

ENVIRONMENT AND STOCK-RAISING IN DUTCH SETTLEMENTS
THE BRONZE AGE AND THE MIDDLE AGES

Wietske Prummel

CONTENTS

1. INTRODUCTION
2. DIFFERENCES IN PERCENTAGES OF FRAGMENTS
 - 2.1. Pig
 - 2.2. Sheep/goat and cattle
3. A HYPOTHETICAL EXPLANATION FOR THE DIFFERENCES IN LIVESTOCK COMPOSITION
 - 3.1. The chronological factor
 - 3.2. The formerly prevailing types of environment
*Introduction, The West-Frisian Bronze Age settlements,
The Early Medieval settlements, Late Medieval Alkmaar*
4. THE METHODOLOGICAL BASIS OF THE INVESTIGATION
5. ACKNOWLEDGEMENTS
6. LITERATURE

1. INTRODUCTION

The study made of a small sample of faunal remains, found during an excavation just south of Schagen (fig. 1), prompted an investigation as to whether the information available on several types of environment prevailing in the Netherlands in former times can give an explanation for the composition of livestock in settlements situated in these environments, as evident from excavated faunal remains. The actual description of the faunal remains from Schagen will appear elsewhere (Clason & Prummel, in press).

In the same region as Schagen, faunal remains of a number of settlements dating from various periods have been investigated by archaeozoologists. These include the neolithic settlement of Zandwerven (Clason, 1967); the Middle Bronze Age settlements of Zwaagdijk (Clason, 1967); Hoogkarspel-Watertoren (Van Mensch & IJzereef, 1977); Hoogkarspel – 1000 B.C. (Smits, 1978) and Andijk (Van Mensch & IJzereef, 1975); a late Bronze Age settlement (700 B.C.) at Hoogkarspel (Smits, 1978); and finally late-medieval Alkmaar during the 10th-12th centuries A.D. (Clason, 1973) and the 14th century A.D. (Clason & Brinkhuizen, 1978). Two sites contemporaneous with Schagen, i.e. dating from early medieval times, are Rijnsburg (Clason, 1967) and Dorestad (Prummel, in prep.). The location of the sites is shown in fig. 1.

Table 1 shows for each site the numbers of bone fragments identified of seven species of domesticated mammals – cattle, sheep, goat, pig, horse, dog and cat. In none of the settlements concerned were remains of wild animals found in any great quantity. The settlements are therefore similar inasmuch as the most important animals were the domesticated ones.

The settlements vary considerably, as regards the percentages of the different animal species represented (table 1). It is questionable whether these differences in percentage values can be attributed exclusively to differences in livestock composition. Butchery methods such as smashing bones into many pieces would probably make it more difficult to identify bones to species level than butchery methods which leave bones more intact. Moreover the method of butchery and division of the carcass may also be different for each species, just as the

bones of different species may vary in their resistance to decay in the soil.

When bones are collected from a site merely by picking up those bones that are immediately visible to the naked eye, the bones of larger animals generally stand a better chance of being collected than those of smaller animals. This will not happen if samples of earth are sieved, when all faunal remains larger than the mesh-width of the sieve are retrieved. All groups of finds listed in table 1 are

