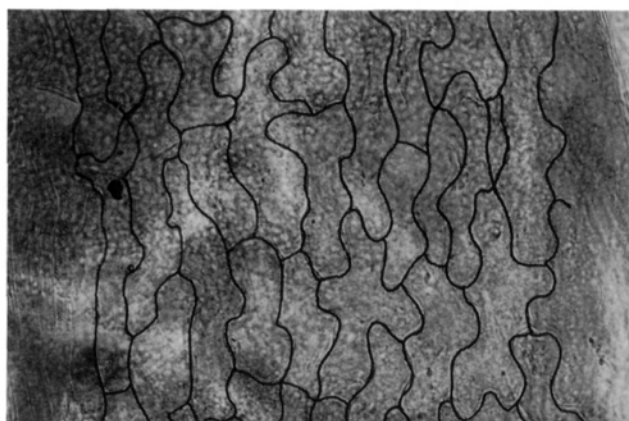
Fig. 77 *Carex acuta*-type (20x). Sp.17-35:598.
Fig. 78 *Carex acutiformis* (20x). Sp.17-35:598.
Fig. 79 *Carex cuprina*-type (20x). Sp.17-30:126.
Fig. 80 *Carex distans* (20x). Rock. 10-2-56.
Fig. 81 *Carex disticha* (20x). Sp.17-34:311.
Fig. 82 *Carex hirta* (20x). Sp.17-34:306.
Fig. 83 *Carex oederi* s.l. (20x). Rock. 10-2-56.
Fig. 84 *Carex* cf *remota* (20x). Sp.17-35:598.
Fig. 85 *Carex pilulifera* (20x). Rock. 10-2-56.
Fig. 86 *Carex paniculata*-type (20x). Sp.17-35:598.
Fig. 87 *Carex panicea* (20x). Sp.17-34:332.
Fig. 88 *Carex pseudocyperus* (20x). Sp.17-35:436.
Fig. 89 *Carex pseudocyperus* utricule (12x). Sp.17-35:598.
Fig. 90 *Carex riparia* (20x). Sp.17-35:598.
Fig. 91 *Carex* spec. (cf *flava*) (20x). Zl.17-27:8.
Fig. 92 *Carex riparia* utricule (20x). Sp.17-35:598.
Fig. 93 *Rhynchospora alba* (20x). Rock. 10-2-52.
Fig. 94 *Schoenus nigricans* (20x). Sp.17-34:411.
Fig. 95 *Scirpus sylvaticus* (20x). Rock. 10-2-56.
Fig. 96 *Scirpus lacustris tabernaemontani* (20x). Sp.17-30:126.
Fig. 97 *Scirpus maritimus* (20x). Nh.09-89:3036.
Fig. 98 *Artemisia* cf *vulgaris* with pollen grains (c. 250x). Rock. 2-0-12.
Fig. 99 Cell pattern of *Artemisia* cf. *vulgaris* (250x). Rock. 2-0-12.

Scale bars equal 1 mm, except for fig. 89.

Scirpus lacustris ssp *tabernaemontani* (= ssp *glaucus*).
Sp.17-34:278 (n = 25): 2.23 (1.92-2.59) × 1.62 (1.41-1.79) mm
Sp.17-35:600 (n = 25): 2.18 (1.89-2.40) × 1.45 (1.18-1.73) mm
Nh.09-89:3036 (n = 18): 2.25 (1.95-2.62) × 1.50 (1.34-1.76) mm
Rock.10-2-52 (n = 25): 2.15 (1.92-2.53) × 1.51 (1.31-1.76) mm

The sizes clearly fall in the range of this species. The majority of the subfossil material still had the perianth-bristles (see *fig. 96*), which are absent in *S. maritimus*. The seeds are always biconvex; triangular forms, resembling *S. lacustris* s.s. were not found.

Scirpus maritimus
Nh.09-89:3036 (n = 50): 3.13 (2.78-3.58) × 2.29 (1.76-2.85) mm
Rock.1-0-6 (n = 25): 2.92 (2.56-3.68) × 1.94 (1.66-2.14) mm
Sp.17-35:615 (n = 2): 3.26 × 2.11 mm; 3.81 × 2.24 mm

The plump seeds of this species often still had the shiny outer layer. After corrosion a layer with a coarse cell pattern remains. The prominent shoulders further characterize this species (see *fig. 97*). Perianth-bristles (deciduous according to Berggren 1969) were never found.

Scirpus sylvaticus
Sp.17-34: div. (n = 8): 0.86 (0.78-0.93) × 0.55 (0.48-0.67) × 0.40 (0.38-0.45) mm

This small Cyperaceae seed closely resembles *Cyperus fuscus*. In recent seeds, *Scirpus sylvaticus* has perianth-bristles, which are lacking in *Cyperus fuscus*. However, their absence can not be used with confidence for subfossil material, since these bristles are more or less deciduous. One of the subfossil seeds did still have one perianth-bristle (see *fig. 95*). In palaeobotanical descriptions, authors who have found one of these species seldom discuss the difference with the other species. Only Wieserowa (1979) and Knörzer (1981) mention that *Cyperus fuscus* has three equally wide sides in contrast to the *Scirpus* species. Wieserowa (1979: 158) reported both species. In her material, the lengths are equal but the width of *Cyperus fuscus* is 0.45-0.50 mm and of *Scirpus sylvaticus* 0.6-0.7 mm. The perianth-bristles were not preserved in Wieserowa's *Scirpus*. Wasylikowa (1978: 142) found *Scirpus sylvaticus* seeds, some of which still possessed perianth-bristles. Size: 0.95 (0.7-1.15) × 0.63 (0.45-0.7) mm. Because of the greater similarity of the present seeds to the Polish *S. sylvaticus* size-ranges and the presence of the perianth-bristle on one specimen, all seeds are attributed to *Scirpus sylvaticus*.

Ericaceae
Andromeda polifolia
Nh.09-89:3009(n = 1): 1.09 × 0.96 mm
Nh.09-89:3048(n = 1): 1.05 × 0.90 mm
Zl.17-22:1 (n = 3): 0.99 (0.80-1.12) × 0.73 (0.64-0.83) mm

Recent seeds collected from wild plants (Joensuu, Finland, via Hortus of Joensuu) produced the following measurements (n = 10): 1.19 (0.99-1.23) × 0.78 (0.66-0.90) mm.

The seeds have an irregularly egg-shaped outline with a sunken, oval hilum near the top. The cross-section is elliptic. The brown surface is lustrous (see *fig. 100*). Kroll (1987) found leaves of cf. *Andromeda polifolia* among many other heath species, Grosse-Brauckmann (1974, 1976) gives illustrations of stems and leaves from natural deposits. Seeds have so far not been described in palaeo-ethnobotanical literature.

Vaccinium spec.
Zl.17-27:9 (n = 1): 1.17 × 0.78 mm.

Tallantire (1976) discusses the identification of subfossil *Vaccinium* seeds. His conclusion is that, if a reasonably large number of well preserved seeds is present, specific identification seems possible. Since only one seed was found in the present study, there was no sound base for further identification.

Euphorbiaceae
Euphorbia palustris
Sp.17-30:127 (n = 2): 3.42 × 2.88 mm; 3.74 × 2.98 mm.

Only Körber-Grohne (1967) has described the seeds of this species. The seeds are egg-shaped, the smaller end being truncated on one side. This is the place where the caruncula is situated in recent seeds (Brouwer/ Stählin 1973). On the longitudinal axis, the hilum is present as a small groove (see *fig. 102*).

Gentianaceae
Centaurium spec.
Rock.10-1-4 (n = 15): 0.41 (0.35-0.45) × 0.33 (0.27-0.38) mm

The small seeds have a distinctly reticulate surface pattern. They resemble the equally small seeds of *Calluna vulgaris* and *Erica tetralix*. The very fragile seed of *Calluna* has a relatively large, collar-like hilum and finer epidermis-cells than *Centaurium*. In *Calluna*, the cell-walls are more or less straight. Seeds of *Erica* and *Centaurium* are less fragile and have cell-walls like jig-saw puzzle pieces (more prominent in *Erica*). *Erica* has smaller epidermis cells than *Centaurium*. In *Erica*, about nine cells are present along the length of the seed, in contrast to ca. five cells in *Centaurium*.

Gramineae

For the identification of waterlogged Gramineae fruits the publication of Körber-Grohne (1964) is indispensable. Carbonized specimens are often even more difficult to identify than uncarbonized ones, but species with a very characteristic hilum (e.g. *Agrostis*) can be identified beyond the level of Gramineae indet.

Danthonia (Sieglingia) decumbens
Rock.10-2-56 (n = 14): 2.38 (2.14-2.56) × 1.32 (1.15-1.50) mm

The broadly oval fruits of *Danthonia* show a very characteristic bright whitish hilum covering 26-37% of the fruit length. This species is not included in Körber-Grohne's (1964) publication, where it keys out to *Phalaris arundinacea* or *Molinia caerulea*. The bright hilum of *Danthonia*, which is a little shorter than that of *Molinia* and not lateral as in *Phalaris*, makes a clear distinction between these species possible.

Glyceria fluitans
Sp.17-34:580 (n = 50): 2.40 (2.16-2.70) × 0.98 (0.78-1.17) mm

The measurements concern carbonized fruits. The *Glyceria* species are characterized by a long hilum, which ends near the apex. In some cases, carbonized subfossil specimens still had the typical bifurcated projection on top of the seeds (see *fig. 37*). The surface cells are isodiametrical. The different species can be distinguished by their size (Dickson 1970: 240; Hubbard 1976; Jansen 1951). *G. maxima* has the smallest seeds (sic!), *G. declinata* and *G. plicata* (united in *G. notata* at present) have intermediate sizes (up to 2.5 mm), *G. fluitans* is the largest. The remarkable concentration of *G. fluitans* in Spijkenisse 17-34 is discussed in *4.5.5*.

Phalaris arundinacea
Sp.17-35:612 (n = 8): 1.81 (1.47-2.05) × 1.14 (0.99-1.28) mm

The lateral position of the hilum, which covers about half the fruit length, makes this species unmistakable.

Molinia caerulea

Apart from seeds which possess a very stout hilum reaching up to 2/3 of the fruit length, some grass stems also were found. These did not have the adventive bud which characterizes *Phragmites*-stems. Consequently, they resembled cereal straw. Examination of the epidermis revealed that the characteristic cereal epidermis, with alternating longitudinal rows with and without stomata (cf. Brinkkemper 1991), was absent. Instead rows of one long and usually two short cells

(see *fig. 103*) were present, very similar to Grosse-Brauckmann's (1972) illustration of the *Molinia*-epidermis. Since other Gramineae species might also have this epidermis-type, the stems are recorded as *Molinia*-type stems in the present study.

Parapholis strigosa
Ro.08-52:1073 (n = 1): 3.1 × 1.1 mm

Only Van Zeist (1974) described the fruits of this species. The central hilum measures 600 × 90 µm in the present specimen. In combination with the size of the fruit, all other Gramineae can be excluded. The epidermis cells are hardly discernable in this species (see *fig. 105*).

Puccinellia distans
Ro. 10-2-58 (n = 25): 1.44 (1.19-1.60) × 0.72 (0.65-0.82) mm

Puccinellia species have remarkably regular epidermis patterns of rectangular cells. The ovate hilum is blackish. The species differs from *P. maritima* by its smaller size (cf. Van Zeist 1974; Behre 1976c).

Hypericaceae

Hypericum quadrangulum
Sp.17-30:309 (n = 20): 0.72 (0.64-0.82) × 0.32 (0.28-0.36) mm
Sp.17-35:600 (n = 7): 0.70 (0.57-0.79) × 0.31 (0.28-0.35) mm

The cylindrical seeds have a distinctly reticulate surface. They are smaller than most of the other *Hypericum* species. *H. elodes* is even smaller than *H. quadrangulum* (0.5-0.6 mm in our reference material). *H. montanum* is similar in size to *H. quadrangulum*, but in *H. montanum*, the surface pattern consists of a very fine reticulum which is hardly visible.

Juncaceae

As for uncarbonized grass fruits, the key published by Körber-Grohne (1964) is of great value for the identification of *Juncus* seeds. It provided the base for the following identifications.

Juncus effusus-type

The subfossil seeds of *J. effusus*, *J. inflexus* and *J. subuliflorus* (= *conglomeratus*) are very similar. They are included in this type after Behre (1976c, 1983), Kroll (1987) and Pals (1987).

Juncus maritimus
Rock.10-2-58 (n = 25): 0.70 (0.61-0.77) × 0.33 (0.25-0.39) mm

The sizes have been measured on flattened seeds in micro-
scopic slides (as in Körber-Grohne 1964). The characteristic
thickening of some but not all of the transverse cell walls is
very striking. These thick-walled transverse cells alternate
with cells with thinner walls. (see *fig. 104; 106*; Körber-
Grohne 1964: Taf. III, Abb. 2). Subfossil records of this
species are unknown to me. The size range is very similar to
the range in recent seeds reported by Körber-Grohne.

Luzula multiflora
Nh.09-89:3009 (n = 1): 1.06 × 0.77 mm
Nh.09-89:3043 (n = 1): 1.10 × 0.75 mm

The oval seeds are lustrous and show a fine point at one
end. The surface has an isodiametric reticulum. According
to Körber-Grohne and Piening (1983: 59), *L. campestris* has
an elongated reticulum. Moreover, seeds of *L. campestris* are
almost as wide as long (Reichgelt 1964; Van der Meijden
1990). Recent specimens of *L. multiflora* in our reference
collection (n = 10, Valais, Switzerland: Hortus Geneva) meas-
ured 1.24 (1.18-1.27) × 0.81 (0.74-0.87) mm, seeds of *L.
campestris* (n = 10, Texel, Netherlands: IPL) measured 1.16
(1.09-1.24) × 0.93 (0.90-0.99) mm, which indicates that the
width is a reliable criterion for separating the two species.

Juncaginaceae
Triglochin palustris
Zl.17-27:9 (n = 15): 6.07 (4.11-7.82) × 0.86 (0.63-1.03) mm

The very slender, awl-shaped fruits are characteristic. The
basal horseshoe-shaped hilum and the often bifurcated apex
further typify this species (see *fig. 107*).

Labiatae
Galeopsis bifida-type
Sp.17-35:612 (n = 8): 3.47 (3.23-3.71) × 2.78 (2.50-3.10) mm

The oval seeds have a characteristic, large hilum at the
pointed end. The large width of the seeds excludes those of
G. ladanum/segetum. G. bifida, G. speciosa and *G. tetrahit*
are, however, very similar (see also Fredskild 1978; Wasyli-
kowa 1978; Jacomet *et al.* 1989) and they are lumped to-
gether in the *G. bifida*-type. *G. bifida* is ignored by many
other authors, remarking upon the similarity between *G.
tetrahit* and *G. speciosa* (e.g. Allison *et al.* 1952; Behre 1970,
1976c, 1983; Jacquat 1988; Van Zeist 1974; Van Zeist/
Palfenier-Vegter 1983). Knörzer (1976) mentions the
similarity between *G. tetrahit* and *G. bifida* and leaves *G.
speciosa* out of consideration. According to Van der Meijden
(1990), *G. bifida* occurs in ruderal places in peaty areas,
especially near reed (*Phragmites*) piles and along ditches.
This makes an occurrence of this species in prehistoric times
quite possible.

Linaceae
Linum catharticum
Rock.10-2-56 (n = 6): 1.31 (1.25-1.44) × 0.80 (0.74-0.86) mm

The shape and the pronounced beak are similar to those of
Linum usitatissimum. Cultivated linseed, however, has much
larger seeds.

Malvaceae
Althaea officinalis
09-89:3009 (n = 6): 3.30 (2.91-3.62) × 3.01 (2.46-3.42) mm

The disc-shaped seeds are of uneven thickness, the outer
edge being the thickest. In consequence, the cross section is
wedge-shaped. The surface has coarse ribs which fade out
towards the thinner part.

Myricaceae
Myrica gale
09-89:3009(n = 25): 2.46 (1.95-3.20) × 2.25 (1.89-2.72) mm

The characteristic fruits consist of a central nut enveloped
by closely adhering bracts, both bracts are pointed at one
end. The central nut is fused with two sterile bracts. The nut
is often split in the middle. The small whitish glands on the
surface are well preserved in some fruits. Apart from the
fruits, some leaf fragments and buds of *Myrica gale* were
also found. The leaves are obovate, the abaxial side shows
whitish glands. The bud scales have pale translucent margins
and hairs along the lower part of the margin, similar to
those described by Tomlinson (1985).

Najadaceae
Najas marina
Sp.17-34:337 (n = 13): 3.61 (3.01-4.54) × 1.23 (0.83-1.92)
mm

Najas seeds are oblong-ellipsoid and show a distinct reticu-
lation (see *fig. 108*). They have a characteristic reddish-
brown colour in the present samples. The seeds easily split
into two halves, in which state they were usually recovered.

Onagraceae
Epilobium hirsutum-type
Sp.17-35:612 (n = 25): 1.01 (0.90-1.17) × 0.54 (0.47-0.66)
mm

The seeds are narrowly obovate and have fine warts. The
ventral hilum widens towards the apex. Seeds of *E. hirsu-
tum, E. montanum, E. parviflorum, E. obscurum, E. roseum*
and *E. tetragonum* are very similar. Jacomet (1986: 174)
gives provisional distinguishing characteristics which, accord-
ing to her, need further examination. *E. montanum* accord-
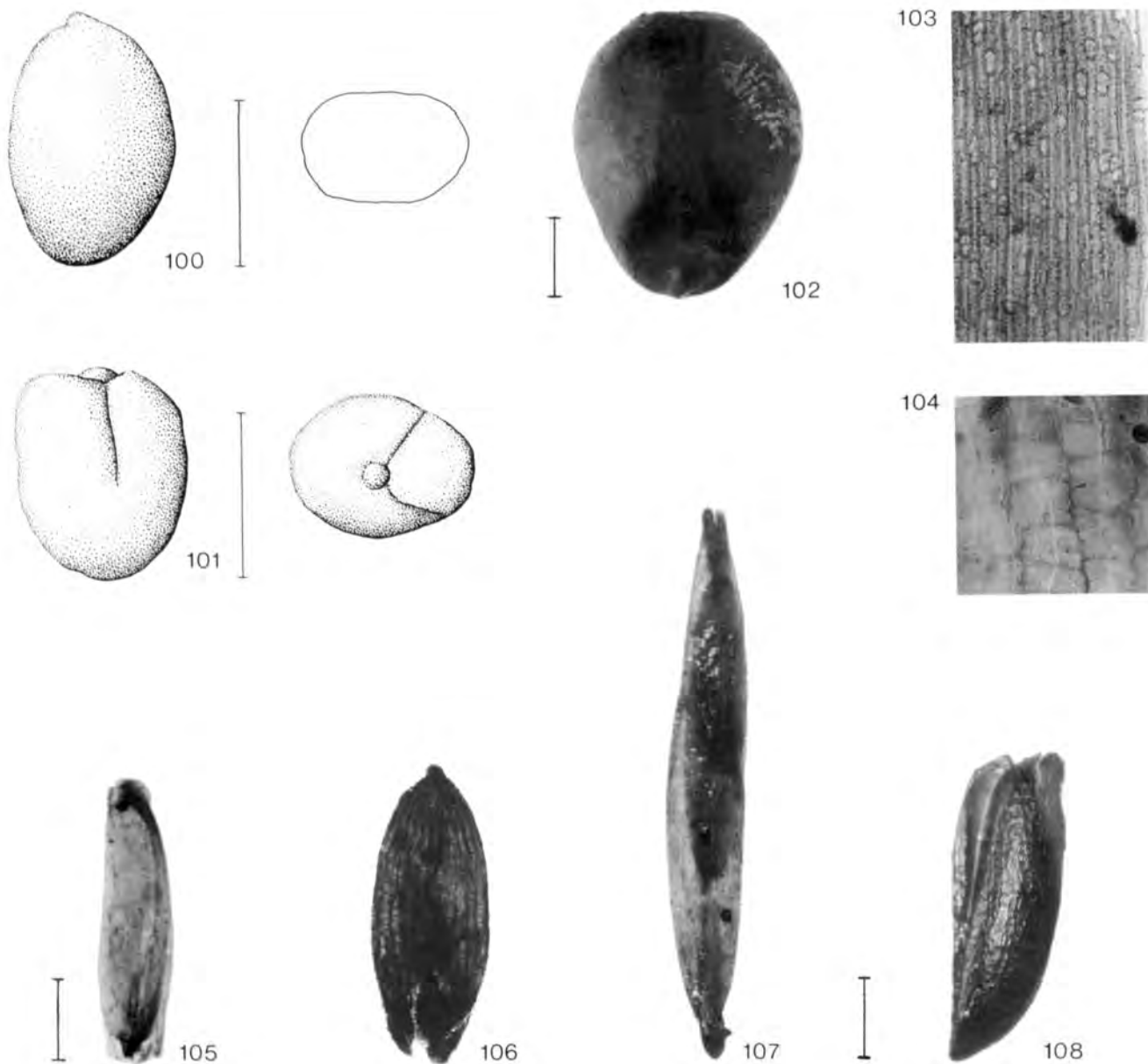
Fig. 100 *Andromeda polifolia* (25x). Nh.09-89:3009.
Fig. 101 *Trifolium repens/fragiferum* (25x). Sp.17-30:127.
Fig. 102 *Euphorbia palustris* (12x). Sp.17-30-127.
Fig. 103 Epidermis cells of *Molinia*-type stem (240x).
Fig. 104 *Juncus maritimus* (240x). Rock. 10-2-58.
Fig. 105 *Parapholis strigosa* (12x). Ro.08-52:1073.