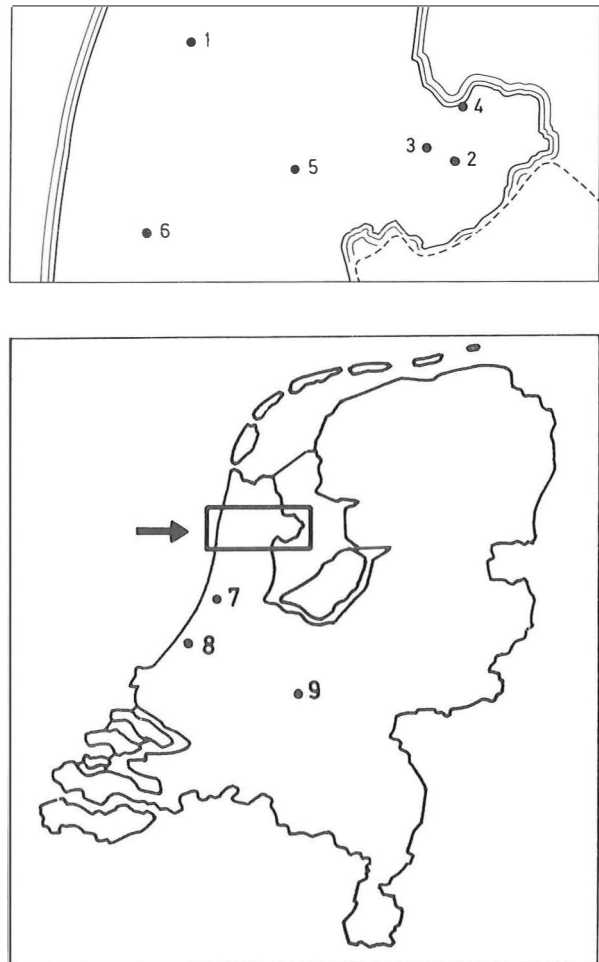


Fig. 1.
Above: the part of the Province of North-Holland in which the West-Frisian sites (1-5) and Alkmaar (6) are situated.
Beneath: the Netherlands at the present time, showing the location of the sites numbered 6-9 and of the area shown enlarged above.

1 – Schagen	4 – Andijk	7 – Haarlem
2 – Hoogkarspel	5 – Zandwerven	8 – Rijnsburg
3 – Zwaagdijk	6 – Alkmaar	9 – Dorestad

faunal remains which were collected with the naked eye. For this reason the percentages of cattle bones may be relatively too high, though presumably to a similar degree for all find complexes. For some find complexes an attempt has been made to identify the ribs and the vertebrae, while for others these bones have been left out of consideration. Since the animal bones will be represented in the ribs and vertebrae in about the same proportion as in those skeletal parts that have been identified, it will make little difference in the percentages whether or not the ribs and vertebrae are included. In spite of the uncertainties mentioned above, it is nevertheless assumed that the percentages of bones of domesticated mammals, found in the settlements indicated in table 1, are directly proportional to the percentages of these animals comprising the livestock of those settlements.

As mentioned previously, there are sometimes great differences between the settlements with regard to the percentages of bones of domesticated mammals. For the most important animals, pig, sheep/goat and cattle, an attempt has been made to ascertain whether the differences in percentages are actually significant, or whether they are merely coincidental. The significance was tested by using the χ^2 test for a 2×2 table as described by Siegel (1956). In the first row of the table we have the number of bones of one species from site 1 against the sum of the numbers of bones of the other species from that site. In the second row we have the comparable numbers for site 2. Site 1 is the site with the highest percentage of fragments of the species concerned. Setting up the 2×2 table, the following scheme emerges:

	No. of fragments of one species	Sum of the no. of fragments of the other species	
1st row site 1	A	B	A + B
2nd row site 2	C	D	C + D
	A + C	B + D	A + B + C + D

$$A + B + C + D = N$$

There are two alternative hypotheses concerning the relation between the number of fragments of

this species and the total number of fragments of domesticated mammals. One of these is the null hypothesis, H_0 , which predicts that there is no difference between sites 1 and 2 with regard to the proportion of the number of fragments of this species. The other hypothesis, H_1 , predicts that the proportion of the number of fragments of this species is greater in site 1 than in site 2. The value of χ^2 is then calculated as follows:

$$\chi^2 = \frac{N (|A \times D - B \times C| - N/2)^2}{(A + B) \times (C + D) \times (A + C) \times (B + D)}$$

This χ^2 value is read off, under one degree of freedom, in a table of one-tailed critical values. The levels of significance used were $\alpha = 0.05$ for a χ^2 of 3.85 (indicated as weak), $\alpha = 0.01$ for a χ^2 of 6.64 (indicated as strong) and $\alpha = 0.001$, for a χ^2 of 10.83 (indicated as very) (tables 2, 3, 4). For a χ^2 lower than 3.85 the difference in percentage is called not significant (N.S.). In fact the χ^2 -test does not test differences in percentages; for this we can use the difference of proportions-test, which is more exacting as regards data, e.g. a large sample and a normal distribution are required. The χ^2 -test tests differences in frequencies. For the sake of convenience, however, in this article we shall speak of differences in percentages.

2. DIFFERENCES IN PERCENTAGES OF FRAGMENTS

2.1. Pig

Table 2 gives the χ^2 values and the degree of significance calculated for each pair of settlements. On the basis of these values the find complexes were divided into three groups:

Group 1 – low percentage of pig bones. In this group we have the West-Frisian Bronze Age settlements Hoogkarspel – 1000 B.C., Andijk and Zwaagdijk, early medieval Schagen and 14th-century Alkmaar, with percentages of pig bones between 1.8 and 4.1%. Neolithic Zandwerven probably also belongs to this group. The χ^2 values for Zandwerven have not been calculated as only one fragment of pig was found there.

Group 2 – somewhat higher percentage of pig bones. Included in this group are the West-Frisian Bronze Age settlements Hoogkarspel-Watertoren and Hoogkarspel – 700 B.C., as well as 12th-century Alkmaar, with percentages between 7.3 and 8.4%.

Group 3 – high percentage of pig bones. In this group we have the early-medieval settlements of Dorestad and Rijnsburg, where pig accounted for 12.4 and 20.2% of the bones respectively.

The differences in percentage of pig bones between the sites of group 1 and those of group 3 were consistently strongly or very significant. The sites of group 1 had in many cases a significantly (strongly to very) lower percentage of pig bones in comparison with the sites of group 2 as well. Within group 1 the sites did not differ significantly with regard to the percentage of pig bones (not even when $\alpha = 0.05$). This applied to group 2 also. The percentages of pig bones in group 2 were consistently significantly (strong to very) lower than

those in group 3. Within group 3 Rijnsburg had a significantly (very) higher percentage of pig bones than Dorestad. Dorestad deviated from Rijnsburg in two respects:

1. The difference between the percentage of pig remains in Dorestad and in Hoogkarspel-Watertoren was slightly less strongly significant than that between Rijnsburg and Hoogkarspel-Watertoren.
2. With respect to 10th-12th century Alkmaar Dorestad did not have significantly more pig bones. It is assumed that this difference in percentage of pig bones is indeed real, but that this cannot be established definitively on account of the small size of the sample for this Alkmaar period and possible differences in method of collection.

The difference in percentage of pig bones between 10th-12th century Alkmaar (group 2) and 14th century Alkmaar (group 1) was weakly significant. It is not certain whether this is the result of too small a

TABLE 1

The numbers of fragments of domesticated mammals from Schagen compared with other pre- and protohistoric sites in North-Holland and the more or less contemporaneous settlements Rijnsburg (South-Holland) and Dorestad (Wijk bij Duurstede);

abs. = absolute number of bones.

	Zandwerven		Zwaagdijk		Hoogkarspel-Watertoren		Hoogkarspel	
	2500-2200 B.C.		1250±60 B.C.		1000 B.C.		1000 B.C.	
	abs.	%	abs.	%	abs.	%	abs.	%
<i>Bos taurus</i> – cattle	44	93.6	231	83.7	228	75.5	846	84.6
<i>Ovis aries/Capra hircus</i> – sheep/goat	2	4.3	32	11.6	27	8.9	101	10.1
<i>Sus scrofa domesticus</i> – pig	1	2.1	11	4.0	22	7.3	41	4.1
<i>Equus caballus</i> – horse							6	0.6
<i>Canis familiaris</i> – dog			2	0.7	25	8.3	6	0.6
<i>Felis catus</i> – cat								
total	47		276		302		1000	

sample size, or whether the difference in percentage of pig bones between the two periods is merely coincidental.

2.2. Sheep/goat and cattle

As was the case with pig, the sites of table 1 show fairly big differences in the percentages of the fragments of sheep/goat and cattle. For sheep/goat this varied between 4 and 41%, while for cattle the percentages ranged from 5.1 to 93%. The differences in percentages of cattle and sheep/goat have been tested, as in the case of pig, using χ^2 -tests (tables 3 and 4).

With regard to the percentage of sheep/goat bones the sites of table 1 can be divided into three groups. The sites within each group do not differ significantly from one another, but they do differ significantly from sites in the other groups (table 4). The sites with a low percentage of sheep/goat fragments were Zandwerven, the West-Frisian Bronze Age settlements and Rijnsburg. For Dorestad the percentage was somewhat higher, while in Schagen and Alkmaar (both periods) sheep/goat accounted for 32 to 41% of the bones.

As for cattle, Schagen and Alkmaar (both periods) had the lowest percentages of fragments (table

3). Dorestad and Rijnsburg had higher percentages, while Zandwerven and the Bronze Age settlements had extremely high percentages of fragments of cattle. Among the West-Frisian Bronze Age sites Hoogkarspel-Watertoren (1000 B.C.) and Hoogkarspel – 700 B.C. had a significantly lower percentage of cattle fragments than the other sites (table 3). It is precisely these two Bronze Age sites that have a somewhat higher percentage of fragments of pig (table 2), while the percentage of sheep/goat fragments at these two sites is low, as in the other Bronze Age settlements (table 4). It is probable that the large numbers of pig remains had a moderating effect on the percentage of cattle fragments.

The fragments of cattle and sheep/goat seem to correspond proportionally in such a way that where the percentage of cattle fragments is high, that of sheep/goat is low, as for example at Zandwerven and the West-Frisian Bronze Age settlements. The reverse situation, few fragments of cattle and many of sheep/goat, we find in Schagen and Alkmaar (tables 1, 3 and 4). In all the sites listed in table 1 the number of bones identified with certainty as goat varies from extremely few to none at all. Therefore sheep/goat can be taken to mean only “sheep” with a high degree of certainty. Goats were probably hardly present in these settlements.