Fig. 106 *Juncus maritimus* (60x). Rock. 10-2-58.
Fig. 107 *Triglochin palustris* (12x). Zl.17-27:9.
Fig. 108 *Najas marina* (12x). Sp.17-34:337.

Scale bar equals 1mm.

Table 40. Sizes of Epilobium species.

E. hirsutum	
Leiden, Netherlands: IPL, Leiden	0.97 (0.93-1.05) × 0.48 (0.45-0.51) mm
Stockholm, Sweden: Hortus Bergianus	0.98 (0.93-1.05) × 0.51 (0.45-0.54) mm
E. montanum	
Roermond, Netherlands: IPL, Leiden	1.10 (0.96-1.20) × 0.41 (0.39-0.42) mm
Leiden, Netherlands: Hortus Leiden	0.95 (0.84-1.05) × 0.41 (0.34-0.45) mm
E. obscurum	
Duisburg, Germany: Bot. Garden Duisburg	1.03 (0.93-1.14) × 0.50 (0.45-0.54) mm
Bunclody, Ireland: Hortus Glasnevin	0.91 (0.87-0.96) × 0.44 (0.42-0.45) mm
E. parviflorum	
Molenaarsgraaf, Netherlands: IPL, Leiden	0.97 (0.90-1.05) × 0.48 (0.45-0.51) mm
Berlin, Germany: Bot. Garden Berlin	0.95 (0.90-1.05) × 0.46 (0.42-0.50) mm
E. tetragonum	
Hausen, Germany: IPL, Leiden	0.96 (0.93-1.02) × 0.43 (0.42-0.45) mm
Helsingborg, Sweden: Bot. Garden Helsingborg	0.93 (0.87-0.96) × 0.43 (0.40-0.46) mm

ing to her is larger than 1 mm (average 1.18 mm), *E. hirsutum* measures around 1 mm and *E. parviflorum*, *E. roseum* and *E. tetragonum* should be a little smaller than 1 mm. *E. hirsutum* has relatively large papillae, while the other species have very small, often even hardly visible warts. According to Knörzer (1981: 69), *E. hirsutum* has slightly broader seeds than the other species. The further examination recommended by Jacomet has been carried out on our reference material. For every sample ten seeds were measured (see *table 40*).

It seems that size cannot be used as the only criterion for the identification of *Epilobium* seeds but the warts may provide additional information. The value of this characteristic for subfossil material, however, is difficult to assess. The uncorroded specimens in the present study showed very clear warts. The seeds have therefore been listed as *Epilobium hirsutum*-type.

Papilionaceae
Trifolium repens/fragiferum
Sp.17-30:127 (n = 6): 1.29 (1.15-1.44) × 1.09 (0.80-1.22) mm

The radicle of these seeds (see *fig. 101*) is larger than in most *Trifolium* species. In our reference material, such large radicles occur in both *T. repens* and *T. fragiferum*. According to Behre (1976c: 103), *T. fragiferum* is more symmetrical than any other *Trifolium* species. However, in *T. repens* this symmetry also occurs (cf. Knörzer 1970) and in consequence, no distinction has been made here.

Vicia spec.

Some waterlogged seeds of *Vicia* occurred in several samples. They were flattened, but the large hilum could still clearly be discerned on the otherwise smooth, leather-like seeds. Several authors have expressed the importance of the length of the hilum in relation to the total circumference of the seeds for further identification of *Vicia* seeds. Jacomet *et al.* (1989) stated that the length-width ratio of the hilum is a valuable characteristic, but they did not provide further data.

In order to obtain quantitative information, the (dried) seeds present in our reference collection were measured. Both the ratio circumference ($= \pi.D$)/length of the hilum (A) and length/width of the hilum (B) were calculated. These dimensions were measured as indicated in figure 109. It should be noted that the length of the hilum thus obtained is slightly shorter than the actual length, but if consistently applied, this is of minor importance. Only in *Vicia sepium*, where the hilum covers more than half of the circumference, the measurements were taken in three or four steps. The width of the hilum was measured in the middle of the longitudinal axis. Ten seeds were measured from each sample of our collection. The data obtained have been given in table 41. The size ranges and A-values are in agreement with those published by Kulpa (1974: 159-164).

On the basis of these data (waterlogged) seeds can be distinguished according to the following key. Preliminary investigations concerning carbonized material revealed that the seed coat can easily disappear. In that case, the impression of the hilum between the cotyledons is visible. This impression is much wider and slightly longer than the original hilum. Furthermore, the increase in width differs between the various species. Only specimens on which the original hilum on the seed coat is still present, can be identified with the following identification key:

1a. Seeds at least 6 mm in diameter, carbonized specimens rarely smaller, length/width ratio of hilum < 5
.... *Vicia faba*
1 b .Seeds smaller and/or length/width ratio of the hilum > 5.
...2

Table 41. Sizes of *Vicia* species.

	diameter (mm)	A	B
V. cracca			
Leiden, Netherlands: IPL	3.00 (2.73-3.29)	3.4-3.7	5.4-6.6
Eck en Wiel, Netherlands: IPL	2.63 (2.51-2.76)	4.2-4.7	4.6-5.8
V. faba var. *minor*			
Irnsing, Germany: IPL	10.6 (9.67-11.5)	6.5-8.1	3.6-4.8
V. hirsuta			
Besançon, France: Botanical Garden	2.43 (2.20-2.70)	3.8-4.4	6.8-8.9
Schin op Geul, Netherlands: IPL	2.63 (2.39-2.85)	3.5-4.0	7.0-9.6
V. lathyroides			
Gatersleben, Germany: Gene-centre	1.74 (1.46-1.89)	7.8-14.7	1.8-2.4
V. sativa ssp. *angustifolia*			
Roermond, Netherlands: IPL	2.64 (2.42-2.85)	5.0-6.6	3.3-4.4
Schin op Geul, Netherlands: IPL	3.00 (2.48-3.56)	4.4-6.5	3.8-5.7
V. sativa ssp. *sativa*			
Leiden, Netherlands: Botanical Garden	4.33 (3.72-4.71)	5.8-7.3	5.1-7.1
V. sepium			
Bemelerberg, Netherlands: IPL	3.43 (2.79-3.66)	1.7-2.1	16.4-22.9
Zwolle, Netherlands: IPL	3.35 (3.13-3.62)	1.6-1.7	19.5-25.2
V. tetrasperma			
Helsingborg, Sweden: Botanical Garden	1.95 (1.86-2.02)	4.8-5.4	2.8-3.4
Espoo, Finland: Hortus Helsinki	2.00 (1.89-2.17)	4.8-6.1	2.9-3.5

2 a .Hilum very short and relatively wide. Circumference/ hilum length ratio > 7.5, length/width ratio of hilum < 2.5. Recent seeds with distinct warts, which are also apparent in artificially carbonized specimens. Largest diameter < 1.9 mm.

..... *Vicia lathyroides*

2 b .Circumference/hilum length ratio < 7.5, length/width ratio of hilum > 2.5. No distinct warts, largest diameter seldom smaller than 1.9 mm

...3

3 a .Hilum covers ca. 1/2 — 2/3 of the circumference of the seed and hilum more than ten times longer than its width

..... *Vicia sepium*

3 b .Hilum covering at most 1/3 of the circumference of the seed, less than ten times longer than its width

...4

4 a .Length/width ratio of hilum < 4, uncarbonized seeds smaller than 2.3 mm

..... *Vicia tetrasperma*

4 b .Length/width ratio of hilum > 4 and/or seeds larger

...5

5 a .Seeds larger than 3.7 mm, hilum covering about 1/6 - 1/7 of the circumference

..... *Vicia sativa sativa*

5 b .Seeds smaller, hilum covers 1/3 - 1/7 of the circumference

...6

6 a .Length/width ratio of the hilum > 6.7, seeds relatively small, up to 2.85 mm.

..... *Vicia hirsuta*

6 b .Length/width of the hilum < 6.7.

...7

7 a .Length/width of the hilum < 4.5 and/or circumference/ hilum length ratio > 5.2.

..... *Vicia sativa angustifolia*

7 b .Length/width of the hilum > 5.7 and/or circumference/ hilum length ratio < 4.1.

..... *Vicia cracca*

7 c .Length/width ratio of the hilum 4.5-5.7 and circumference/hilum length ratio 4.1-5.2.

Vicia cracca/Vicia sativa angustifolia

Vicia cf. *hirsuta*
Ro.08-52:1069 (n = 3): D = 2.10 (1.8-2.5) mm

The hilum could not be measured, the largest diameter is in the lower range of *Vicia hirsuta*. The identification therefore is tentative.

Vicia cracca
Gv.17-55: 2 (n = 1): D = 2.88 mm, A = 4.95, B = 5.9.
Ro.08-52:1069 (n = 2): D = 2.42-2.64 mm, A = 3.81-4.40, B = ?

The diameter and the ratios indicate that *Vicia cracca* is

concerned here. In the flattened specimen from Geervliet, the diameter is probably too large, resulting in a value for A which is too high.

Plantaginaceae
Plantago coronopus
Rock.1-0-6: (n = 2): 0.98 × 0.65 mm; 1.07 × 0.64 mm

The small, oval seeds have a distinct, light hilum near the middle. *Plantago major* can be equally small, but can readily be distinguished by the two hila and the ridged surface. The other *Plantago* seeds are distinctly larger. The size closely corresponds to Behre's (1976c) description and to our reference material (Noordwijk, Netherlands: IPL, Leiden), which measures 1.02 (0.93-1.11) × 0.60 (0.54-0.66) mm (n = 10). Other subfossil records of this species are unknown to me.

Plantago maritima
Rock.10-2-52 (n = 3): 2.60 (2.30-2.88) × 1.03 (0.93-1.12) mm

The elliptical brownish seeds have a conspicuous circular hilum just out of the middle. The unmistakable, conical capsule lids were also found.

Plumbaginaceae
Limonium vulgare
Ro.08-52:1069 (n = 1): 4.47 × 1.32 mm.
Ro.08-52:1069 (n = 5): length calyces: 5.34 (4.72-5.80) mm.

In Rockanje 08-52, several calyces of this species were found (see *fig. 111*). The calyces have five ribs, in contrast to those of *Armeria maritima* which have ten ribs. Furthermore, *Limonium* calyces only bear hairs on some ribs while *Armeria* ribs are more densely covered with hairs (cf. Van Zeist 1974; Behre 1976c). Some calyces still bore a seed, the apex of which is pentagonal in cross section. The surface is regularly bumpy (see *fig. 113*).

Polygonaceae
Polygonum hydropiper
Sp.17-34:327 (n = 8): 3.24 (2.85-3.62) × 2.16 (1.86-2.46) mm
Sp.17-35:598 (n = 7): 3.56 (3.33-3.84) × 2.22 (1.98-2.43) mm

The ovate fruits with tapering apex show a fine reticulum, best visible in light from a lateral source. Only *Polygonum mite* can also be slightly striate. Jacomet (1986) demonstrated that the size is a useful criterion in distinguishing these species. *Polygonum mite* is seldom larger than 3 mm and seldom wider than 2 mm, wheras *P. hydropiper* is usually larger than 3 mm and wider than 2 mm. *P. hydropiper* also has a more clearly visible reticulum. Thus, the present material is attributed to *P. hydropiper*.

Polygonum lapathifolium
Sp.17-35:612 (n = 25): 2.41 (2.11-2.75) × 2.00 (1.82-2.40) mm

This species can be subdivided into four subspecies with different ecology (cf. Van der Meijden 1990). This division is mainly based on fruits, which is most promising for palaeobotanical research. However, the size range of the present fruits does not allow a definite identification. Only ssp. *lapathifolium*, with fruits smaller than 2 mm (according to Van der Meijden), but 1.7-2.8 mm according to Berggren (1981), might be excluded. Pals' (1987) conclusion that the size of fruits is apparently not a reliable criterion for the identification of subspecies of *P. lapathifolium* seems to be the safest.

Rumex conglomeratus
Sp.17-35:598 (n = 6): 2.38 (2.24-2.75) × 1.98 (1.57-2.46) mm

Some specimens of *Rumex* with more or less complete perigons could be attributed to this species. The measurements do include these perigons. There is no difference in the size of the tubercles present on the long tongue-shaped perigons (see also Kubát 1979; Knörzer 1970). Without these characteristic perigons identification is not possible. In consequence, bare fruits are listed as *Rumex* spec.

Rumex hydrolapathum
Sp.17-34:375 (n = 10): 3.28 (3.07-3.65) × 2.16 (1.86-2.50) mm

A large part of the fruits still had perigons. These are elongated and hardly indented. In contrast to *R. crispus* and *R. obtusifolius*, the perigon base of *R. hydrolapathum* is V-shaped, whereas that of the former two species has an inverse V-shape (cf. Van der Meijden 1990). The fruit of *R. hydrolapathum* is larger than that of the other *Rumex* species (cf. Knörzer 1970; Jacomet *et al.* 1989). The measurements concern fruits without perigons.

Potamogetonaceae
Zannichellia palustris ssp. *pedicellata*
Sp.17-34:278 (n = 10): 2.45 (2.21-2.62) × 0.71 (0.61-0.80) mm
with projections: 3.90 (3.62-4.80) mm

If complete, the remarkable fruits of this species have long projections at both ends and a row of smaller bristles on the dorsal side. The long projections are characteristic of this subspecies (cf. Behre 1976c, 1983; Van Zeist 1974). Large numbers of these fruits as found in Spijkenisse 17-34 are exceptional in palaeobotanical research.

Primulaceae

Centunculus minimus/Samolus valerandi
Sp.17-34:327 (n=1): 0.59 × 0.33 mm
Ro.08-52:D-I (n=25): 0.58 (0.50-0.68) × 0.40 (0.34-0.46) mm

Only Behre (1983) discusses the difference between these small Primulaceae species, which closely resemble each other. Behre identified his single specimen as *Samolus valerandi* on account of the absence of the warts, which characterize *Centunculus minimus*. The recent seeds of *Centunculus* in our reference collection did indeed show these warts. However, only slight finger pressure is sufficient to remove these warts. In the subfossil material, these warts were sometimes still present. They can best be recognized with a transmitted light microscope at a magnification of 200×. The warts are intertwined on the seedcoat. In my opinion, the absence of this characteristic trait does not allow identification of single specimens as *Samolus valerandi*, in view of the easy removal of the warts in *Centunculus*. Only the peaty base of the Dunkirk I deposit covering the site Rockanje 08-52 yielded a large number of seeds, all without any trace of warts. These seeds were attributed to *Samolus valerandi*.

Lysimachia thyrsiflora
Sp.17-34:337 (n=1): 1.45 × 0.78 × 0.59 mm

Lysimachia seeds resemble those of *Anagallis arvensis*. *Anagallis* can be recognized by the small wart-like scales, while in *Lysimachia* the surface bears air-containing tissue. In *L. thyrsiflora* the basal part is regular oval in shape and slightly curving (boat-shaped) (see *fig. 110*; Katz *et al.* 1965, *pl. 74, fig. 8*). The thickened margin which is characteristic of *L. vulgaris* (cf. Knörzer 1970; Katz *et al.*, *pl. 74, fig. 2*) is absent in *L. thyrsiflora*. Apart from some records published by Katz *et al.* (1965), descriptions of palaeobotanical material of *Lysimachia thyrsiflora* are unknown to me. Seeds of *L. nummularia*, a common species in the Netherlands, are not present in our reference collection. Knörzer (1970: 98) did not have these seeds at his disposal either. Therefore, roughly one hundred specimens of the *Rijksherbarium* were inspected for seeds, however, also with a negative result. Apparently, this species nowadays mainly reproduces vegetatively. A comparable situation can be seen in reed (*Phragmites australis*) which also only seldom develops seeds. The consequence of the inability to find *L. nummularia* seeds is that it remains unknown to me whether these seeds can be distinguished from the other two species.

Lysimachia vulgaris
Nh.09-89:3009 (n=14): 1.39 (1.09-1.63) × 0.92 (0.67-1.34) mm

The thickened margin around the basal (abaxial) part of the seed and the irregularly polygonal base typify this species (see *fig. 112*). The basal part is also more flattened than in *L. thyrsiflora*.

Ranunculaceae

Caltha palustris
Sp.17-34:337 (n=10): 2.53 (1.85-2.82) × 1.14 (0.90-1.34) mm

The comma-shaped fruits are usually constricted around the middle. The basal part is smooth-walled, the smaller upper part is rather spongy.

Ranunculus repens-type
Sp.17-35:598 (n=15): 2.57 (2.24-2.94) × 2.02 (1.76-2.43) mm

In most samples distinct *R. repens* fruits were present. In several cases, however, fruits were present that resembled *R. lingua* because of their slenderness. Especially in larger samples of *R. repens*, more deviating specimens occurred. It seems likely that these also belong to *R. repens*. To account for the possible occurrence of *R. lingua*, the fruits are all listed as *R. repens*-type.

Rosaceae

Crataegus laevigata
Sp.17-34:327 (n=1): 6.21 × 3.65 × 2.24 mm

The flattened ventral side indicates that this fruit stone belongs to *Crataegus laevigata* and not to *C. monogyna*, which is round in cross-section. Other Rosaceae fruit stones do not show the characteristic combination of size and shape (see *fig. 114*).

Prunus spinosa
Sp.17-34:436 (n=1): 12.31 × 9.04 × 6.29 mm
Sp.17-34:279 (n=2): 11.14 × 7.07 × 5.11; 7.99 × 6.02 × 5.24 mm
Sp.17-35:612 (n=2): 7.73 × 6.03 × 4.85; 8.78 × 6.94 × 5.76 mm

The highly variable fruit stones are characterized by their large size, the very rough surface and a conspicuous ridge (cf. *fig. 94* in Renfrew 1973). Knörzer and Müller (1968) discuss the differences with other *Prunus* species. The distinction from small *Prunus insititia* var. *juliana* fruitstones can sometimes be difficult to make, but this taxon is highly improbable in the Iron Age material from Voorne-Putten. The form-groups ("*Formenkreise*") which Baas (1974, 1979) recognized are clearly invalidated by Behre (1983) and need no following.
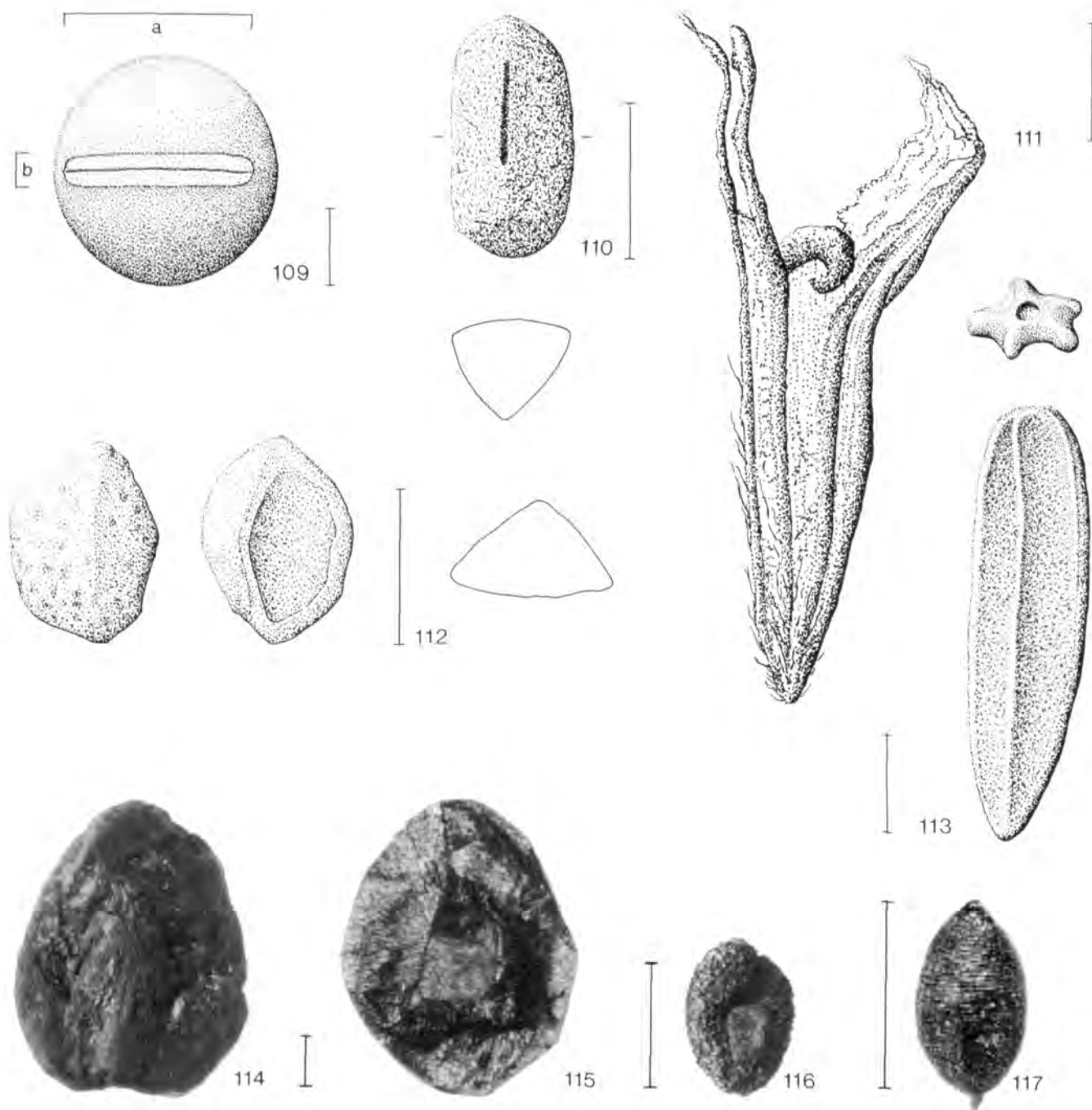
Fig. 109 *Vicia* spec. Measurements of dimensions A and B (12x)
Fig. 110 *Lysimachia thyrsiflora* (25x). Sp.17-34:337.
Fig. 111 Calyx of *Limonium vulgare* (15x), containing seed of fig. 110.
Fig. 112 *Lysimachia vulgaris* (25x). Nh.09-89:3009.
Fig. 113 *Limonium vulgare* (15x). Ro.08-52:1069.