Hoogkarspel		Andijk		Alkmaar		Alkmaar		Rijnsburg		Dorestad		Schagen	
700 B.C.		Middle Bronze Age		10th-12th century A.D.		14th century A.D.		600-1000 A.D.		700-850 A.D.		early medieval	
abs.	%	abs.	%	abs.	%	abs.	%	abs.	%	abs.	%	abs.	%
4396	80.7	986	86.2	84	58.7	60	55.0	558	65.6	3624	66.4	347	54.0
528	9.7	102	8.9	46	32.2	44	40.4	95	11.2	997	18.3	263	40.9
436	8.0	40	3.5	12	8.4	2	1.8	172	20.2	677	12.4	15	2.3
13	0.2			1	0.7			23	2.7	126	2.3	15	2.3
75	1.4	16	1.4			2	1.8	1	0.1	29	0.5	1	0.2
						1	0.9	1	0.1	3	0.1	2	0.3
5448		1144		143		109		850		5456		643	

3. A HYPOTHETICAL EXPLANATION FOR THE DIFFERENCES IN LIVESTOCK COMPOSITION

3.1. The chronological factor

Chronologically, Schagen corresponds to Dorestad and Rijnsburg. One might assume that livestock composition was time-dependent, i.e. that it varied from one period to another. In Schagen, the percentages of pig (table 2), of cattle (table 3), and of sheep/goat (table 4) do not correspond to the values for Dorestad and Rijnsburg, which again differ from each other. The contemporaneity of these sites, all of which date from the Early Middle Ages, therefore does not signify any uniformity in livestock composition.

The West-Frisian Bronze Age settlements show a high degree of homogeneity as regards the percentages of pig, cattle and sheep/goat (tables 2-4). It will be evident from the following that the uniformity in livestock composition for all Bronze Age settlements was rather a result of the similarity of environment of these settlements than of their contemporaneity.

The dates established for the settlements investigated do not seem to be of any use as criteria for explaining the differences in percentages of pig, sheep/goat and cattle.

3.2. The formerly prevailing types of environment

3.2.1. *Introduction*

It has already been shown (Nobis, 1955) that there is a connection between the presence of forest in the vicinity of a settlement and the practice of keeping large numbers of pigs in or near that settlement. In the autumn pigs were driven into the forests under the watchful eye of a swineherd to feed upon the acorns, beechnuts and chestnuts, collectively referred to as mast. This fattening of pigs in the forests was not a simple matter, even in times of classical antiquity, and very early on it was necessary to lay down rules and regulations.

The first charter in the Netherlands regulating the grazing of pigs in forest dates from A.D. 855, and concerns the forests of Putten and Ermelo on the Veluwe (Slicher van Bath, 1967, p. 97). Two

other Dutch sources concerning pannage mention 13th-century rights in the forests of Susteren and Montfort in Limburg. Also in the 13th century, rights had been established for grazing pigs in the woods around Didam in Gelderland (Ten Cate, 1972, pp. 94-5, 131, 102-3). Neither Slicher van Bath nor Ten Cate mention any sources referring to pannage in any other part of the Netherlands. It is possible that the deforestation especially of the Central and Western parts of the Netherlands, already far advanced in the Late Middle Ages, accounts for the lack of any such sources.

In view of the differences in the relative numbers of pig bones described in 2.1., the question arose whether these differences could be connected with variation in the amount of forest present in the environments of these settlements.

Reichstein (1975) has commented on differences in percentages of sheep and cattle. He explained differences in percentages of cattle and sheep between two *terpen* (artificial dwelling mounds), Feddersen Wierde and Elisenhof, on the basis of results of palaeobotanical research: at Elisenhof, a settlement with markedly brackish environment, there was a high percentage of sheep and a low percentage of cattle, while at Feddersen Wierde, where the salinity was lower, the situation is reversed: more cattle and fewer sheep (N.B. Reichstein compared the estimated minimum numbers of individuals). In attempting to explain this disparity Reichstein argues that cattle cannot tolerate very brackish pasture, while sheep are less demanding in this respect (see: Aitken, 1976, pp. 193-4). In addition to the fact that sheep are more salinity-tolerant there is possibly another factor involved, not mentioned by Reichstein, namely that in a very brackish environment such as at Elisenhof, the liver-fluke parasite is absent.

The liver-fluke is a flatworm, *Fasciola hepatica*, which inhabits the liver of various animals, including sheep and cattle (Herweyer, 1978). The lifecycle of the liver-fluke involves an intermediate host, namely the dwarf pond-snail, *Galba* (= *Lymnaea*) *trunculata*. In the liver of the host the adult liver-fluke lays large numbers of eggs which leave the host with the faeces. In damp pasture these eggs hatch into larvae, which subsequently find their way into a pond-snail, where they reproduce again. Eventually larvae leave the snail and attach them-

group 1					group 2			group 3		
Alkmaar – 14th century A.D. 1.8%	Schagen – early medieval 2.3%	Andijk – Middle Bronze Age 3.5%	Zwaagdijk – Middle Bronze Age 4.0%	Hoogkarspel – Middle Bronze Age, 1000 B.C. 4.1%	Hoogkarspel-Watertoren – 1000 B.C. 7.3%	Hoogkarspel – Late Bronze Age, 700 B.C. 8.0%	Alkmaar – 10th-12th century A.D. 8.4%	Dorestad – 700-850 A.D. 12.4%	Rijnsburg – 600-1000 A.D. 20.2%	
0.0	0.4	0.5	0.8	3.4	4.8	3.9	10.2	20.8	Alkmaar – 14th century A.D. 1.8%	
NS	NS	NS	NS	NS	WEAK	WEAK	STRONG	VERY		
	1.5	1.4	3.2	12.1	26.1	11.2	57.1	105.5	Schagen – early medieval 2.3%	
	NS	NS	NS	VERY	VERY	VERY	VERY	VERY		
		0.0	0.4	7.4	28.0	6.6	76.6	142.1	Andijk – Middle Bronze Age 3.5%	
		NS	NS	STRONG	VERY	WEAK	VERY	VERY		
			0.0	2.3	5.3	2.7	16.9	39.3	Zwaagdijk – Middle Bronze Age 4.0%	
			NS	NS	WEAK	NS	VERY	VERY		
				4.4	18.2	4.3	58.2	115.8	Hoogkarspel – Middle Bronze Age, 1000 B.C. 4.1%	
				WEAK	VERY	WEAK	VERY	VERY		
				0.1	0.1		6.6	25.8	Hoogkarspel-Watertoren – 1000 B.C. 7.3%	
				NS	NS		WEAK	VERY		
					0.0		57.3	124.7	Hoogkarspel – Late Bronze Age, 700 B.C. 8.0%	
					NS		VERY	VERY		
							1.7	10.6	Alkmaar – 10th-12th century A.D. 8.4%	
							NS	STRONG		
							38.0		Dorestad – 700-850 A.D. 12.4%	
							VERY			
									Rijnsburg – 600-1000 A.D. 20.2%	

TABLE 2

Pig percentages of total number of bones of domesticated mammals. In the squares: above, the χ^2 for row and column complexes; beneath, the strength of the difference.

selves to grass and marsh plants. The larvae are thus ingested by animals grazing on these plants. A large number of liver-flukes in the liver seriously affects the health of the host.

A damp and warm environment is essential for the development of both the dwarf pond-snail and the liver-fluke. The intermediate host, *Galba trunculata*, is generally only found in a damp, fresh-

	Zandwerven – neolithic 93.6%	Andijk – Middle Bronze Age 86.2%	Hoogkarspel – Middle Bronze Age, 1000 B.C. 84.6%	Zwaagdijk – Middle Bronze Age 83.7%	Hoogkarspel – Late Bronze Age, 700 B.C. 80.7%	Hoogkarspel-Watertoren – 1000 B.C. 75.5%	Dorestad – 700-850 A.D. 66.4%	Rijnsburg – 600-1000 A.D. 65.6%	Alkmaar – 10th-12th century A.D. 58.7%	Alkmaar – 14th century A.D. 55.0%	Schagen – early medieval 54.0%
	ns	ns	2.4	4.2	6.7	14.3	14.6	18.0		26.4	Zandwerven – neolithic 93.6%
		1.0		18.7	19.8	174.3				223.9	Andijk – Middle Bronze Age 86.2%
			0.1	8.2	12.7						Hoogkarspel – Middle Bronze Age, 1000 B.C. 84.6%
				1.3	5.4						Zwaagdijk – Middle Bronze Age 83.7%
					4.6	284.5					Hoogkarspel – Late Bronze Age, 700 B.C. 80.7%
					10.2	9.5	12.2	15.0	39.4	39.4	Hoogkarspel-Watertoren – 1000 B.C. 75.5%
						0.2	3.3	5.7	38.8	38.8	Dorestad – 700-850 A.D. 66.4%
							2.3	4.3	20.2	20.2	Rijnsburg – 600-1000 A.D. 65.6%
								0.2	0.9	0.9	Alkmaar – 10th-12th century A.D. 58.7%
									0.0	0.0	Alkmaar – 14th century A.D. 55.0%
											Schagen – early medieval 54.0%

TABLE 3

Cattle percentages of total number of bones of domesticated mammals. In the squares: above, χ^2 for row and column faunal complexes; beneath, the strength of the difference (in capitals: tested, in small letters: not tested, but presumed).

water to moderately brackish environment, and cannot thrive under conditions of high salinity or drought. As the liver-fluke is dependent on the dwarf pond-snail for part of its life-cycle, livestock

is free from liver-fluke infestation in those areas where the dwarf pond-snail is absent, i.e. where dry conditions prevail and where salinity is high.