Fig. 114 *Crataegus laevigata* (8x). Sp.17-34:337.
Fig. 115 *Galium aparine* (8x). Sp.17-35:612.
Fig. 116 *Galium saxatile* (20x). Sp.17-35:612.
Fig. 117 *Euphrasia/Odontites* (30x). Rock. 10-1-4.

Scale units equal 1 mm.

Rosa spec.
Rock.10-2-56 (n = 1): 4.67 × 2.56 × 1.54 mm
Sp.17-34:279 (n = 1): 4.03 × 2.43 mm
Sp.17-34:306 (n = 2): 4.86 × 2.17 × ?; 4.93 × 3.20 × 2.24
mm

Rosa fruitstones are irregularly angular with a conspicuous groove on the longitudinal axis. Identification below the genus-level is not possible because of the large variation in the size of the different species.

Rubiaceae
Galium aparine
Sp.17-35:612 (n = 25): largest diameter: 3.54 (3.17-4.16) mm

The uncarbonized fruits are completely flattened, which causes the large diameters. The round opening is clearly discernible (see *fig. 115*). The surface consists of elongated cells. The size and surface pattern exclude other *Galium* species (Lange 1979).

Galium saxatile (= *hercynicum*).
Sp.17-35:612 (n = 9): 1.14 (0.90-1.25) × 0.77 (0.51-0.90) mm

The fruits are elliptical in outline. The surface is densely covered with fine spines. On the ventral side a large, sunken hilum is present, which is symmetrically placed on the longitudinal axis of the fruit (see *fig. 116*). Corroded *Epilobium hirsutum*-type fruits may at first glance resemble these small *Galium* seeds, the hilum, however, is completely different. The only *Galium* species with equally small fruits is *G. uliginosum*, but this species has a more verrucate surface (cf. *fig. 865* and *870* in Beijerinck 1947). Katz *et al.* (1965, *pl. 81, fig. 28* and *29*) illustrate a spiny *Galium* fruit as *G. uliginosum*. Our reference collection is in agreement with Beijerinck's illustration and the subfossil specimens are in consequence attributed to *G. saxatile*. To my knowledge, this species has not been described in palaeobotanical studies before.

Scrophulariaceae
Euphrasia/Odontites spec.

Uncarbonized seeds are characterized by a scalariform surface pattern and a broad keel on one side. In a carbonized state both these marked features disappear. What remains is the "inner" seed, with pointed ends and on the surface a fine transverse striation (cf. Van Zeist/ Palfenier-Vegter 1983; *fig. 117*). Both genera produce very similar seeds, which cannot be separated.

Pedicularis palustris
Sp.17-35:598 (n = 3): 1.85 (1.61-2.02) × 1.06 (0.96-1.12) mm

The obovate seed of this species has a distinct, elongated reticulate pattern and a longitudinal groove on the ventral side.

Veronica beccabunga-type
Sp.17-34:266 (n = 25): 0.62 (0.45-0.72) × 0.45 (0.37-0.56) mm

The small seeds have a conspicuous hilum about 1/3 from the base. The transparent seeds show a fine surface pattern. According to Conolly *et al.* (1950) and Jacquat (1988), *V. anagallis-aquatica* has even smaller seeds than *V. beccabunga*, the size range of which corresponds well to the present ones. Conolly *et al.* also report that *V. catenata* (= *aquatica*) is as small as *V. anagallis-aquatica*, but in our reference collection the seeds have the same size as *V. beccabunga*. Bakels (1981) mentioned that *V. longifolia* and *V. scutellata* are similar in size to *V. beccabunga*. The seeds of these two species are, however, substantially larger (ca. 1 mm), and in Oss-IJsselstraat we are probably dealing with them, condisering their sizes of 0.9 × 0.7 and 1.2 × 0.8 mm.
In conclusion, it is *V. beccabunga* (or probably *V. catenata*) that is involved here. They are included in the *Veronica beccabunga*-type. The large amounts recorded in Spijkenisse 17-34 are exceptional. They were mainly present in the residue on the 1/4 mm sieve, which may partly explain their near absence in palaeobotanical literature.

Solanum dulcamara
Sp.17-35:600 (n = 2): 2.22-2.42 × 1.79-2.14 mm
Nh.09-89:3035(n = 4): 2.38 (2.24-2.56) × 2.02 (1.86-2.14) mm

Solanum nigrum
Sp.17-35:612 (n = 16): 1.90 (1.60-2.05) × 1.51 (1.22-1.66) mm
Nh.09-89:3035(n = 15): 1.88 (1.66-2.14) × 1.48 (1.25-1.73) mm

The seeds of these species can in most cases be distinguished by their size and shape. *S. dulcamara* is larger and more rounded than the smaller *S. nigrum*, which has a pointed end. In practice, large seeds with more or less pointed ends do occur. Villaret-von Rochow (1967) already noticed that these characteristics show an overlap. Behre (1976c) in this respect observed that it is not always possible to distinguish the two species. In the present study pointed seeds hardly ever exceeded 2 mm in length, they were attributed to *S. nigrum*. Seeds well over 2 mm were identified as *S. dulcamara*, although some were rather elongated. Doubtful specimens are always attributed to the species already present in the sample concerned, or listed as *Solanum* spec., if no seeds
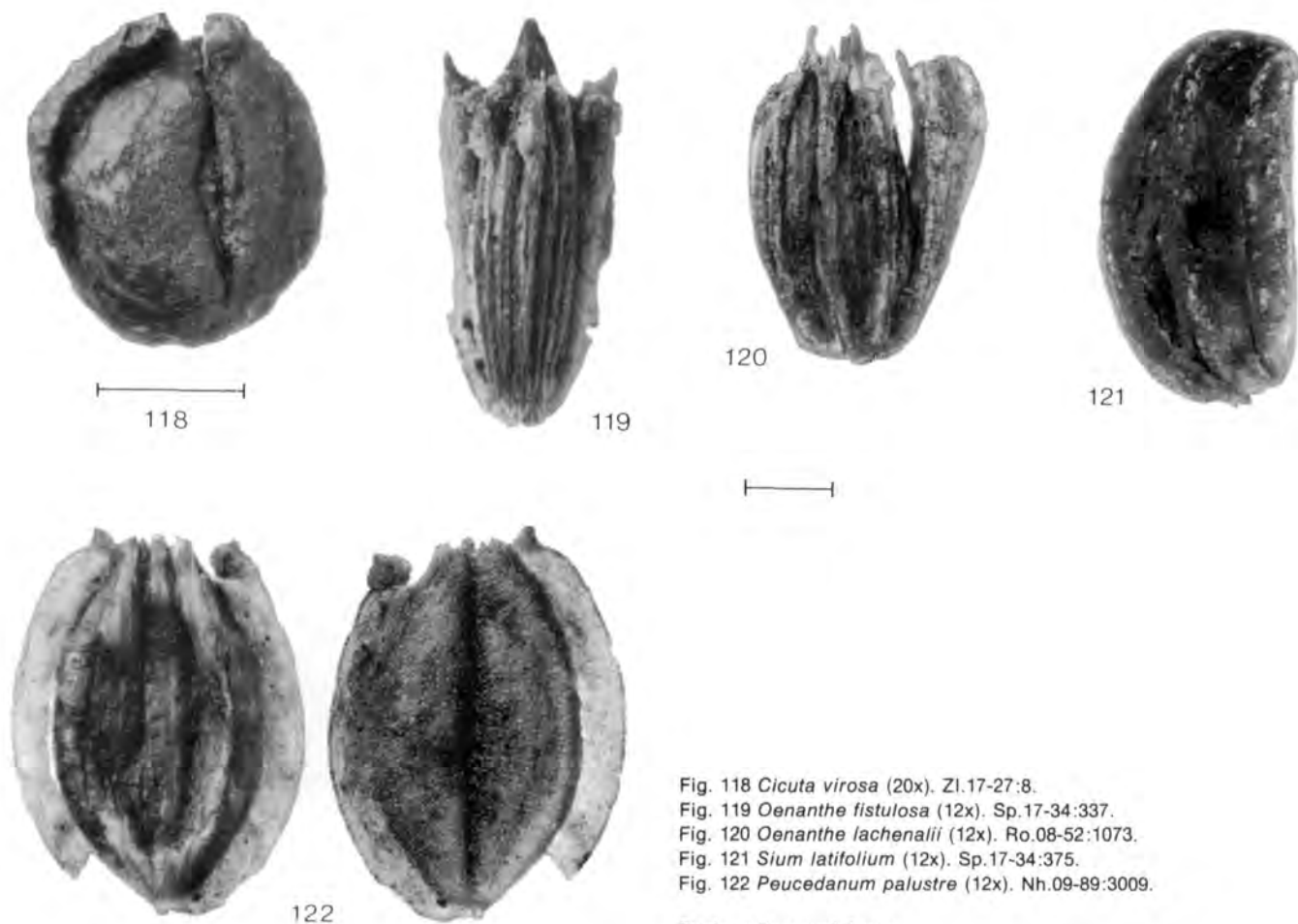
Fig. 118 *Cicuta virosa* (20x). Zl.17-27:8.
Fig. 119 *Oenanthe fistulosa* (12x). Sp.17-34:337.
Fig. 120 *Oenanthe lachenalii* (12x). Ro.08-52:1073.
Fig. 121 *Sium latifolium* (12x). Sp.17-34:375.
Fig. 122 *Peucedanum palustre* (12x). Nh.09-89:3009.

Scale units equal 1 mm.

in that sample could be identified with certainty. *Solanum nigrum* is the most common of these species in the present study.

Umbelliferae

Angelica sylvestris
Sp.17-34:279 (n = 1): 3.81 × 3.30 mm

The fruits (mericarps) are broadly winged and have three high ribs on the dorsal side. The two ventral wings do not touch each other, whereas they do so in *Peucedanum palustre*. The latter species is shown in figure 122.

Cicuta virosa
Zl.17-27:8 (n = 2): 2.24 × 1.66 mm; 2.46 × 2.30 mm

The fruits are semi-circular with a flat ventral side. They are unwinged. The presence of one flattened side and broad ribs

point to an Umbelliferae species, the shape is characteristic of *Cicuta virosa* (see *fig. 118*).

Oenanthe fistulosa
Sp.17-35:598 (n = 25): 3.40 (2.88-4.00) × 1.80 (1.44-2.24) mm

The fruits are characteristic, with large lateral ribs of spongy tissue and three projections on the top of the fruits (see *fig. 119*). The similarly trapezoidal fruits of *O. lachenalii* are much smaller than those of *O. fistulosa* (cf. Van Zeist 1974).

Oenanthe lachenalii
Nh.09-89:3037 (n = 10): 2.36 (2.14-2.67) × 1.42 (1.27-1.83) mm.

The small size and the trapezoidal shape of the fruits are typical (see *fig. 120*). When the spongy tissue has corroded,

which was often the case, identification presented many more difficulties.

Sium latifolium
Sp.17-34:375 (n = 8): 2.66 (2.34-3.20) × 1.55 (1.18-2.08) mm

The fruits are unwinged and slightly concave on the ventral side. The dorsal side is more convex, which results in a shape resembling a banana (see *fig. 121*). The fruits have five light ribs (see also Körber-Grohne 1967).

Umbelliferae Indet.

Heavily corroded umbelliferous fruits were quite often found. If the ribs and wings are absent, nearly all species become very similar. They are therefore listed under this taxon.

Violaceae
Viola palustris-type
Sp.17-35:612 (n = 4): 1.77 (1.68-1.91) × 1.13 (1.05-1.17) mm

On the basis of lengths and widths of recent *Viola* seeds, Jacomet *et al.* (1989: 291) distinguished three groups. The group with the smallest seeds, with a length of 1.5-1.8 mm, includes *Viola arvensis*, *V. tricolor*, *V. rupestris*, *V. palustris*, *V. canina* and *V. montana*. The first two species seem to be too small for the present material, the remaining four species seem indistinguishable at present. *Viola palustris*, the most likely species concerned, has been chosen to name this type.

acknowledgements

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summary

The investigations presented here concern the habitation in an area to the south of the Meuse estuary during the Iron Age and the Roman Period. The area studied comprises the present-day Dutch islands Voorne and Putten (province of Zuid-Holland). These islands will hereafter be referred to as Voorne-Putten.

From a botanical point of view, the investigations concern the reconstruction of former landscapes, the environmental changes that occurred and the agricultural possibilities that these landscapes offered. Furthermore, the possible effects of the incorporation of Voorne-Putten into the Roman Empire were studied.

Before the start of the investigations, it had been demonstrated that settlements during both the Early and Middle Iron Age (c. 625-225 BC) were built on peaty soils in the area of the present-day Bernisse. There appears to be a hiatus in the habitation between those two periods. Man lived in usually three-aisled farms which housed livestock as well. The settlements, consisting of single farms, were situated in the vicinity of creeks in the landscape.

Geological investigations had revealed that considerable environmental changes took place after the Middle Iron Age. Marine inundations during the so-called Dunkirk I transgression phase caused sedimentation of clastic sediments in large parts of the area, and the present-day Bernisse was formed. The inhabitation during the Late Iron Age (c. 225-50 BC) was concentrated in settlements on these clayey sediments. On western Voorne, some settlements were established on raised bog cushions. The Dunkirk I sediments on western Voorne were deposited on top of the Late Iron Age remains. These Dunkirk sediments are therefore asynchronous, even within such a small area as Voorne-Putten. The habitation during the Roman Period (c. 50-275 AD) mainly occured again on the clayey sediments, but also on peat in the vicinity of these clayey soils.

Palynological investigations of peaty sediments demonstrated the Early and Middle Iron Age inhabitants to have settled on eutrophic peat where the vegetation was dominated by reed. The landscape surrounding the farms was open, with only few trees. During the Middle Iron Age, the shrub bog myrtle could spread over large parts of the area, which can be attributed to oxidation and mineralisation of the peaty soils. These processes will have been caused by an increased drainage of the peat as a result of the extensive system of gullies formed by the transgressive sea.

Along the Meuse, several kilometres away from the settlements, lay elevated levees, covered with trees characteristic of river valleys. Oak and elm grew on the higher parts, alder and willow on the more frequently inundated, lower parts. During the Early Iron Age inhabitation, human activities caused deforestation of the levees. The forests recovered during a hiatus between the Early and Middle Iron Age inhabitation, but during the latter renewed deforestation took place.

The Dunkirk I transgression phase caused peat growth to come to an end in virtually the whole area. Some renewed peat growth occurred just after the end of the Roman inhabitation. Reconstruction of the landscape during the Late Iron Age and the Roman Period is therefore not possible. Near Rockanje, local peat growth did occur between the Late Iron Age and the Roman Period. However, the peat contained a large proportion of clay and pollen originating from elsewhere. Therefore, the pollen does not necessarily provide information on the investigated area itself. The peat near Heenvliet, studied by the *Rijks Geologische Dienst*, also revealed growth continuing well into the Roman Period.

Investigations of the wood remains demonstrated that elm and sycamore were preferred for the heavier, roof-supporting construction elements in two Early Iron Age farms. By today's standards, these trees provide relatively durable timber. For the other parts of the constructions, alder was commonly used, whereas willow was preferred for wickerwork. These two trees provide the least durable woods. In a third Early Iron Age farm, only alder and one single willow were used. Remarkable is the absence of oak, because of its durability highly suitable for critical construction elements, despite the fact that this tree had been felled on a large scale, as the pollen diagrams showed.

Alder and willow are the dominant trees found in a Middle Iron Age farm. However, only a long wall of a farm could be excavated on this site. The only sycamore found

was in one of the scarce roof supports. The role of more durable trees in this period is therefore difficult to assess, but will have been smaller than in the Early Iron Age.

Rockanje 08-52 is the only excavated Late Iron Age site to date. The wood of this site has not yet been fully investigated.

During the Roman Period, four farms were built, one above the other, near Nieuwenhoorn. In the oldest farm, elm and sycamore were selected for the roof-supporting elements, in the following three phases oak was used. The large quantities of oak made dendrochronological research possible. This showed that the different constructions were built in the years 57 AD, 62 AD, 86 AD and 107 AD respectively. The trees used were probably obtained locally. The trees used in the last building phase had grown more irregularly, indicating that the supply of oak was probably running short.

In view of the good correlations of the yearring patterns with those of oaks from mineral soils and no correlation with oaks from wet environments, it can be deduced that the oaks used in Nieuwenhoorn were obtained from mineral soils. The levees along the Meuse or the Older Dunes may well have supplied these oaks.

In the native Roman settlement near Rockanje, only alder and ash could be demonstrated, the latter species being preferred for crucial construction elements. A granary found on this site had sixteen alder posts, each with a diameter of 25 cm or more. The wood remains in the third Roman settlement, Simonshaven, was only fragmentarily preserved due to the height above the water table. The high proportion of oak recovered on this site may be biased due to the greater resistance of oak against decomposition.

In most cases, the remains of the investigated former settlements ended up under the water table during or after inhabitation. As a result of the absence of oxygen, organic matter was not decomposed. As well as wood, an abundance of seeds and other plant remains was preserved in an uncarbonized state.

The investigations of the many waterlogged as well as the less common carbonized botanical macroremains has yielded numerous data that support and supplement the results of the palynological studies. The location of the Early and Middle Iron Age sites in reed swamps is apparent again. The Late Iron Age inhabitants near Rockanje and the Roman ones near Nieuwenhoorn had settled on a raised bog. The common presence of bog myrtle points to drainage and oxidation. This will have been an important factor influencing man's decision to inhabit the formerly wet peat. The rapid deposition of material on the Nieuwenhoorn site probably compensated subsidence due to compaction.

The Roman site near Rockanje was located on a higher part of a salt marsh, where fresh water occurred during greater parts of the year. The sea will have been near the site only sporadically. Low dwelling mounds were raised to protect the settlement against inundations.

A number of cultivated crop plants and deliberately gathered plants occurred among the botanical macroremains. The cereals emmer wheat and four-row barley occur in nearly all Iron Age sites, as well as crops with oil-rich seeds, linseed and/or gold of pleasure. Two Early Iron Age sites differ considerably in this respect. No carbonized or uncarbonized remains of crop plants were found in Rotterdam-Hartelkanaal. The only cereal remains from this site are impressions of grains on pottery.

Barley was absent in the Early Iron Age site of Spijkenisse 17-30, Next to emmer wheat, a limited number of broomcorn millet grains occur. The oil-rich crops linseed and gold of pleasure are absent as well, while rape seed does occur. The spectrum of crop plants from the third Early Iron Age site, Spijkenisse 17-35, is more like that of the Middle and Late Iron Age sites, with barley, linseed and gold of pleasure.

The crops found in the native Roman settlement of Nieuwenhoorn are dominated by barley, whereas emmer wheat, linseed and gold of pleasure play only a minor role. In addition, some Celtic beans were found here. In the settlement of Rockanje, four-row barley is even more important and only very few wheat remains occurred.

Striking is the fact that all crop weeds found are characteristic of arable fields sown in spring (so-called summercrop weeds). Weeds that characterize wintercrops are completely absent. The absence of wintercrop weeds and deforestation of the levees in the Iron Age, not due to the use of these trees for building purposes may indicate that the levees were cleared for agriculture. The fertility of the soils is guaranteed as these levees are frequently inundated in winter, making the growth of wintercrops impossible. After sedimentation of Dunkirk I deposits, these clastic soils created a large extension to the potentially arable area. In wintercrops on heavy clayey soils, as occurred near Roman Rockanje, only summercrop weeds develop due to the richness of the soil. Sowing of wintercrops in Rockanje therefore cannot be ruled out on the basis of the absence of wintercrop weeds. However, experiments in present-day salt marshes have demonstrated that the risk of inundations is high in winter, which also renders the cultivation of wintercrops on these soils unlikely.

Cluster analyses revealed that samples obtained from one single site resemble each other more closely than samples from different sites. Salinity is shown to be the ecological key factor for the greater intersite variation.

The cluster analysis of crop plants only resulted in a much higher similarity between the different sites. The similarity between the sites was even higher in the cluster analysis of crop weeds and of all carbonized macroremains.

Conspicuous differences occur in the proportion of crop weeds and plants of grasslands. In the Early and Middle Iron Age sites grassland plants are much more common and an increase of crop weeds can be observed over time. In the Roman site of Rockanje, the crop weeds are clearly dominant. It is assumed that a relationship exists between the share of grassland plants and the importance of stockbreeding. In settlements, seeds of crop weeds are systematically over-represented in comparison to seeds of grassland plants, so the relationship between the share of grassland plants and the importance of stockbreeding is not one to one.

The share of wild plants deliberately gathered for food is small. Only a few seeds of sloe, blackberry species, rose and elder could be found. Mannagrass was also gathered during the Middle Iron Age, as appears from a concentration of seeds in a hearth.

Dr. W. Prummel and Drs. P.J. van Mensch investigated faunal remains from Iron Age and Roman sites on Voorne-Putten. The preservation of bone, in contrast to botanical remains, is rather poor due to the peaty sediments. The individual sites yielded too few data to provide conclusive results. Therefore, the faunal remains have been grouped for each period.

The remains of hunted animals are negligable in all three phases of the Iron Age as well as in the Roman Period. Only one Late Iron Age site yielded large amounts of sturgeon remains. The majority of bone remains comes from domestic animals. Within these domesticates, cattle was by far the most important, especially during the Iron Age. Whether the production of milk was important cannot be ascertained well. Sheep/goat remains were the next most important. When the remains could be attributed to one of these two species, they belonged to sheep.

Pig comes third in importance among the faunal remains. Bones of dogs and horses were also found, but they were not kept for meat, as the bones lack butchering marks.

Faunal remains from Roman sites were studied less extensively. An increase in the importance of sheep/goat is apparent, but this might be due to better preservation conditions. Cattle remains, however, the dominant animal for slaughter.

In the reconstruction of the agricultural economies, an important question is whether the inhabitants were self-supporting, i.e. whether they could produce enough to fulfill their own requirements. It is relevant to know the demands are of the crops and domesticates found. Apart from such data, which are mainly based on factual criteria, palaeobotanical data can be used to make statements on local production versus import of certain crops. The cereals barley and millet could probably have been cultivated on the peaty soils

around the Early and Middle Iron Age settlements, but not emmer wheat. The various crops with oil-rich seeds could not have been grown on peat, with possible exception of gold of pleasure. In this species, a distinct discrepancy arises between palaeobotanical and recent data. Experimental cultivation of the Iron Age crops on peaty soils could offer an important contribution to our knowledge. This does apply to cereals as well.

Botanical macroremains may provide data about local cultivation of a crop versus import. The crop-processing by-products ("waste") provide relevant information in case of barley, linseed and gold of pleasure. Prerequisite is the investigation of a sufficient number of samples from as many different context-types as possible.

In case of emmer wheat, it must be noted that by-products, which according to ethnographic research point to local cultivation, i.e. larger stem fragments as well as culm nodes, are very rarely found in palaeobotanical investigations. As chaff remains of emmer (glumes) can be found on importing as well as producing sites, we can draw no conclusion as to the local production or import of emmer.

It must be assumed that domestic animals were kept near the farms. This assumption is supported by the regular occurrence of partitions (bays) as well as by the thick layers of dung in farmhouses. The most important meat supplier, cattle, could have been grazed in the reed vegetations around the settlements. During the Late Iron Age and the Roman Period, such vegetation types will have been present in the vicinity of the settlements as well. Recent investigations in the Dutch wetland area "Oostvaardersplassen" have shown that cattle can feed on reed. Grazing by cattle results in an increase of vegetation types with smaller herbs that can be digested by sheep as well. The elliptical droppings with virtually nothing but remains of the locally growing bog myrtle were most probably produced by goats.

The three excavated Early Iron Age farms show a remarkable trend. In Rotterdam-Hartelkanaal, the wood for construction purposes is of a poor quality and crops as well as crop weeds are absent in the samples for macroremains. In Spijkenisse 17-30, more durable timber was used, but the assortment of crop plants, with millet and rape seeds, differs considerably from the third Early Iron Age site, Spijkenisse 17-35 and the Middle Iron Age sites. Furthermore, botanical macroremains which indicate the local cultivation of a crop, are absent in Spijkenisse 17-30, and so are ecologically restricted crop weeds. In Spijkenisse 17-35, barley, linseed and gold of pleasure were cultivated as well as threshed by the Early Iron Age inhabitants. Besides, some specific summer-crop weeds were found on this site.

The results of the botanical investigations of these three settlements fit well into a model developed by Brandt et al. (1984) to explain Iron Age habitation of the peaty area in

the Assendelver Polders. These Polders are situated in another Dutch estuary, viz. that of the Oer-IJ. According to this model, a formerly uninhabited peaty area is first explored during short visits. Subsequently, the area is used for cattle-grazing during summer. The inhabitation is non-permanent and no arable farming is practised. This phase may be represented by the site of Rotterdam-Hartelkanaal. In the next phase, man settles permanently in the area, but only to practise stockbreeding. Arable products are obtained through exchange with relatives elsewhere. Spijkenisse 17-30 could probably represent this phase. Finally, arable farming would be practised by the peat dwellers themselves, thereby returning to a mainly self-supporting economy. This phase is most probably represented by the site of Spijkenisse 17-35.

The inhabitants of all Middle Iron Age sites studied seem to have been mixed arable and pastoral farmers. A hiatus in inhabitation between the Early and the Middle Iron Age does not seem to have been followed by a step-wise colonization as described above. Provisionally it can be concluded that the knowledge of the agricultural potential of the area was retained during a hiatus in habitation of ca. one century, although this needs to be confirmed by the study of more Middle Iron Age sites.

The find of a concentration of carbonized seeds of mannagrass in combination with several carbonized crop plants in a hearth of the Middle Iron Age site of Spijkenisse 17-34 is an indication of the use of this grass as food. Written sources attest the gathering of mannagrass for consumption until the 18th century. During the Middle Iron Age, the energy requirements near Spijkenisse could apparently not be completely satisfied by cereals.

The Late Iron Age follows the Middle Iron Age without an hiatus. During the Late Iron Age, a self-supporting food production existed. The environment did no longer provide limitations because of the clayey Dunkirk I deposits around the Bernisse.

During the Roman Period a farm near Nieuwenhoorn existed in the 1st and early 2nd centuries of our era. Wheat is of minor importance here, and so are linseed and gold of pleasure. Barley is the dominant crop, Celtic beans were cultivated as well. Near Rockanje, situated in a salt marsh environment during the 2nd and 3rd centuries AD, almost exclusively barley was grown. Although gold of pleasure and Celtic bean can be cultivated successfully in such an environment, do these crops lack completely. The arable farming practiced in Rockanje seems to have been specialized.

After assessing which crops were probably grown by the inhabitants of the sites and which animals contributed to the food production, an attempt was made to assess whether man could completely fulfill his own requirements for food.

Based on the number of stalls in farms, estimates of the meat- and milk production were made. Subsequently, the share of the total calorific and protein requirements provided by these animal products were calculated. For the Iron Age, hypothetical farms with six and ten stalls were chosen. For these farms, the number of inhabitants were alternatively estimated at four and six. The lower number is based on the area of the living quarters of the farms and 10 m² per person is assumed. The higher number is often quoted in relevant literature.

On a farm with six stalls, animal products can provide 47-67% of the energy requirements of a hypothetical family of four persons. The remaining calories will mainly have been supplied by cereals. In that case, the protein requirements will also have been fulfilled. If this farm with six stalls was inhabited by six persons plus a baby, 31-44% of the energy required would be covered by animal products. The amount of grain needed to provide the balance could have been obtained from three ha of arable land.

On the hypothetical farm with ten stalls, 58-84% of the energy requirements of four inhabitants could be obtained from animal products. Six inhabitants plus a baby could have obtained 38-54% of the needed calories through animal products. In this case, a maximum of 2.5 ha of land under cereals cultivation would be needed.

The inhabitants of Rotterdam-Hartelkanaal, with six stalls, had to consume vegetable products to meet their demands for energy. The import of grain suggested in the model of Brandt et al. obliged the inhabitants to maintain contacts with a community that produced grain in excess of its own needs (surplus). The inhabitants of Spijkenisse 17-30 would have had to import grain, in this case emmer, or they could have grown it themselves on the levees along the Meuse. Crop remains proving local production or import are absent in Spijkenisse 17-30, so it is not possible to decide between the above-mentioned alternatives.

In the case of Spijkenisse 17-35 and, more markedly, in the Middle Iron Age sites, evidence for cultivation of crops by the inhabitants was found, they were thus essentially self-supporting. Since barley is the only cereal found in the Early Iron Age samples of Spijkenisse 17-35, local cultivation on peat cannot be excluded. For emmer, which occurs regularly in the Middle Iron Age sites, cultivation on peat is highly improbable. As these settlements are as far removed from the levees along the Meuse as Spijkenisse 17-30, viz. several kilometres, this distance probably did not pose unsuperable problems. In present-day, non-mechanized societies, this distance can be bridged as well. The fact that all Early and Middle Iron Age sites were situated along gullies will have been of great importance for the bulk-transport of grain.

During the Late Iron Age, arable production could take place close to the settlements. The sandy to clayey Dunkirk I deposits around the Bernisse could have supported dozens of self-sufficient Iron Age farms.

The number of contemporary farms was estimated on the

basis of the known number of sites and the estimated duration of each phase. The number of inhabitants during all phases of the Iron Age was so small, that contacts with other groups were necessary, despite a self-supporting food production. The number of inhabitants was too small to maintain an independent population. Based on similarities in pottery, inhabitants of the Older Dunes and probably of the levees along the Meuse were involved here.

The clear partitions of the Iron Age byres are not discernible in the native Roman farms. On the basis of the sizes of the farms and the thickness of the layers of dung in the heightening material, especially in Nieuwenhoorn, it can be concluded that pastoralism was an important economic activity. The number of inhabitants of the farms probably exceeded that of the Iron Age, six to eight persons per farm are assumed here. The sizes of the farms seem to indicate that at least as many animals could be housed as in the Iron Age farm with ten stalls. In case of six inhabitants, 38-54% of the calorific requirements can thus be provided by animal products again, for eight inhabitants this share may have been 25-36%.

The granaries found in the native Roman settlements near Rockanje and Simonshaven were so large that they could easily have stored grain far in excess of the yearly cereal requirements of a family. More than 7000 kg of barley could have been stored if a wall of 30-35 cm high was present on the floor of a granary. It is assumed here that these stockpiles did not serve to compensate for harvests failures in several successive years, but that it concerns a surplus to be supplied to others.

Calculations of the amount of land required in the various models reveal that during the Iron Age enough herbaceous reed vegetations existed for both pastures and hay-making. The levees along the Meuse may have provided arable land for dozens of self-supporting Iron Age farms. The highest estimate for the number of contemporary Iron Age farms in the peaty area is ten. This is far below the area's carrying capacity for agriculture. During the Late Iron Age the clayey area around the Bernisse could have supported up to a hunderd contemporary settlements.

A much larger area of cereal cultivation is required in the Roman Period, to produce the surpluses calculated. If a fallow is cautiously estimated for every other year, an area of ca. 29-34 ha is required to fill one granary. The area around the Bernisse may have supported 21-25 contemporaneous farms, provided that livestock was grazed in peaty areas. It is estimated that 30 contemporaneous native Roman farms existed in this area. All farms combined cannot have produced the amount of grain needed to fill granaries the size of those of Simonshaven or Rockanje. The far larger clay cover on western Voorne will not have limited production, the more so since probably fewer settlements were located there.

Subsequently, the amount of labour required in the various models has been estimated to ascertain whether this would have been a limiting factor. The cutting of reed for winterfodder may have taken one person one month of labour. This time may well have been available after the harvesting of cereals and other crops. As far as the cereals are concerned, the method of sowing is of primary importance. It is assumed here, that the labour-intensive method of sowing in rows was practiced during the Iron Age. In that case, a maximum of 3 ha was required to obtain the amount of grain calculated above. The critical point in the Iron Age grain supply will have been harvesting, which had to be completed within one month. Harvesting 3 ha takes ca. 60 working days, so two persons were required to harvest cereals in just one month.

These calculations have important implications for the model of colonization of peaty areas. The 3 ha which can be harvested at a maximum can meet the demands of a family, which relies primarily on pastoral farming. Severe complications arise if it is assumed that the inhabitants of Rotterdam-Hartelkanaal and Spijkenisse 17-30 obtained their cereals from relatives specialising in arable farming. The latter not only had to produce the cereals they required for themselves, but also for the pastoral peat dwellers. This implies that they had to cultivate at least 6 ha of arable land. This can only have been possible if they were assisted by the peat inhabitants during critical periods such as the harvest.

The difference with the alternative situation, in which the inhabitants of the peaty area had their own arable fields on the levees at several kilometres distance, becomes rather small. With such a marginal difference, the economy of the peat dwellers may well have been autonomous or relied on an exchange with assistance in harvesting.

Calculations for the Roman Period revealed that 14-17 ha of grain sown in rows was required to fill a granary. Harvesting such an area in one month would have required ten persons, while the native Roman farms probably had six to eight inhabitants. Sowing in rows was therefore impossible. The alternative, broadcast sowing, would require 150-180 working days, as in that case the same gross-yield is obtained from a smaller area. With this method of sowing, five to six people would be needed, which is just feasible. A larger part of the grain stored in the granaries must be reserved for sowing the following year. The surplus may have been supplied to the Roman army, enough to feed eleven soldiers. This amount of grain could have been produced by a household of eight persons.

It is assumed that the transition from the Iron Age to the Roman Period had considerable implications for the autochthonous inhabitants of the area occupied. Groenman-van Waateringe distinguished several phases of development in

the agricultural economy during Roman times. During the occupation campaigns, food will have been supplied from areas occupied earlier. The local production could not have met the demands, quantitatively nor qualitatively. Especially the fact that the legions would mainly consume wheat, and not barley, is stressed by Groenman-van Waateringe. The second phase is the adjustment of the local production to the military demands. This phase is thought to have lasted until the first part of the 2nd century AD. The last phase, one of stabilisation, lasted until the second part of the 3rd century. The production would thereafter decline due to soil exhaustion and erosion. Grain for the Roman army is imported from Great-Britain by ship.

The two native Roman settlements on Voorne-Putten can be viewed in this light. Both Nieuwenhoorn, dating from the 1st and the start of the 2nd century and Rockanje, dating from the second half of the 2nd and the first half of the 3rd century, appear to have produced mainly barley. Particularly in the case of Rockanje a specialisation in this crop seems to have occurred. A change to wheat cannot be demonstrated. Moreover, in the saline environment around Rockanje, wheat could not have been grown. Alternatively,

the surplus of barley was not consumed by the Roman soldiers but by their horses. Horses were numerous in the Roman army, as can be deduced from the presence of cavalry divisions in the Roman *castella*.

Quantitative changes did occur after the transition from the Iron Age to the Roman Period, as is clearly evidenced by the large granaries with a storage capacity far above the requirements of a single household. The diversification of houseplans and the few crop species found point to specialization in agricultural production. Qualitative changes, however, are not discernible.

The investigations were only possible due to the excellent preservation of organic matter on Voorne-Putten. This preservation does not occur in the presence of oxygen as the remains decompose. In that case, only carbonized material will endure the ragaves of time. Oxidation, due to artificial lowering of the water table for agrarian purposes, threatens to have a devastating and irreversible effect on the remains that have been preserved for thousands of years, and thereby on the possibilities for meaningful archaeological and ecological investigations.

samenvatting

Het hier gepresenteerde onderzoek richt zich op de bewo-
ning van het gebied ten zuiden van het Maas-estuarium
gedurende de IJzertijd en de Romeinse Tijd. De huidige
Zuidhollandse eilanden Voorne en Putten vormden het
onderzoeksgebied. In het vervolg worden deze eilanden kort-
weg aangeduid met Voorne-Putten. Vanuit een botanisch
perspectief werd onderzocht hoe het landschap eruit zag, of
zich landschappelijke veranderingen voordeden, welke agra-
rische mogelijkheden deze landschappen boden en wat het
eventuele gevolg was van de inlijving van het gebied in het
Romeinse Rijk.

Door middel van archeologische opgravingen was reeds
vastgesteld dat de bewoning in de Vroege en Midden-IJzer-
tijd (van ca. 625 tot ca. 225 v. Chr.) zich had gevestigd in
het veengebied rond de huidige Bernisse. Er is een bewo-
ningshiaat tussen de Vroege en Midden-IJzertijd. Men
woonde in drieschepige woon-stalhuizen. Het vee was onder
hetzelfde dak gehuisvest als de mensen. De nederzettingen,
bestaande uit geïsoleerde boerderijen, lagen in de onmiddel-
lijke nabijheid van kreken in het landschap.

Uit geologisch onderzoek bleek, dat het landschap na de
Midden-IJzertijd sterk veranderde. Door inbraken van de
zee tijdens de zogenaamde Duinkerke I transgressie-fase
werd op aanzienlijke schaal klei afgezet. Tevens werd de
Bernisse, zoals we die nu kennen, gevormd. De bewoning in
de Late IJzertijd (ca. 225 tot ca. 50 v.Chr.) rond de Bernisse
concentreerde zich op deze klei-afzettingen. In het westelijke
deel van Voorne woonde men op een hoogveen-kussen. Op
westelijk Voorne zijn de Duinkerke I afzettingen pas
gevormd na de Late- IJzertijd-bewoning aldaar, wat de
asynchroniteit van deze afzettingen, zelfs in een beperkt
gebied als Voorne-Putten, demonstreert. De bewoning in de
Romeinse Tijd (ca. 50 tot ca. 275 AD) is eveneens vooral in
de kleigebieden gelocaliseerd, maar ook het veen in de nabij-
heid van de kleidekken werd bewoond.

Door middel van stuifmeel-onderzoek (palynologie) van
veen-afzettingen kon in het huidige onderzoek worden vast-
gesteld dat de bewoners zich tijdens de Vroege en Midden-
IJzertijd hadden gevestigd op voedselrijk (eutroof) veen; de
begroeiing werd gedomineerd door riet. Het landschap rond
de nederzettingen was zeer open; er was nauwelijks boom-
groei. Ten tijde van de Midden-IJzertijd-bewoning kon de

gagelstruik zich sterk uitbreiden, wat toegeschreven kan
worden aan oxydatie en mineralisatie van het veen. Dit zal
het resultaat zijn geweest van verbeterde ontwatering van
het veen, wat veroorzaakt kan zijn door de vorming van een
uitgebreid stelsel van geulen ten gevolge van de toenemende
invloed van de zee.

Verderweg van de bewoning, langs de oevers van de
Maas, lagen oeverwallen, begroeid met karakteristieke
boomsoorten van ooibossen. Eik en iep groeiden in de ooi-
bossen op de drogere delen, els en wilg op de nattere plaat-
sen. Tijdens de bewoning van de Vroege IJzertijd trad op
grote schaal ontbossing van de oeverwallen op door hout-
kap door de mens. Tijdens het hiaat in de bewoning tussen
de Vroege en de Midden-IJzertijd kon de ooibos-vegetatie
zich enigszins herstellen, maar tijdens de Midden-IJzertijd
werd opnieuw op grote schaal gekapt.

Doordat als gevolg van de Duinkerke I transgressie-fase
het veen ontwaterde, kwam de veengroei in vrijwel het
gehele gebied tot stilstand. Op een enkele uitzondering na
trad veenvorming pas weer op vlak na het verdwijnen van
de Romeinse bewoning in het gebied. Hierdoor levert paly-
nologisch onderzoek geen informatie op over het landschap
in de Late IJzertijd en de Romeinse Tijd. Veenlagen, die
onontbeerlijk zijn voor de conservering van stuifmeel (pol-
len) zijn immers niet of nauwelijks meer voorhanden. Welis-
waar bevatten klei-afzettingen eveneens pollen, maar dit kan
met water van ver uit het achterland zijn aangevoerd. Dit
pollen levert niet altijd informatie over het gebied van
onderzoek zelf. Eén van de weinige bekende veenpakket dat
tussen de Late IJzertijd en de Romeinse Tijd werd gevormd
op Voorne-Putten ligt bij Rockanje. Dit veen bevatte zoveel
klei en tevens pollen dat via het water van ver moet zijn
aangevoerd, dat er geen betrouwbaar beeld van het land-
schap mee kon worden verkregen. Ook het door de Rijks
Geologische Dienst onderzochte veen nabij Heenvliet ver-
toonde veengroei tot in de Romeinse Tijd.