Sheep are especially susceptible to liver-fluke in-

	Zandwerven - neolithic 4.3%	Andijk - Middle Bronze Age 8.9%	Hoogkarspel-Watertoren - 1000 B.C. 8.9%	Hoogkarspel - Late Bronze Age, 700 B.C. 9.7%	Hoogkarspel - Middle Bronze Age, 1000 B.C. 10.1%	Rijnsburg - 600-1000 A.D. 11.2%	Zwaagdijk - Middle Bronze Age 11.6%	Dorestad - 700-850 A.D. 18.3%	Alkmaar - 10th-12th century A.D. 32.2%	Alkmaar - 14th century A.D. 40.4%	Schagen - early medieval 40.9%
		0.6	1.0				1.6	5.3	13.2		Zandwerven - neolithic 4.3%
	ns	NS	NS	ns	ns	ns	NS	WEAK	VERY	very	very
		ns	ns	ns	ns	ns	NS	VERY	very	very	very
				0.2	0.8						Andijk - Middle Bronze Age 8.9%
			ns	NS	NS	NS	NS	very	very	very	very
											Hoogkarspel-Watertoren - 1000 B.C. 8.9%
							166.2				
				ns	ns	ns	NS	VERY	very	very	very
											Hoogkarspel - Late Bronze Age, 700 B.C. 9.7%
							39.4				
					ns	ns	NS	VERY	very	very	very
											Hoogkarspel - Middle Bronze Age, 1000 B.C. 10.1%
							0.0	25.4			
							NS	VERY	very	very	very
											Rijnsburg - 600-1000 A.D. 11.2%
							7.5	25.0			
							STRONG	VERY	very	very	very
											Zwaagdijk - Middle Bronze Age 11.6%
								16.8		178.3	
								VERY	very	VERY	VERY
											Dorestad - 700-850 A.D. 18.3%
									1.5	3.4	
									NS	NS	
											Alkmaar - 10th-12th century A.D. 32.2%
										0.0	
										NS	
											Alkmaar - 14th century A.D. 40.4%
											Schagen - early medieval 40.9%

TABLE 4

Sheep/goat percentages of total number of bones of domesticated mammals. In the squares: above, the χ^2 for the row and column complexes; beneath, the strength of the difference (in capitals: tested; in small letters: not tested, but presumed).

festation. In serious cases death may occur. Cattle are far less susceptible.

In the following, an attempt is made to ascertain

whether these theories on the relation between environment and the presence of pig, sheep and cattle can explain the frequencies of the faunal remains of these species at the sites investigated.

3.2.2. *The West-Frisian Bronze Age settlements*

The West-Frisian Bronze Age settlements of Andijk, Hoogkarspel and Zwaagdijk all date from the end of, or several centuries after the end of a transgression which covered the eastern part of West-Friesland with a layer of marine sediment (Van Regteren Altena *et al.*, 1977, Note 9). Palaeobotanical research on the environment of these settlements has been carried out by Van Zeist (1964), Bakels (1974) and Pals (1977).

The vegetation around Zwaagdijk (Van Zeist, 1964) in the Middle Bronze Age was evidently a natural grass-land, totally devoid of trees. From the pollen analysis it was not possible to ascertain whether fresh-water or brackish conditions prevailed in this area.

A palaeobotanical study (seeds and fruits) of Hoogkarspel-Watertoren has been carried out by Pals (1977), who came to the conclusion that this settlement was situated on a high, initially brackish salt-marsh suitable for pasture, which gradually became fresher and at the same time suitable for arable farming. Among the vegetation types distinguished by Pals around Hoogkarspel-Watertoren there is not a single type of woodland. In the list of plant species found at Hoogkarspel-Watertoren not a single tree is represented by seeds or fruits.