Bij onderzoek van het bouwhout kon in twee Vroege-IJzer-
tijd-boerderijen bij Spijkenisse geconstateerd worden, dat bij
voorkeur iep en esdoorn voor de zwaardere, dakdragende
constructie-elementen zijn toegepast. Naar huidige maat-
staven zijn dit redelijk duurzame houtsoorten. Voor het
overige constructie-hout was vooral veel elzehout gebruikt

en wilg voor het vlechtwerk. Dit zijn de minst duurzame inheemse houtsoorten. In de derde hier onderzochte Vroege-IJzertijd-boerderij, Rotterdam-Hartelkanaal, blijkt vrijwel uitsluitend els en eenmaal wilg te zijn gebruikt. Opvallend is dat eikehout nagenoeg ontbreekt in deze drie boerderijen, terwijl het pollen-onderzoek wel een grootschalige kap van eik in de Vroege IJzertijd aangaf.

De enige Midden-IJzertijd-boerderij waarvan het hout kon worden onderzocht, wederom bij Spijkenisse, leverde ook hoofdzakelijk els en wilg op. Op deze vindplaats kon echter vrijwel uitsluitend een lange wand van de boerderij worden opgegraven. De enige aangetroffen esdoorn was één van de weinige resterende middenstaanders. De rol van duurzamere houtsoorten is niet goed te bepalen, maar zal kleiner zijn geweest dan in de twee Vroege-IJzertijd-boerderijen bij Spijkenisse.

Het houtonderzoek van de Late-IJzertijd-boerderij van Rockanje 08-52 is op dit moment nog niet afgerond.

Bij Nieuwenhoorn werden in de Romeinse Tijd vier boerderijen op dezelfde plaats, over elkaar, gebouwd. In de oudste inheemse boerderij zijn iep en esdoorn gebruikt voor de dakdragende elementen; in de volgende drie bouwfasen is hiervoor vooral eik toegepast. Het vele eikehout bood de mogelijkheid van dendrochronologisch onderzoek. Hiermee kon worden vastgesteld dat de boerderijen respectievelijk in de jaren 57 AD, 62 AD, 86 AD en 107 AD zijn gebouwd. Het eikehout van de opeenvolgende bouwfasen is waarschijnlijk uit hetzelfde gebied afkomstig; aanvoer van grote afstand is onwaarschijnlijk. In de laatste bouwfase moest men kennelijk onregelmatiger gegroeid hout gebruiken; wellicht raakte de beschikbare voorraad uitgeput.

Gezien de goede correlatie van de jaarring-patronen met die van eiken van minerale gronden en het ontbreken van correlaties met eiken uit een zeer nat milieu kan worden geconcludeerd dat de eiken van Nieuwenhoorn van zand- of kleigrond afkomstig waren, bijvoorbeeld van oeverwallen langs de Maas. In hoeverre de kleiige Duinkerke I afzettingen al met ruim honderdjarige eiken begroeid waren in de eerste eeuw van onze jaartelling kan niet worden vastgesteld door het ontbreken van pollen-gegevens.

In de inheems-Romeinse vindplaats bij Rockanje konden alleen els en es worden aangetoond, waarbij laatstgenoemde soort werd geprefereerd voor de cruciale constructie-elementen. Een graanschuur in deze vindplaats was geplaatst op zestien elzen palen, die echter wel een dikte van 25 cm of meer hadden.

Het hout van een derde inheems-Romeinse nederzetting, bij Simonshaven, was zeer fragmentair bewaard gebleven door de hogere ligging ten opzichte van de grondwaterstand. Het hoge aandeel van eik in Simonshaven kan vertekend zijn door de grote resistentie tegen afbraak van deze houtsoort.

In de meeste gevallen zijn de resten van de onderzochte voormalige nederzettingen onder de grondwaterspiegel komen te liggen tijdens of na de bewoning. Hierdoor is veel organisch materiaal door afwezigheid van zuurstof gevrijwaard gebleven van biologische afbraak-processen. Naast hout konden ook zeer veel zaden en andere plantendelen in onverkoolde toestand bewaard blijven.

Het onderzoek van de vele onverkoolde zowel als van de minder talrijke verkoolde plantaardige macroresten heeft een scala gegevens opgeleverd die een aanvulling en een uitbreiding vormen van het pollen-onderzoek.

De ligging van de Vroege- en Midden-IJzertijd-vindplaatsen in een rietveen-gebied komt ook bij het zadenonderzoek duidelijk naar voren. De Late-IJzertijd-bewoning bij Rockanje en de Romeinse bij Nieuwenhoorn hadden zich gevestigd in een door veenmos en heide gedomineerde hoogveen-vegetatie. Ook hier wijst de talrijk voorkomende gagel op oxydatie en ontwatering. Dit zal een van de belangrijkste oorzaken zijn, waardoor het daarvoor zeer natte veen bewoonbaar werd geacht.

Een in korte tijd opgebrachte ophogingslaag in Nieuwenhoorn diende mogelijk om klink door compactie van de ondergrond te compenseren.

De Romeinse bewoning bij Rockanje lag op een hoog deel van een kwelderlandschap, waar gedurende een groot deel van het jaar zoet water kon voorkomen. Slechts sporadisch zal de zee nabij geweest zijn. Er werden lage terpjes opgeworpen om de nederzetting tegen overstroming te beschermen.

Bij de macroresten konden ook allerlei resten van gekweekte voedselgewassen en van verzamelde planten worden aangetoond. In vrijwel alle IJzertijd-vindplaatsen treden de granen emmertarwe en vierrijige gerst op, aangevuld met gewassen met olierijke zaden, lijnzaad en/of huttentut. Twee Vroege-IJzertijd-vindplaatsen wijken sterk af van dit beeld. In Rotterdam-Hartelkanaal zijn in het geheel geen verkoolde of onverkoolde resten van voedselplanten gevonden. Het enige wat aan graan aan ons is overgeleverd zijn de indrukken van gerst-korrels in aardewerk.

In de Vroege-IJzertijd-vindplaats Spijkenisse 17-30 werd geen gerst aangetroffen. Naast emmertarwe is hier ook een beperkte hoeveelheid gierst aangetoond. De oliehoudende gewassen lijnzaad en huttentut ontbreken eveneens, raapzaad treedt er voor in de plaats. Het soortenspectrum van cultuurgewassen van de derde Vroege-IJzertijd-vindplaats (Spijkenisse 17-35) sluit aan op het normale patroon van de Midden- en Late IJzertijd.

Het arsenaal cultuurgewassen van de inheems-Romeinse nederzetting bij Nieuwenhoorn vertoont een veel groter aandeel van gerst en een bescheiden rol van emmertarwe, lijnzaad en huttentut. Naast deze gewassen is een aantal tuinbonen gevonden. In de Romeinse nederzetting bij Rockanje is vrijwel uitsluitend vierrijige gerst aangetroffen.

Opvallend is dat alle aangetroffen akkeronkruiden soorten zijn van akkers die in het voorjaar ingezaaid worden (zomergraan-akkers). Kenmerkende soorten van in het najaar ingezaaide akkers ontbreken volledig.

Het ontbreken van wintergraan-akkeronkruiden en de ontbossing van oeverwallen tijdens de IJzertijd zonder dat het hout op grote schaal voor bouwhout is gebruikt, wijzen op het aanleggen van akkers op deze oeverwallen. Doordat ze 's winters regelmatig overstromen, wordt de vruchtbaarheid van de bodem steeds hersteld, maar is het niet mogelijk wintergraan te verbouwen. Na de vorming van Duinkerke I afzettingen boden deze kleiige gronden een enorme uitbreiding van het potentiële akkerland. Op de zware kleigronden, zoals die bijvoorbeeld bij Rockanje voorkwamen, treden tegenwoordig ook in wintergraan-akkers uitsluitend zomergraan akkeronkruiden op. Voor Rockanje kan zaai van wintergraan dan ook niet volledig worden uitgesloten. Experimenten in hedendaagse kwelder-omstandigheden tonen echter, dat ook daar het risico van overstroming in de winter groot is, zodat waarschijnlijk ook op deze gronden in hoofdzaak zomergewassen werden geteeld.

Met behulp van cluster-analyses kon worden gedemonstreerd, dat de zadenmonsters genomen binnen een vindplaats onderling meer overeenkomst vertonen dan monsters genomen in verschillende vindplaatsen. De ecologische factor saliniteit is hierbij de sleutelfactor gebleken. Bij de cluster-analyse op basis van uitsluitend de cultuurgewassen is er een grotere overeenkomst tussen de diverse vindplaatsen, wat in nog sterkere mate geldt voor de cluster-analyses op basis van akkeronkruiden en van al het verkoolde materiaal.

Opmerkelijk zijn de grote verschillen die optreden in het aandeel van akkeronkruiden en graslandplanten in de onderzochte vindplaatsen. In de nederzettingen uit de Vroege en Midden-IJzertijd zijn graslandplanten duidelijk in de meerderheid; in de loop van de tijd treedt een toename van akkeronkruiden op. In het Romeinse Rockanje hebben laatstgenoemden duidelijk de overhand. Het aandeel van graslandplanten wordt geacht verband te houden met het belang van veeteelt in de voedsel-economie, met name in verband met hooi voor wintervoer voor het vee. Graslandplanten zijn echter systematisch ondervertegenwoordigd in nederzettingen, zodat er geen één op één relatie bestaat tussen het aandeel van graslandplanten en het belang van veeteelt.

Het aandeel van wilde planten die voor voedseldoeleinden zijn verzameld, is zeer gering. Slechts enkele zaden van sleedoorn, braam-soorten, roos en vlier zijn aangetroffen. Daarnaast is blijkens een concentratie in een haard uit de Midden-IJzertijd ook mannagras verzameld.

Faunaresten uit vindplaatsen uit de IJzertijd en de Romeinse

Tijd op Voorne-Putten zijn onderzocht door Dr. W. Prummel en Drs. P.J. van Mensch. Doordat de bewoningsresten vaak in venige sedimenten bewaard zijn gebleven, is de conservering van bot, in tegenstelling tot die van de botanische resten, in de regel niet zo goed. Hierdoor leveren de individuele vindplaatsen te weinig gegevens op voor een coherent beeld. Het botmateriaal is daarom per periode gegroepeerd.

In de drie fasen van de IJzertijd zowel als in de Romeinse Tijd is de jachtcomponent verwaarloosbaar; slechts in de Late IJzertijd lijkt steur-visserij van enig belang voor de voedselvoorziening te zijn geweest. Het overgrote deel van de botresten is afkomstig van gedomesticeerde dieren. In de IJzertijd is het rund verreweg de belangrijkste vleesleverancier geweest. Of ook met melkproductie moet worden gerekend, is niet goed vast te stellen. Na het rund wordt de tweede plaats ingenomen door schaap/geit. Waar nader determineerbare resten voorhanden waren, betrof het steeds schaap. Het varken is de volgende soort op de ranglijst. Resten van hond en paard zijn ook regelmatig aangetroffen, maar door het ontbreken van snijsporen op de botten moet worden aangenomen dat ze niet voor het vlees werden gehouden. Het paard zal als rijdier zijn benut, waarbij een status-functie ook zeker niet moet worden genegeerd. Honden kunnen hun diensten hebben bewezen als waakdieren en bij het hoeden van schapen.

Faunaresten uit de Romeinse Tijd zijn in veel beperktere mate onderzocht. Er lijkt zich evenwel een toename van het aandeel van schapen en/of geiten af te tekenen. Dit zou echter het gevolg kunnen zijn van gunstigere conserveringsomstandigheden. Het rund blijft het belangrijkste slachtvee.

Bij de reconstructie van de voedsel-economie is getracht te bepalen of men zelfvoorzienend geweest kon zijn of niet. Hierbij is het van belang te weten welke eisen de aangetroffen voedselgewassen en huisdieren stellen aan het milieu. Naast dergelijke gegevens op grond van tegenwoordige criteria kunnen paleo-botanische gegevens worden gebruikt om een uitspraak te doen over lokale teelt versus import van bepaalde voedselgewassen. Op de veengronden rond de nederzettingen uit de Vroege en Midden-IJzertijd kunnen mogelijk de graangewassen gerst en gierst verbouwd zijn, emmertarwe zeer waarschijnlijk niet. De diverse gewassen met olierijke zaden konden waarschijnlijk niet op veen verbouwd worden; voor huttentut moet in dit opzicht echter een slag om de arm gehouden worden. Er treedt hier namelijk een discrepantie op tussen paleo-botanische en hedendaagse gegevens. Experimentele verbouw van de IJzertijd-cultuurgewassen op veengrond zou een belangrijke bijdrage kunnen leveren in deze. Ook waar het de granen betreft kunnen hiermee belangrijke inzichten verworven worden.

De botanische macroresten kunnen gegevens opleveren over teelt door de bewoners van de nederzetting versus

import. Van de gewassen gerst, lijnzaad en huttentut leveren bij-produkten van het dorsproces ("afval") in dit opzicht relevante informatie. Voorwaarde hierbij is, dat voldoende monsters uit zoveel mogelijk verschillende context-typen zijn onderzocht.

In het geval van emmertarwe moet geconstateerd worden, dat de bij-produkten die blijkens etnografisch onderzoek wijzen op lokale teelt, met name de grotere stengelfragmenten en de stengelknopen, zelden worden aangetroffen in paleo-botanisch onderzoek. Ook in een producerende nederzetting komen geen stengelfragmenten terecht. Kafresten van emmertarwe kunnen ook in het afval van importerende nederzettingen worden aangetroffen. Hierdoor is het niet mogelijk lokale produktie of import van emmer aan te tonen.

Van het vee wordt aangenomen dat het bij de boerderijen werd gehouden. Dit wordt zowel door de vaak aanwezige stalboxen als door de veelal dikke mestpakketten aangetoond. De belangrijkste vleesleverancier, het rund, kan zijn geweid in de rietvegetaties rond de nederzettingen. Ook tijdens de Late IJzertijd en de Romeinse Tijd zullen dergelijke rietvegetaties in de nabijheid van de nederzettingen hebben gelegen. Uit recent begrazingsonderzoek in de Oostvaardersplassen is het eten van riet door rundvee als reële mogelijkheid naar voren gekomen. Door deze begrazing onstaan vegetatie-typen met lagere kruiden, die ook door schapen begraasd kunnen worden. Naast schapen werden waarschijnlijk ook enkele geiten gehouden. Elliptische uitwerpselen met vrijwel uitsluitend resten van de lokaal aanwezige gagel zijn waarschijnlijk geproduceerd door geiten.

De drie opgegraven boerderijen uit de Vroege IJzertijd tonen een opmerkelijke ontwikkeling. In Rotterdam-Hartelkanaal is het bouwhout zeer weinig duurzaam. Daarnaast ontbreken cultuurgewassen en akkeronkruiden in de zadenmonsters, die echter minder stelselmatig zijn verzameld als op de andere besproken opgravingen. In Spijkenisse 17-30 is duurzamer hout verwerkt. Het assortiment cultuurgewassen wijkt door de aanwezigheid van gierst en raapzaad en de afwezigheid van gerst af van de derde Vroege-IJzertijd-boerderij, Spijkenisse 17-35 en van de Midden- en Late-IJzertijd-boerderijen. Bovendien zijn in 17-30 geen aanwijzingen voor de lokale verbouw van cultuurgewassen, noch komen specifieke akkeronkruiden voor. In Spijkenisse 17-35 is gerst, lijnzaad en huttentut door de bewoners verbouwd en gedorst. Tevens zijn in 17-35 een aantal specifieke zomer-graan-akkeronkruiden aangetroffen.

De drie nederzettingen zijn op grond van deze botanische gegevens goed in te passen in een model, dat is ontwikkeld voor veenbewoning in de Assendelver Polders door Brandt *et al.* (1984). Volgens dit model wordt een voorheen onbewoond veengebied eerst door korte bezoeken verkend. Dan wordt het gebied benut voor het weiden van vee gedurende

de zomer. De bewoning is niet permanent en er wordt geen akkerbouw bedreven. Deze fase kan mogelijk door Rotterdam-Hartelkanaal zijn vertegenwoordigd. Vervolgens treedt een fase op, waarbij men zich wel permanent in het gebied vestigt, maar zich alleen toelegt op veeteelt. Akkerbouw-producten worden via ruilhandel met verwanten verkregen. Spijkenisse 17-30 zou deze fase kunnen representeren. Tenslotte zou ook akkerbouw worden bedreven door de veenbewoners, die daarmee terugkeren naar een zoveel mogelijk zelfvoorzienende economie. Deze fase wordt mogelijk vertegenwoordigd door de vindplaats Spijkenisse 17-35.

In alle onderzochte vindplaatsen uit de Midden-IJzertijd lijkt men zowel akkerbouw als veeteelt bedreven te hebben. Het bewoningshiaat tussen de Vroege en de Midden-IJzertijd heeft niet aantoonbaar tot hernieuwde staps-gewijze kolonisatie van het gebied geleid. Als dit ook na onderzoek van meer nederzettingen uit de Midden-IJzertijd het geval blijft, moet geconcludeerd worden dat het agrarische potentieel van het gebied na een bewoningshiaat van ongeveer een eeuw nog steeds bekend was.

De vondst van een concentratie verkoolde zaden van mannagras in een haard van de Midden-IJzertijd-boerderij Spijkenisse 17-34, tesamen met diverse verkoolde cultuurgewassen, toont aan dat dit gras tot voedsel diende. Tot in de 18[e] eeuw werd dit gras voor consumptie verzameld. Kennelijk kon de energie-behoefte in de Midden-IJzertijd bij Spijkenisse niet steeds volledig door graan gedekt worden.

De Late IJzertijd volgt zonder hiaat op de Midden-IJzertijd. Ook in deze fase is sprake van een zelfvoorzienende voedselproductie. Het landschap levert in dit opzicht geen beperkingen meer op door de kleiige afzettingen van Duinkerke I rond de Bernisse.

In de Romeinse Tijd lag bij Nieuwenhoorn een boerderij uit de eerste en begin tweede eeuw van onze jaartelling. Tarwe is hier van ondergeschikt belang, evenals lijnzaad en huttentut. Gerst is het belangrijkste cultuurgewas, veld- of duivebonen werden eveneens gekweekt. Bij Rockanje werd in de 2[e]/3[e] eeuw in een kweldermilieu vrijwel uitsluitend gerst verbouwd. Hoewel ook huttentut en veld- of duiveboon in een dergelijk milieu met succes gekweekt kunnen worden, ontbreken deze gewassen volledig. Er lijkt sprake van een gespecialiseerde akkerbouw.

Nadat is vastgesteld welke cultuurgewassen mogelijk door de bewoners van de nederzettingen werden gekweekt en welke dieren aan de voedselvoorziening bijdroegen, is getracht te bepalen of men geheel in de eigen voedselbehoefte kon voorzien.

Met behulp van de geschatte vlees- en melkproductie op basis van het aantal stalboxen is berekend welk deel van de calorie- en eiwitbehoefte kan zijn geleverd door dierlijke produkten. Voor de IJzertijd zijn als model boerderijen met zes en met tien stalboxen gekozen. Voor beide boerderijen

wordt het aantal inwoners geschat op vier en zes. De lage schatting is naar aanleiding van de oppervlakte van het woondeel, waarbij is aangenomen dat een persoon 10 m² behoeft. De hogere schatting is op basis van een vaak in de literatuur terugkerende aanname.

In de boerderij met zes stalboxen kunnen dierlijke produkten in 47-67% van de energiebehoefte van een model-familie met vier inwoners hebben voorzien. De overige calorieën zullen hoofdzakelijk door graan zijn geleverd. Hiermee zal ook de eiwitbehoefte zijn gedekt. Als de boerderij met zes stalboxen door een model-huishouden van zes personen plus een baby bewoond werd, wordt in 31-44% van de energiebehoefte voorzien door dierlijke produkten. De hoeveelheid graan die vereist is om de calorie- en eiwitbehoefte te dekken, kan door maximaal 3 ha akkerland opgebracht worden.

In de hypothetische boerderij met tien stalboxen kan 58-84% van de energiebehoefte van vier inwoners door dierlijke produkten worden geleverd. In het model voor zes inwoners met baby wordt 38-54% van de vereiste calorieën geleverd. In dit geval is maximaal 2.5 ha graanland vereist.

De bewoners van Rotterdam-Hartelkanaal, met zes stalboxen, moeten derhalve plantaardige produkten gegeten hebben om in hun energiebehoefte te voorzien. De hiervoor geopperde import van graan verplicht de bewoners relaties te onderhouden met een graanoverschot producerende gemeenschap. Ook de bewoners van Spijkenisse 17-30 zullen graan, in dit geval emmer, hebben moeten importeren, danwel het zelf hebben verbouwd op de oeverwallen langs de Maas. Doordat gewassen, waarvan eigen produktie aantoonbaar is in deze vindplaats ontbreken, is er geen keuze mogelijk tussen deze alternatieven.

In Spijkenisse 17-35 en in de Midden-IJzertijd-vindplaatsen zijn wel duidelijke aanwijzingen voor verbouw van cultuurgewassen door de bewoners, die in hoofdzaak zelfvoorzienend geweest zullen zijn. Aangezien van de granen alleen gerst is aangetroffen in de Vroege-IJzertijd-monsters van 17-35, is teelt nabij de nederzetting niet uitgesloten. Voor de in de Midden-IJzertijd talrijke emmer is teelt op veen echter onwaarschijnlijk. Omdat deze nederzettingen net als die van Spijkenisse 17-30 op enkele kilometers van de goede akkerbouwgronden langs de Maas lagen, zal deze afstand geen onoverkomelijk probleem opgeleverd hebben. Ook in hedendaagse, niet gemechaniseerde samenlevingen blijkt een dergelijke afstand goed overbrugbaar. De ligging van alle nederzettingen langs kreken zal in het bulk-transport van graan van wezenlijk belang zijn geweest.

In de Late IJzertijd kon de agrarische produktie dichter bij de nederzettingen plaatsvinden. De zandig tot kleiige Duinkerke I afzettingen rond de Bernisse boden ruimte aan tientallen zelfvoorzienende IJzertijd-boerderijen.

Op grond van het aantal bekende nederzettingen kan worden vastgesteld, dat er waarschijnlijk slechts enkele

gelijktijdige boerderijen waren in de IJzertijd. Het aantal inwoners van het gebied was dermate klein, dat ondanks een zelfvoorzienende voedseleconomie en de aanwezigheid van voldoende potentieel akkerland, toch banden moeten hebben bestaan met andere bevolkingsgroepen. Op grond van aarde-werk-overeenkomsten moet hier vooral aan de Oude Duinen en/of de oeverwallen langs de Maas worden gedacht.

In de Romeinse Tijd zijn de duidelijke stalboxen uit de IJzertijd-boerderijen niet meer herkenbaar. Op grond van de grootte van de betreffende inheemse boerderijen en de aanzienlijke hoeveelheid mest in de ophogingslagen, met name in Nieuwenhoorn, kan worden aangenomen dat veeteelt een belangrijk onderdeel van de bedrijfsvoering uitmaakte. Het aantal bewoners van de boerderijen was mogelijk groter dan in de IJzertijd, naar schatting zes tot acht personen. Door de grootte kon zeker zoveel vee gehuisvest worden als in de IJzertijd-boerderij met tien stalboxen. Bij zes inwoners kan derhalve weer in 38-54% van de caloriebehoefte worden voorzien door dierlijke produkten, bij acht inwoners kan dit aandeel 25-36% geweest zijn.

De graanschuren die zijn gevonden bij de inheems-Romeinse nederzettingen bij Rockanje en Simonshaven hebben een dermate grote inhoud, dat veel meer dan de graanbehoefte voor één jaar van een gezin kon worden opgeslagen. Indien er een 30-35 cm hoog muurtje op de vloer van de schuren stond, kon ruim 7000 kg gerst voor consumptie worden opgeslagen. Aangenomen wordt, dat deze hoeveelheid niet diende om misoogsten in een aantal opeenvolgende jaren op te vangen, maar dat het een surplus was, dat voor levering aan derden diende.

Berekeningen van de benodigde hoeveelheid land in de diverse modellen toont aan, dat in de IJzertijd zowel voor weide- als voor hooiland ruim voldoende kruidige rietvegetaties beschikbaar waren. De oeverwallen langs de Maas kunnen akkerland voor tientallen (zelfvoorzienende) IJzertijd-boerderijen geboden hebben. Het geschatte aantal gelijktijdige IJzertijd-boerderijen in het veengebied is met maximaal zes, gedurende de Midden-IJzertijd, ver beneden de draagkracht van het gebied. In de Late IJzertijd kan het grote klei-gebied van Duinkerke I afzettingen rond de Bernisse zelfs ruimschoots in het akkerland van honderd gelijktijdige nederzettingen hebben voorzien.

In de Romeinse Tijd is een veel groter graanareaal vereist om het berekende surplus te produceren. Bij een voorzichtige inschatting van een braak-periode van om het jaar is ca. 29-34 ha nodig om een graanschuur te vullen. Het gebied rond de Bernisse kan in de Romeinse Tijd plaats bieden aan 21-25 gelijktijdige boerderijen, op voorwaarde dat het vee geweid werd in de veengebieden. Naar schatting waren er 30 gelijktijdige inheems-Romeinse nederzettingen rond de Bernisse, zodat niet in alle een graanschuur ter grootte van die van Simonshaven en Rockanje vol kon worden geproduceerd. Het veel grotere kleidek op westelijk Voorne zal geen

beperkingen hebben geboden, te meer daar hier waarschijnlijk ook minder nederzettingen lagen.

Na de beschikbare hoeveelheid land is geschat of de hoeveelheid te verrichten arbeid een beperkende factor kan zijn geweest in de diverse modellen. Voor wat betreft het maaien van rietvegetaties voor wintervoer moest men ongeveer een maand werk voor één persoon uittrekken. Na de graanoogst zal deze benodigde tijd beschikbaar zijn geweest. Voor wat het graan betreft, hangt alles van de zaaimethode af. Aangenomen wordt, dat in de IJzertijd de arbeidsintensieve zaaimethode op rijen werd toegepast. Hiervoor zal gedurende de IJzertijd maximaal 3 ha benodigd zijn geweest. Het cruciale punt voor de IJzertijd-graanvoorziening zal het oogsten zijn geweest, wat binnen een maand diende te geschieden. Het oogsten van drie hectare zal wellicht 60 mens-dagen gekost hebben. Hiermee kunnen twee personen in een maand juist al het benodigde oogsten.

Deze berekeningen hebben belangrijke implicaties voor het model omtrent de kolonisatie van veengebieden. De maximaal oogstbare 3 ha kan namelijk in de voedselbehoefte voorzien van een bevolking, die voor een belangrijk deel van veeteelt leeft. Als wordt aangenomen, dat de bewoners van Rotterdam-Hartelkanaal en van Spijkenisse 17-30 hun graan van in akkerbouw gespecialiseerde verwanten betrokken, treden er aanzienlijke complicaties op. Deze akkerbouwers zouden namelijk niet alleen in hun eigen graanbehoefte moeten voorzien, maar ook in die van de veeteelt bedrijvende veenbewoners. Dit betekent dat ze tenminste zes hectare moesten bewerken. Dit kan alleen mogelijk zijn geweest, als ze bij de cruciale bewerkingen, vooral bij het oogsten, hulp kregen van de veenbewoners. Het verschil met het alternatief, akkerbouw door de veenbewoners zelf in de vroege ijzertijd op de enkele kilometers ver gelegen oeverwallen, wordt daarmee wel heel klein. De economie van de veenbewoners bevond zich derhalve in het niet meer onderscheidbare overgangsgebied tussen uitwisseling plus hulp bij de oogst en zelfvoorziening.

De berekeningen voor de Romeinse Tijd leverden op, dat 14-17 ha op rijen gezaaid graan vereist waren, om een graanschuur te vullen. De oogst zal in dit geval de inzet van ongeveer tien arbeidskrachten gedurende één maand vereist hebben, terwijl de inheems-Romeinse boerderijen waarschijnlijk zes tot acht inwoners telden. Op rijen zaaien was derhalve onmogelijk. De oogst na breedwerpig zaaien zou 150-180 werkdagen vereisen, omdat in dat geval hetzelfde oogstgewicht van een kleinere oppervlakte verkregen kan worden. In dit geval zijn vijf tot zes arbeidskrachten vereist. Dit is aan de bovengrens van het haalbare. Van de hoeveelheid die in een graanschuur kon worden opgeslagen, moet nu echter een groter deel voor uitzaai in het volgende jaar worden gereserveerd. Het resterende surplus kan aan het Romeinse leger geleverd zijn. In dat geval kunnen elf soldaten van graan worden voorzien. Deze hoeveelheid kon worden geleverd door een huishouden met maximaal acht personen.

Er wordt verondersteld, dat de overgang van de IJzertijd naar de Romeinse Tijd belangrijke gevolgen heeft gehad voor de autochtone bewoners. Groenman-van Waateringe onderscheidt een aantal fasen van aanpassing van de voedsel-economie. Tijdens de veroverings-campagnes zal het voedsel vanuit al eerder bezet gebied zijn aangevoerd. De lokale produktie zal zowel kwantitatief als kwalitatief niet aan de eisen hebben voldaan. Met name het feit dat de legioenen vrijwel uitsluitend tarwe, en geen gerst, zouden consumeren, wordt door Groenman-van Waateringe benadrukt. De tweede fase in de overschakeling is de aanpassing van de lokale produktie aan de militaire behoefte; deze fase wordt geacht tot het begin van de tweede eeuw geduurd te hebben. Daarna volgde tot de tweede helft van de derde eeuw een periode van stabilisatie. Vervolgens treedt door bodem-uitputting en erosie een daling van de produktie op; het graan voor de Romeinse legioenen moest per schip van Groot-Brittannië worden aangevoerd.

In dit licht kunnen de twee onderzochte inheems-Romeinse nederzettingen op Voorne-Putten worden bezien. Zowel Nieuwenhoorn, daterend uit de eerste tot begin tweede eeuw, als Rockanje, uit de tweede helft van de tweede en de eerste helft van de derde eeuw, blijken in hoofdzaak gerst geproduceerd te hebben. Met name in het geval van Rockanje lijkt men zich gespecialiseerd te hebben in dit gewas. Er is geen overschakeling naar tarwe aantoonbaar. In het zoute milieu rond Rockanje kan tarwe ook niet geproduceerd zijn. De mogelijkheid bestaat, dat het overschot aan gerst niet door de Romeinse soldaten werd geconsumeerd. Als alternatief kunnen de paarden dienen die blijkens de aanwezigheid van cavalerie-afdelingen in de Romeinse *castella* zeker talrijk aanwezig waren. Ten tweede kunnen de bewoners van Rockanje zelf paarden gefokt hebben voor de legioenen.

Kwantitatieve veranderingen bij de overgang van de IJzertijd naar de Romeinse Tijd worden zeer duidelijk aangetoond door de grote graanschuren met een opslagcapaciteit ver boven de behoefte van een huishouden. De in de Romeinse Tijd optredende diversiteit in huis-plattegronden wijst op specialisatie op agrarisch gebied. Kwalitatieve veranderingen zijn echter niet aantoonbaar.

Dit onderzoek was mogelijk door de bijzonder goede conservering van organisch materiaal op Voorne-Putten. Deze conservering treedt niet op als de resten onder aanwezigheid van zuurstof afgebroken worden. In dat geval kan alleen verkoold materiaal de tand des tijds doorstaan. Kunstmatige verlaging van de grondwaterstand voor agrarische doeleinden dreigt echter door de ermee gepaard gaande oxydatie een verwoestende en onomkeerbare uitwerking te hebben op de sinds duizenden jaren in het bodemarchief bewaard gebleven nederzettingen, en daarmee op de mogelijkheid van gedetailleerd archeologisch en oecologisch onderzoek.

list of abbreviations

B.O.O.R.	Bureau Oudheidkundig Onderzoek van Gemeentewerken Rotterdam.
I.P.L.	Instituut voor Prehistorie Leiden.
I.P.P.	*Instituut voor Prae- en Protohistorie, Amsterdam.*
R.O.B.	Rijksdienst voor het Oudheidkundig Bodemonderzoek, Amersfoort.
N.W.O.	Nederlandse Organisatie voor Wetenschappelijk Onderzoek.
cf.	*confer*, identification uncertain.
ha	hectare (10,000 m², ca. 2.47 acres).
m	metre(s).
kcal	kilocalorie(s); 4.18 KJoule.
N.A.P.	Normaal Amsterdams Peil (Dutch Ordnance Datum).
÷	below.
Ab.	Abbenbroek.
Gv.	Geervliet.
Nh.	Nieuwenhoorn.
Ro.	Rockanje (08-52).
Rock.	Rockanje II.
Sp.	Spijkenisse.
Zl.	Zuidland.

abbreviations/symbols used in tables

gl.b.	glume base.
sp.f.	spikelet fork.
intern.	rachis internode.
?	identification uncertain.
indet.	*indeterminatae*.

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Fig. 13 The relative pollen diagram of Spijkenisse 17-30.

PLOT IVA INFLUX
ANALYSIS

Fig. 14 The pollen influx diagram of Spijkenisse 17-30.
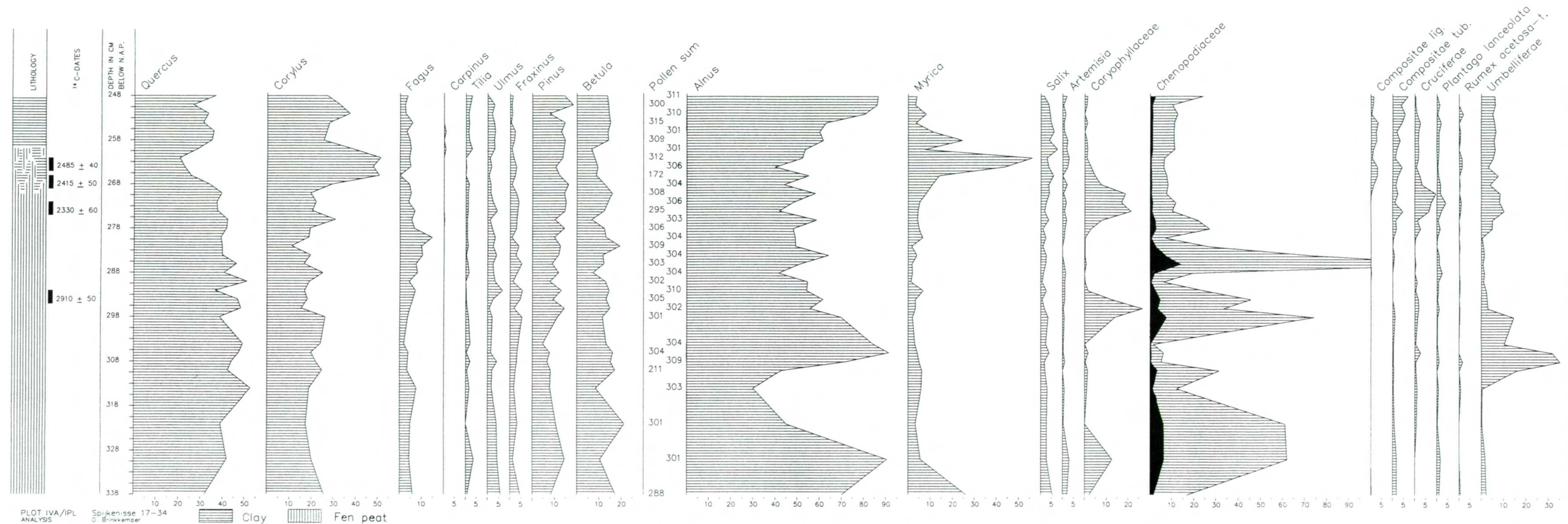
Fig. 16 The relative pollen diagram of Spijkenisse 17-34 (first part).
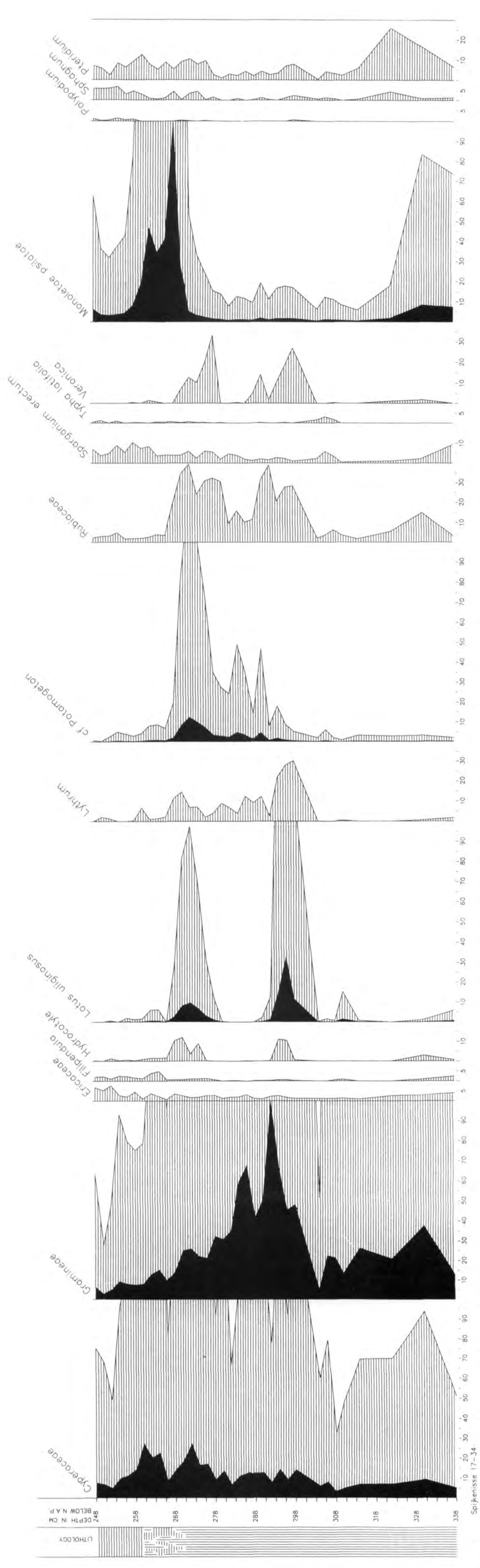
Fig. 16 The relative pollen diagram of Spijkenisse 17-34 (continued).
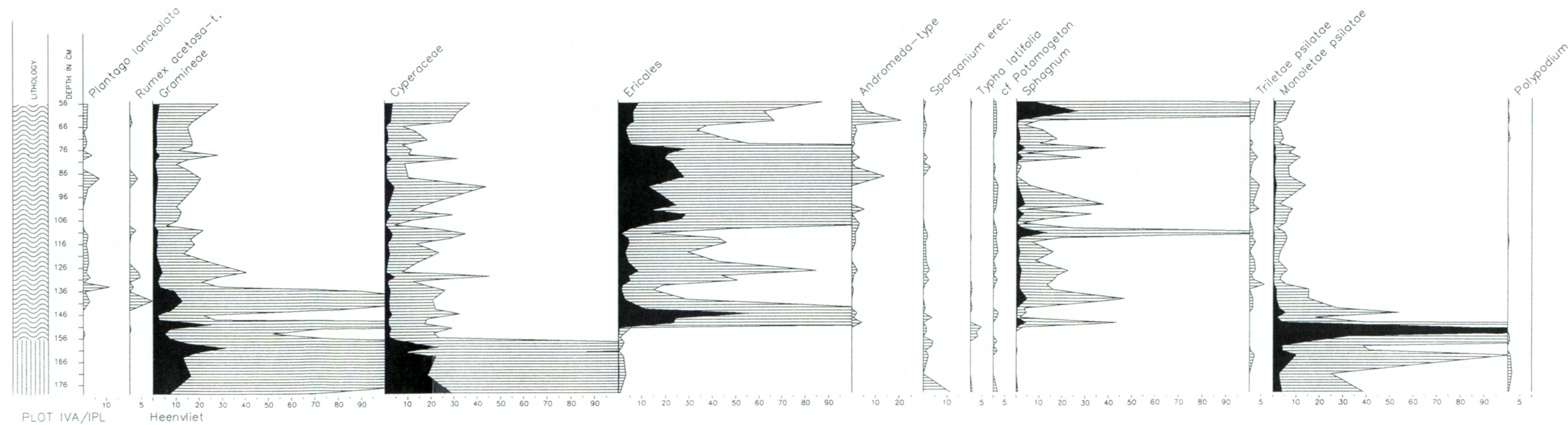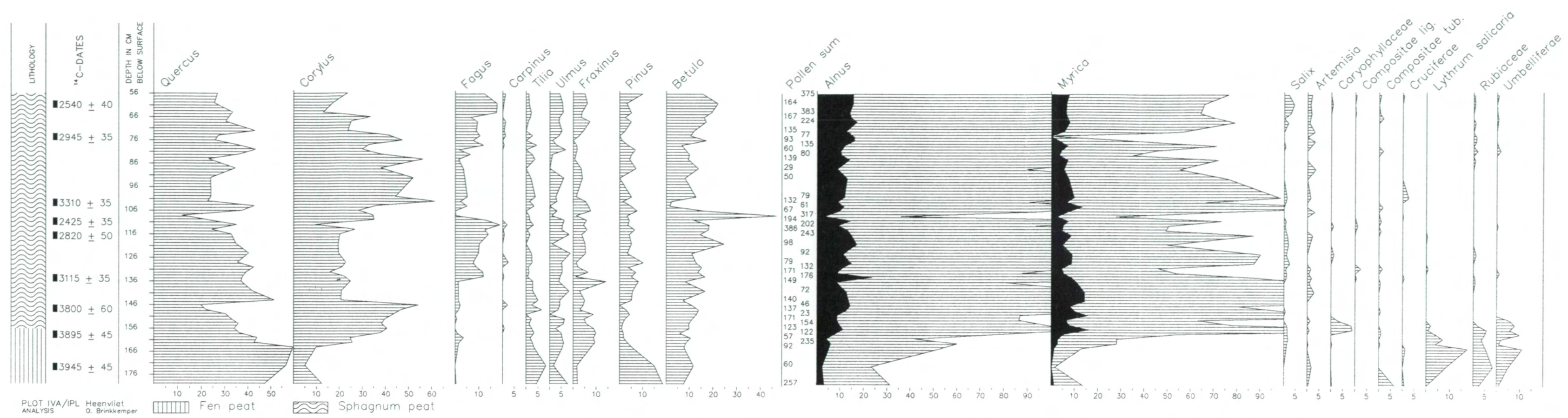
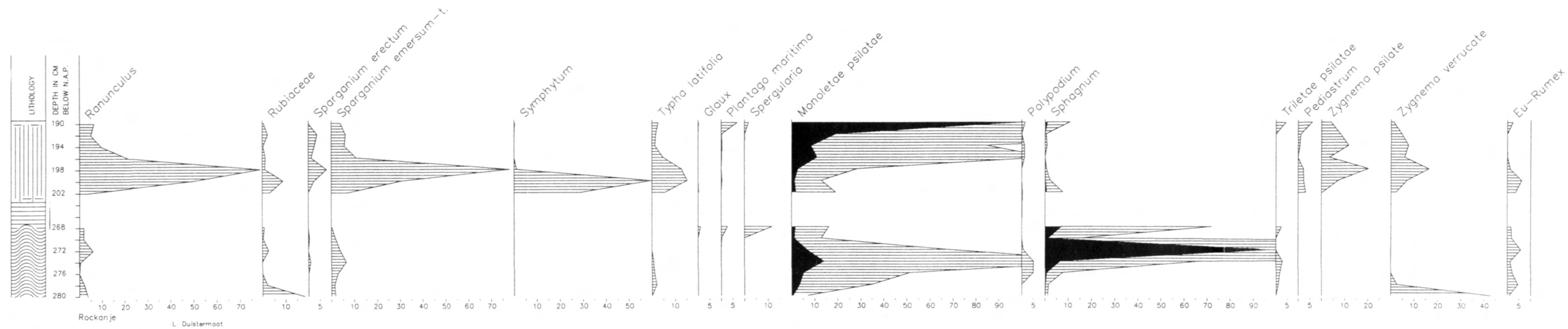Fig. 17 The relative pollen diagram of Heenvliet.