Bakels (1974) studied pollen from the ditches of a Bronze Age burial mound at Hoogkarspel. In her opinion this burial mound was situated in an open environment which was probably not brackish. Pollen of various trees was found, so evidently the environment of this burial mound was not as treeless as the surroundings of Zwaagdijk studied by Van Zeist (1964) and of the Hoogkarspel-Watertoren settlement (Pals, 1977). Bakels (1974, p. 260) states the following: "Perhaps the landscape around a settlement was barer than in the neighbourhood of burial mounds. A reason for this difference could be that the burial mounds were situated along the rim of the area that was inhabited and under cultivation. Then there would have been grass-land and arable land on the ridge, and on the lower ground alongside the ridge groups of trees and alder carr".

Most of the West-Frisian Bronze Age settlements studied so far are characterized by a very low

to fairly low percentage of fragments of pig, with values consistently under 10% (table 1). These low percentages of pig bones seem to fit in with the scarcity of woodland in the surroundings of these settlements as indicated by palaeobotanical studies. Possibly there is some connection between the slightly higher percentages of pig remains in Hoogkarspel-Watertoren and Hoogkarspel - 700 B.C. and the availability of at least some woodland, whether only locally or temporally, as supposed by Bakels (1974) in an otherwise treeless environment. Van Mensch and IJzereef (1977, p. 205) have already commented on differences in the percentage of pig remains between the West-Frisian Bronze Age settlements. Further ecological research will perhaps provide an explanation for these minor differences, although the possibility of cultural factors cannot be excluded.

It has already been mentioned above that palaeobotanical research has given no clear indications of a saline environment in Bronze Age West-Friesland. Conditions were at most somewhat brackish.

Two observations made by Kuijper are of great importance to us here. Kuijper studied mollusc shells from burial mound Ia at Hoogkarspel (Kuijper in Bakels, 1974) and from the Hoogkarspel-Watertoren settlement (Kuijper, 1977). He found that *Galba trunculata* was present among the mollusc remains from both sites. It is therefore most probable that the liver-fluke too was able to live in the surroundings of Hoogkarspel and presumably also around the other West-Frisian Bronze Age settlements.

At Hoogkarspel-Watertoren there are indirect indications of the presence of the dwarf pond-snail and the liver-fluke, for here seeds have been found of *Myosotis scorpioides*, water forget-me-not, and *Hydrocotyle vulgaris*, marsh pennywort (Pals, 1977, pp. 201-202). Bottema and Clason (1979) quote sayings of farmers from which it is evident that these plants are suspected of causing liver-fluke infestation. Bottema and Clason rightly point out that it is not these species of plants themselves that are responsible for liver-fluke infestation, but the damp locality where they occur, which is also the optimal environment for the dwarf pond-snail and the liver-fluke.

The damp and probably fresh-water environ-

ment around the West-Frisian Bronze Age settlements may explain the large number of cattle bones and the small number of sheep (/goat) bones in these settlements. The presence of the liver-fluke, as suggested by the finds of dwarf pond-snail, would have restricted the keeping of sheep. There would have been fewer problems with keeping cattle, which are less susceptible to liver-fluke infestation, for the environment would have been sufficiently fresh.

As for the neolithic settlement at Zandwerven, the number of bones studied is very small (Clason, 1967), so it is unlikely that these bones give a representative picture of the livestock composition. The settlement lay on a ridge of sand, in a salt-marsh environment, as described by Van Regteren Altena and Bakker (1961), which developed from the mud-flats of the Calais IV A transgression (2900-ca. 2300 B.C.). The extreme scarcity of trees in this environment may explain the small number of pig bones. Nothing is known about salinity conditions during the period of occupation. The relatively large number of cattle bones and relatively small number of sheep/goat bones are suggestive of fresh-water conditions, as in the West-Frisian Bronze Age settlements described above.

3.2.3. *The Early Medieval settlements*

3.2.3.1 *Rijnsburg-Rothulfuashem*

Early medieval Rijnsburg (7th-9th century A.D.) was situated in the estuarine region of the Oude Rijn, fairly close to the mouth of this river (Van Es, 1973; Sarfatij, 1977). In the Early Middle Ages there would have been a strip of eutrophic brackish peat just to the east of the actual river mouth, while at a short distance from Rijnsburg was the southern extremity of the Old Dune landscape (Pons & Van Oosten, 1974, p. 25). The Old (or Older) Dunes of South-Holland had gradually become thickly forested from Roman times onwards. The trees growing in these forest included beeches, oaks, birches and alders (Zagwijn, 1970). In the Old Dunes to the north of the mouth of the Oude Rijn we find place-names ending in -um, -em, etc., indicating the presence of settlements as early as about A.D. 800 (Blok, 1957; Pons & Van Oosten, 1974, p. 49, fig. 22c). The name of the early medieval settlement in Rijnsburg, Rothulfuashem, is an example of such a

place-name (Sarfatij, 1975, p. 39; 1977). This indicates that it was in the Early Middle Ages that the forest clearance began in the Old Dunes. The deforestation of the Old Dunes would still have been on a limited scale during the early Middle Ages.