Fig. 18 The relative pollen diagram of Simonshaven.
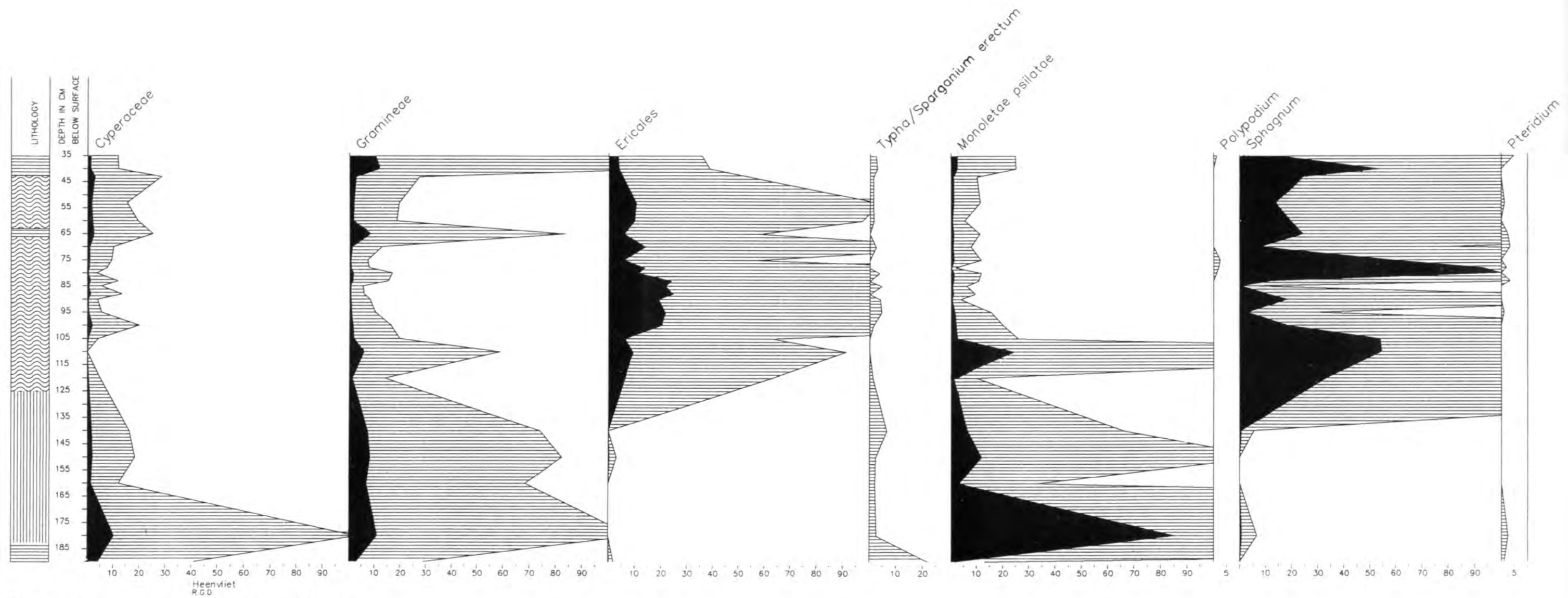
Fig. 19 The relative pollen diagram of Rockanje II (first part).

Fig. 19 The relative pollen diagram of Rockanje II (continued).

Fig. 25 The relative pollen diagram of Heenvliet by the R.G.D. (first part).
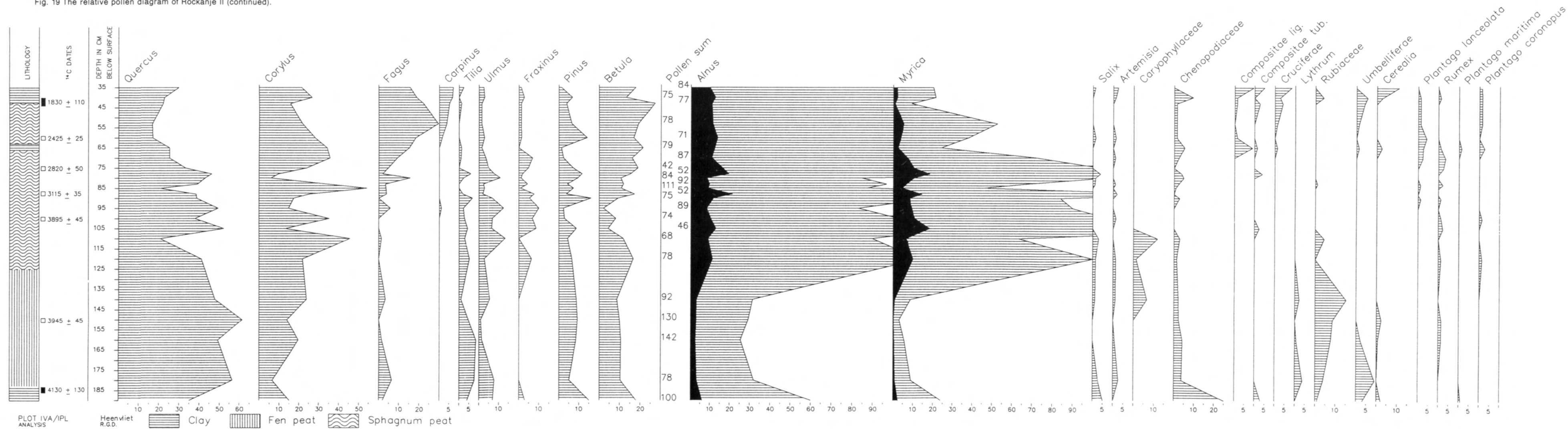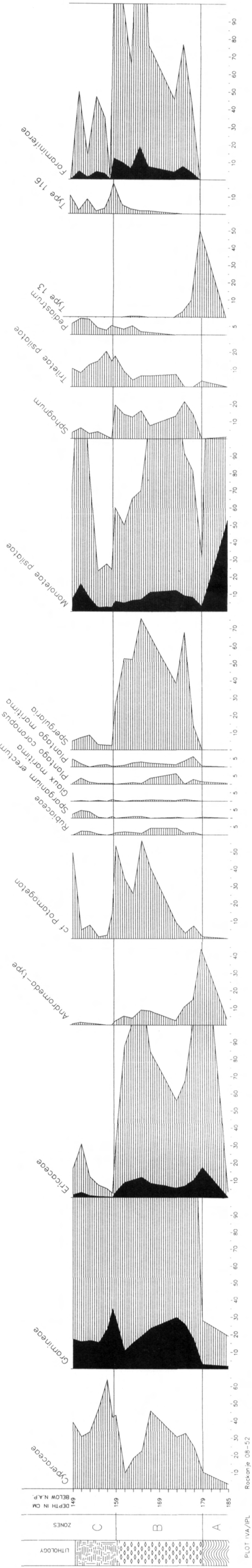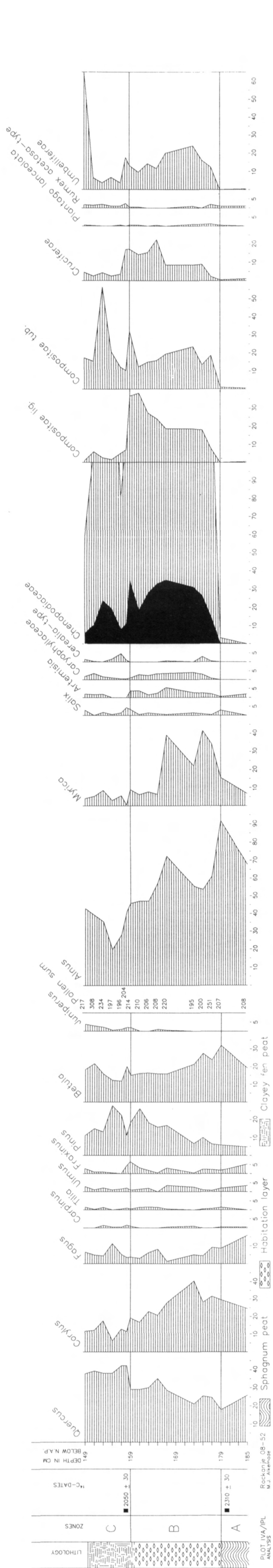
Fig. 21 The relative pollen diagram of Rockanje 08-52.

Fig. 25 The relative pollen diagram of Heenvliet by the R.G.D. (continued).
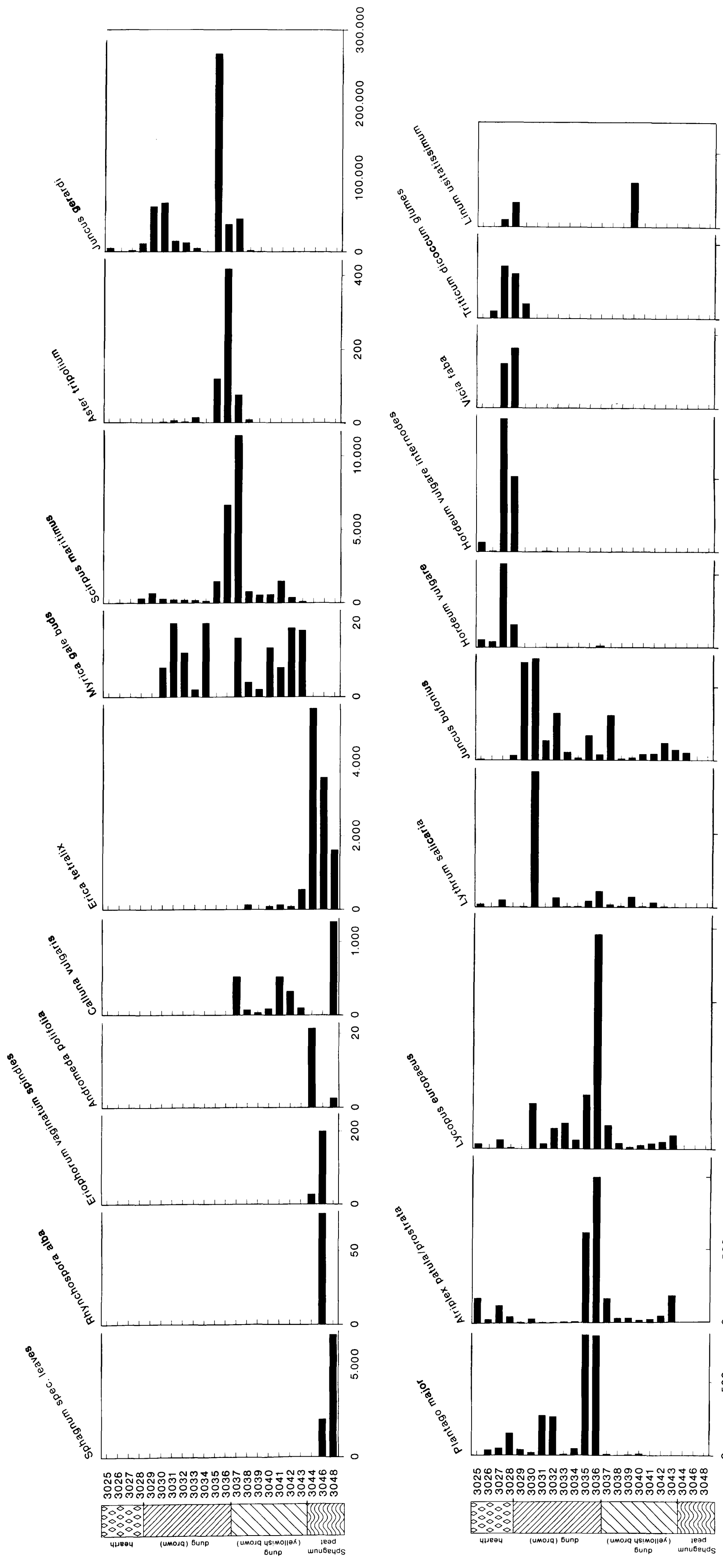
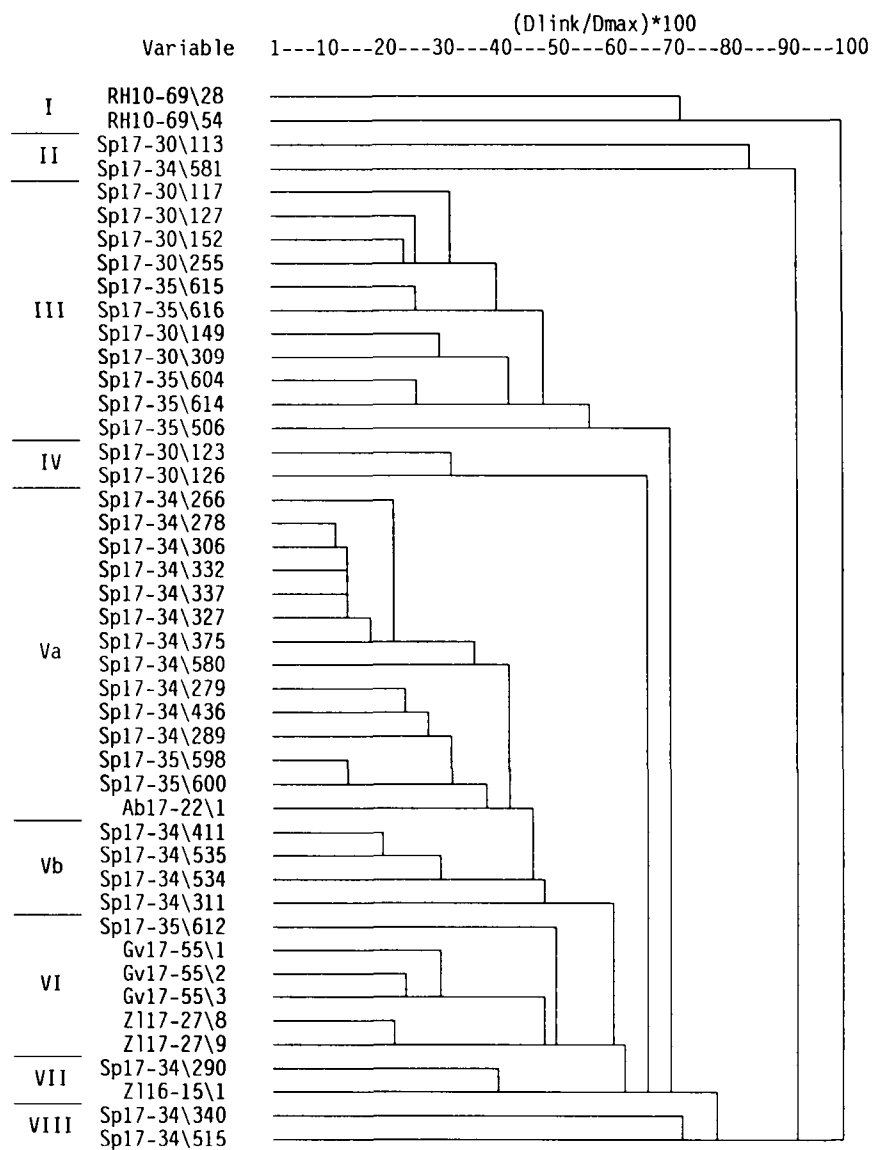Fig. 43 Seed diagram from Nieuwenhoorn 09-89. Densities per litre of sediment.

Variable   (Dlink/Dmax)*100

1---10---20---30---40---50---60---70---80---90---100

Cluster	Variable
I	RH10-69\28
	RH10-69\54
II	Sp17-30\113
	Sp17-34\581
III	Sp17-30\117
	Sp17-30\127
	Sp17-30\152
	Sp17-30\255
	Sp17-35\615
	Sp17-35\616
	Sp17-30\149
	Sp17-30\309
	Sp17-35\604
	Sp17-35\614
	Sp17-35\506
IV	Sp17-30\123
	Sp17-30\126
Va	Sp17-34\266
	Sp17-34\278
	Sp17-34\306
	Sp17-34\332
	Sp17-34\337
	Sp17-34\327
	Sp17-34\375
	Sp17-34\580
	Sp17-34\279
	Sp17-34\436
	Sp17-34\289
	Sp17-35\598
	Sp17-35\600
	Ab17-22\1
Vb	Sp17-34\411
	Sp17-34\535
	Sp17-34\534
	Sp17-34\311
VI	Sp17-35\612
	Gv17-55\1
	Gv17-55\2
	Gv17-55\3
	Zl17-27\8
	Zl17-27\9
VII	Sp17-34\290
	Zl16-15\1
VIII	Sp17-34\340
	Sp17-34\515

Fig. 45 Dendrogram of the cluster analysis based on uncarbonized plant remains from the sites on Putten.
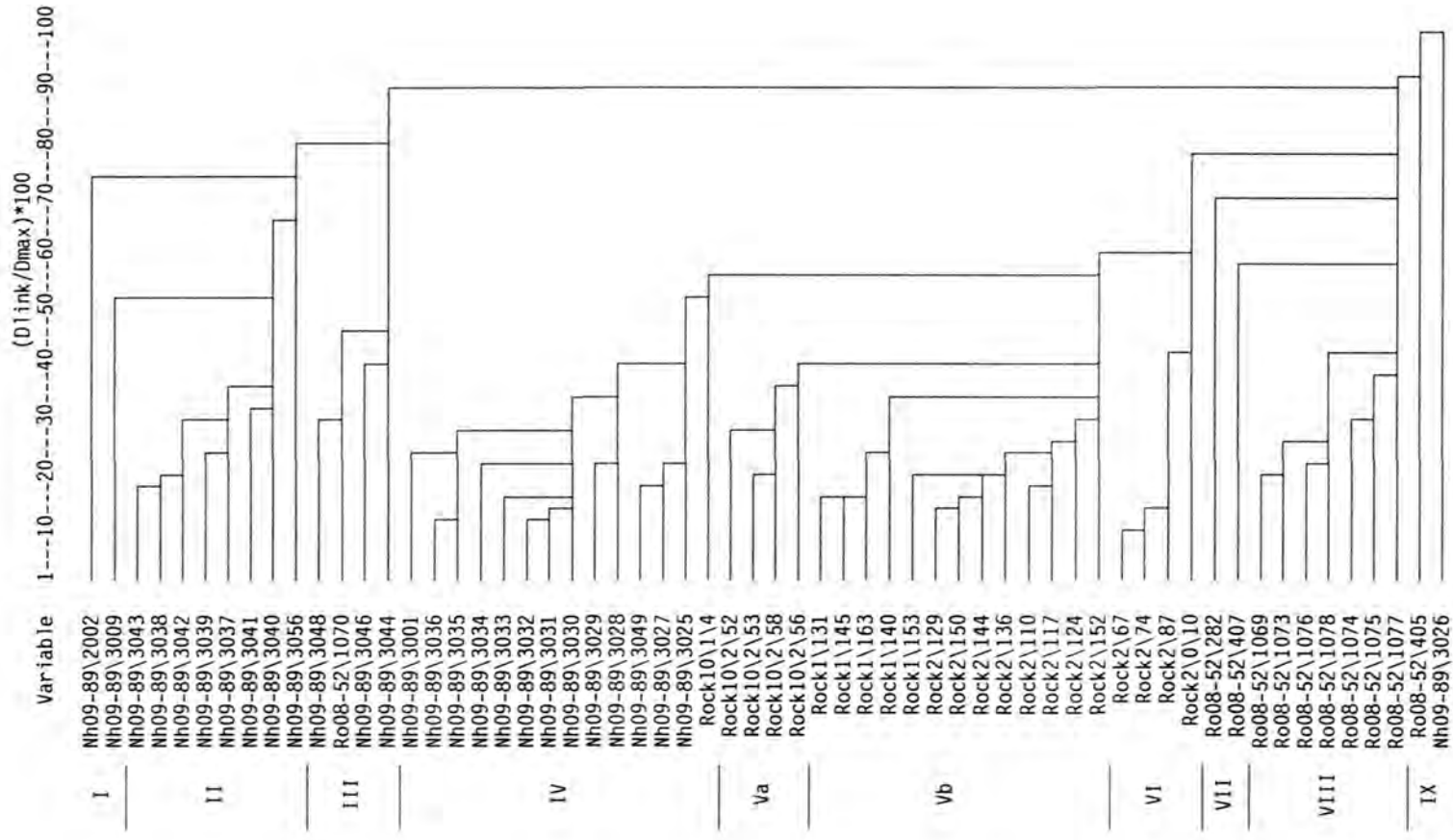
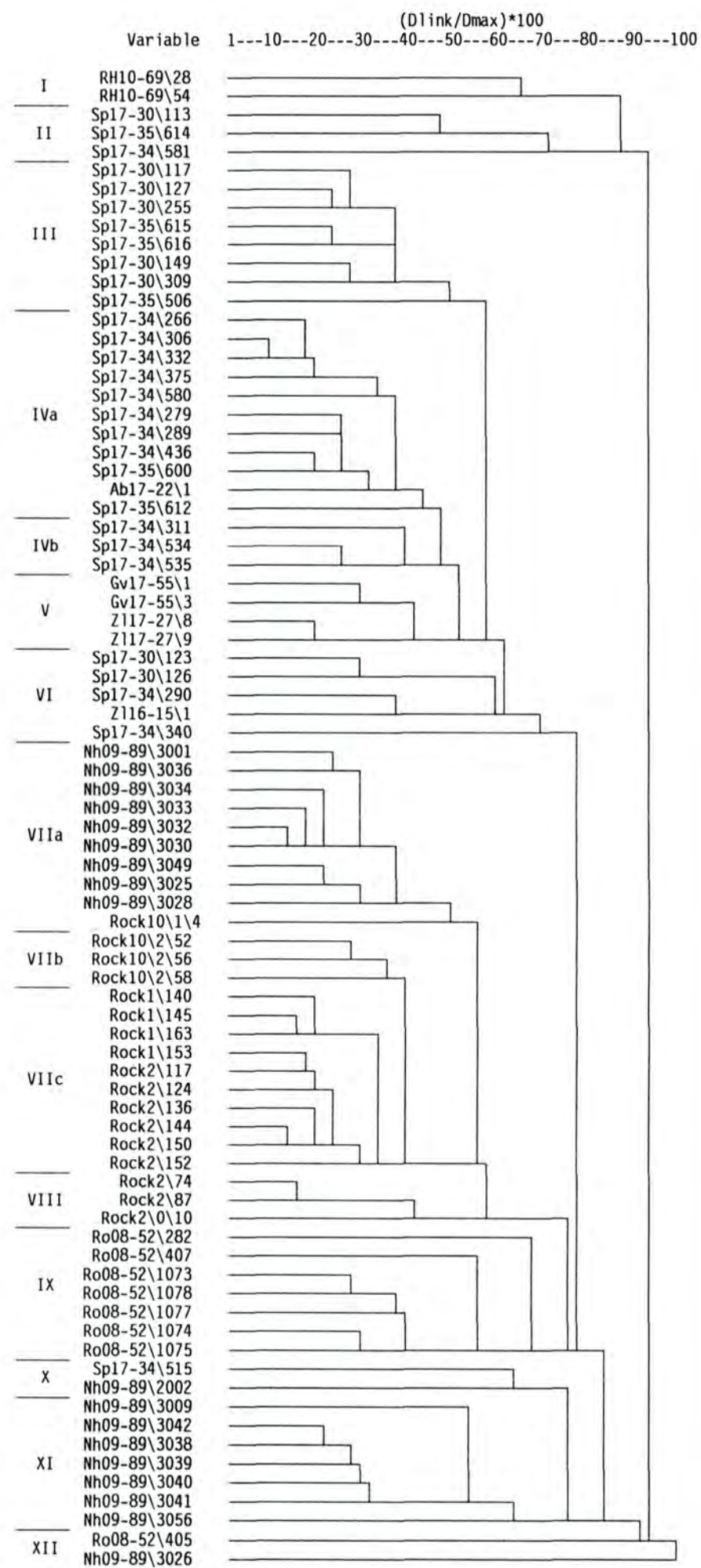Fig. 46 Dendrogram of the cluster analysis based on uncarbonized plant remains from the sites on Voorne.

Fig. 47 Dendrogram of the cluster analysis based on uncarbonized plant remains from 80 samples from Voorne and Putten.
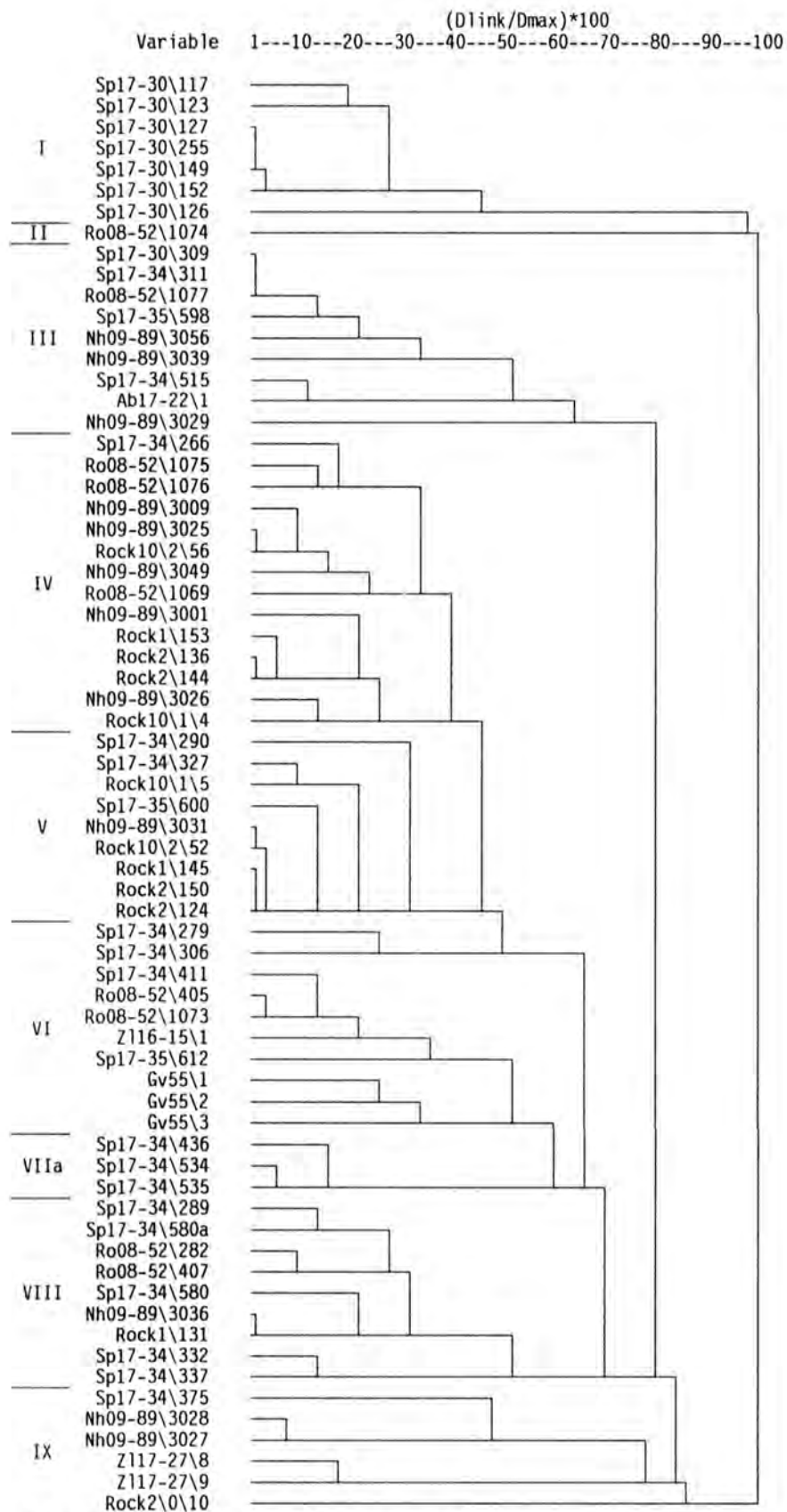
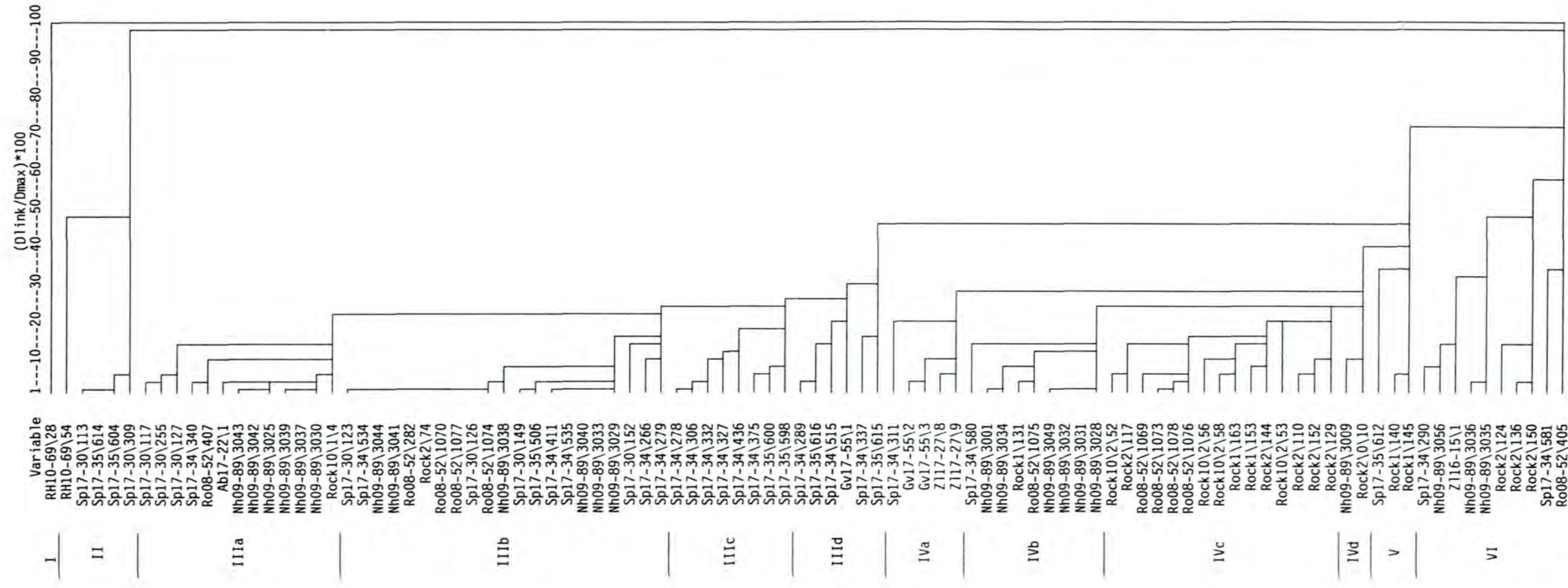Fig. 48 Dendrogram of the cluster analysis based on all crop plant remains.

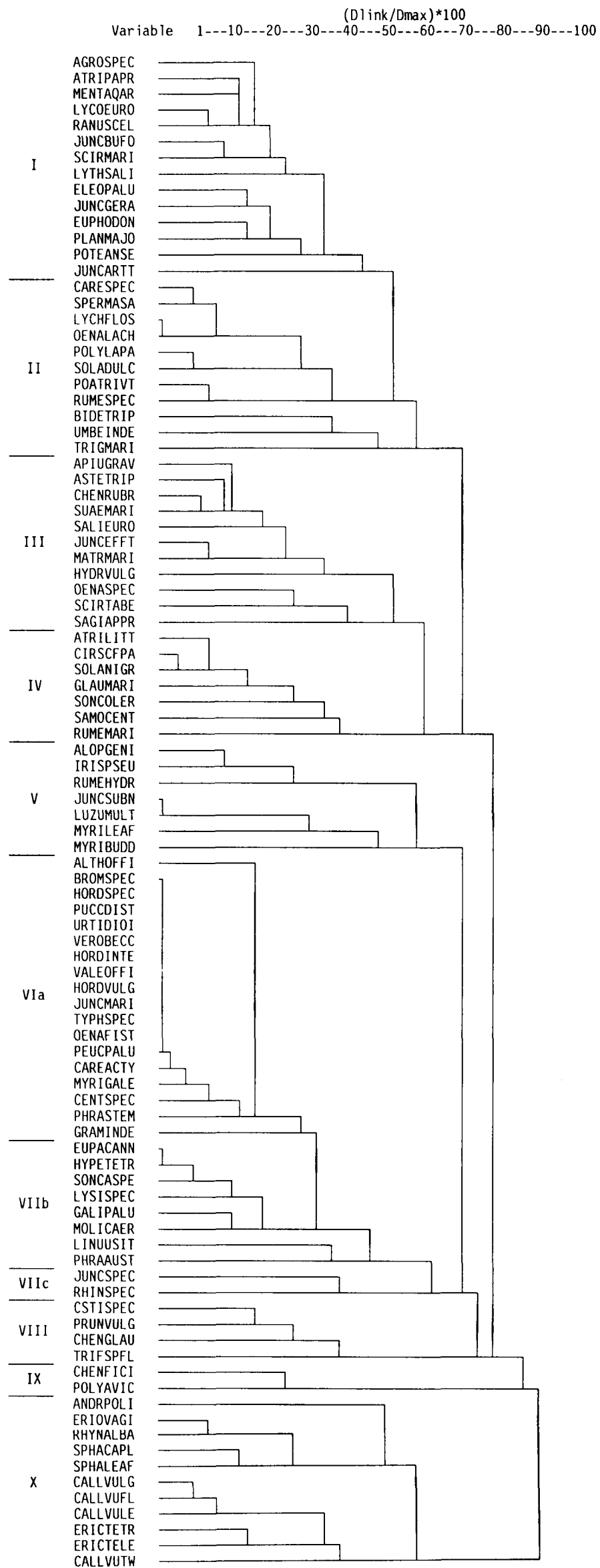Fig. 49 Dendrogram of the cluster analysis based on crop weeds.

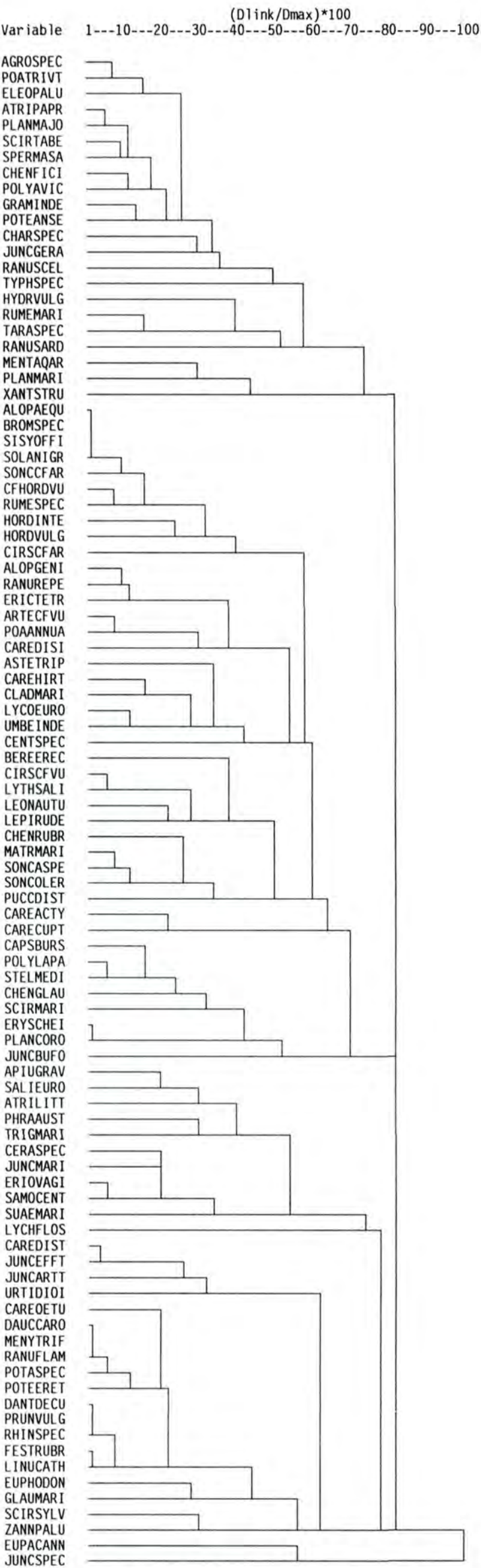Fig. 50 Dendrogram of the cluster analysis of the uncarbonized taxa from Nieuwenhoorn 09-89.

Fig. 51 Dendrogram of the cluster analysis of the uncarbonized taxa
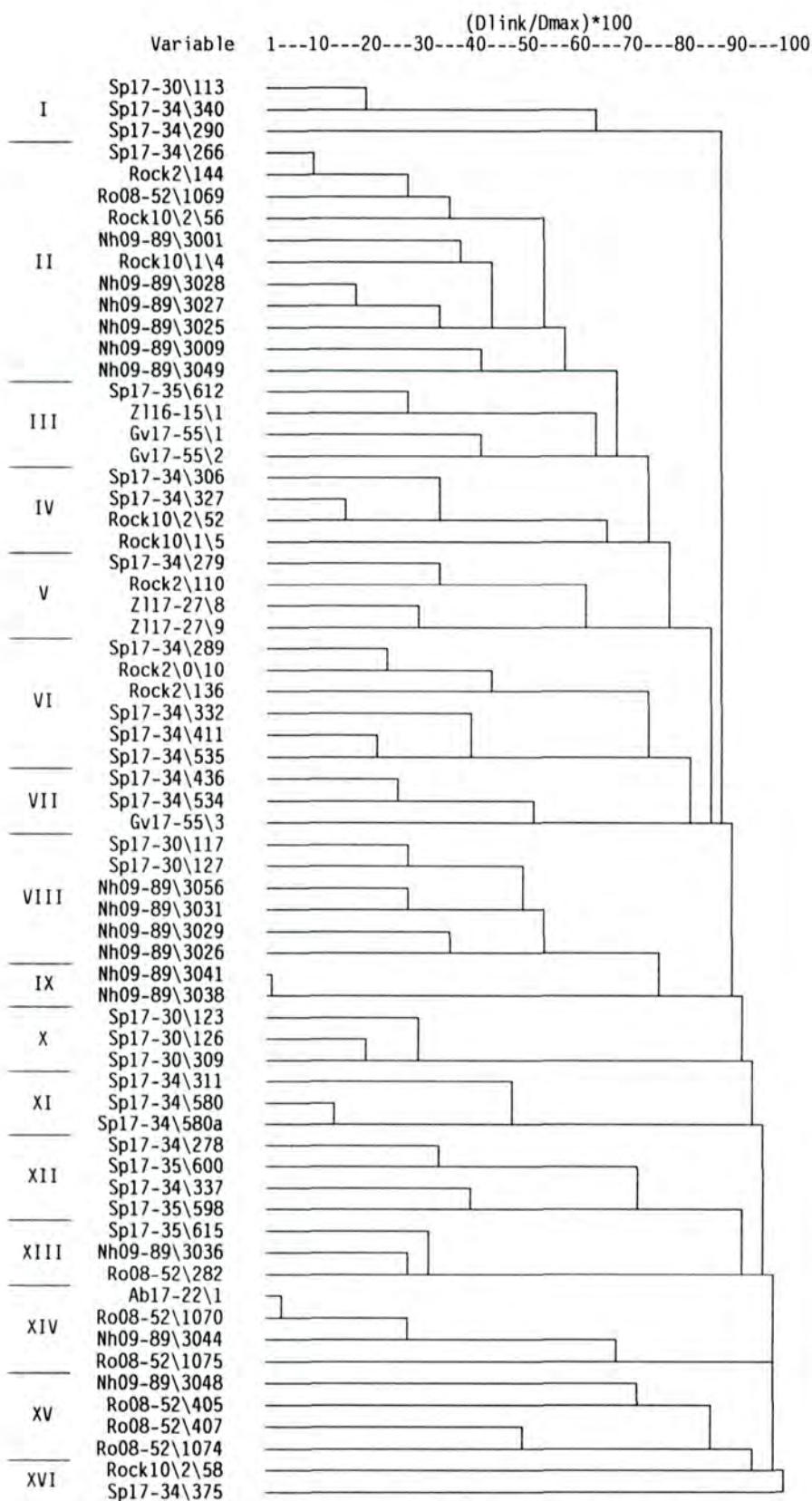from Rockanje II.

Fig. 52 Dendrogram of the cluster analysis based on all carbonized plant remains.