From table 1 it is evident that the percentage of pig bones in Rijnsburg is higher than at all other sites, while the differences in percentage appear to be very significant (table 2). In Rijnsburg we therefore have a situation where a region of natural forest, in which oak and beech were abundant, is accompanied by a high percentage of pig bones. This appears to support the theory that a forest-rich environment induces the keeping of pigs, since here sufficient food for pigs is present in the form of mast.

In the Early Middle Ages the Old Dunes between Kennemerland and Rijnland were, like those further to the north and south, covered with forest. The first settlements in this region appeared only later, not earlier than the 11th-12th century A.D. (Zagwijn, 1970).

On the eastern edge of this former forest, of which the Haarlemmerhout is a remainder, lay the town of Haarlem, from which a small complex of faunal remains from the 14th-15th century has been studied (IJzereef, 1977). Of the bones of domesticated mammals 25% were of pig, i.e. 36 of the 147 bones (ribs not included). This high percentage of pig remains seems to fit in well with the presumed abundance of forest in the 14th-15th century.

The percentages of fragments of cattle and of sheep/goat in Rijnsburg are intermediate in comparison with the other settlements (tables 3 and 4). In the varied environment of Rijnsburg it would have been possible to keep cattle as well as sheep (/goat).

3.2.3.2. *Dorestad*

Twelve per cent of the domesticated mammal bones from Dorestad were of pig (table 1). This percentage was strongly to very significantly higher than those for the sites with the lowest percentages (group 1). The differences with respect to the sites of group 2 were less strongly significant (table 2).

On the basis of their research on the wood of Dorestad, Casparie and Swarts (1978) came to the conclusion that considerable numbers of trees were

felled for the purpose of building and maintaining the settlement and harbour of Dorestad. The timber of Dorestad came on the one hand from the areas of Pleistocene sands, the Utrechtse heuvelrug and the Veluwe, and on the other from the fluvial deposits around Dorestad.

The river-clay region consists of two components: the somewhat higher dry levees and the wetter river basins (Poelman, 1973, pp. 52-53). Both of these were wooded at the beginning of the Early Middle Ages. The elm, a species which in this region can only grow on the levees, was hardly represented at all among the wood remains of Dorestad. Consequently Casparie and Swarts (1978) concluded that the forests on the levees had already been cleared before the Early Middle Ages. Studies of seeds by Van Zeist (1969) indicated the presence of fields and meadows on the deforested levees. The meadows on the levees would have been fairly dry and therefore presumably sufficiently free of the liver-fluke parasite to permit keeping sheep as well as cattle. *Galba trunculata*, the dwarf pond-snail, which is the secondary host for the liver-fluke, has not yet been found in Dorestad, not even in samples obtained by sieving (Prummel, 1978).

The river basins would still have been wooded in the Early Middle Ages, although deforestation may already have started by then. Casparie and Swarts (1978) were able to indicate which types of forest were present on the river basins. The oak and the beech, both producers of mast, were among the dominant species of these forests. It is therefore conceivable that for the inhabitants of Dorestad the basins provided the opportunity for feeding considerable numbers of pigs in the autumn.

Oaks were also present in the forests on the Pleistocene sands of the Utrechtse heuvelrug, but it remains questionable whether pigs from Dorestad were turned out there to feed. To reach these areas it would have been necessary to pass through hardly accessible basins which in the Early Middle Ages were still unreclaimed – reclamation first took place only in the 12th century (Poelman, 1973, p. 60). This would not have been done, for the forest of the basins itself would have provided sufficient mast. No early medieval finds have been made in the basin region (Van Tent, 1978), indicat-

ing that this region was hardly inhabited.

3.2.3.3. *Schagen*

The early medieval settlement traces to the south of Schagen have been provisionally dated as 7th-8th century on the basis of the pottery (Woltering, 1978). They therefore date from before the Dunkirk III transgression phase, during which a large part of the northern extent of the province of North-Holland, where peat bog vegetation was present, became flooded by the sea and covered with a marine sediment (Pons & Van Oosten, 1974, pp. 28, 85). This transgression phase had its height in the 12th century.

The early medieval remains were found in an accumulation layer (Woltering, 1978). It should therefore be taken into account that around Schagen the sea was exerting some influence already in the 7th-8th century. This assumption is supported by the observation of clay layers older than the Dunkirk III deposits in the northern part of North-Holland, namely near Den Helder, Warmenhuizen and in the Geestmerambacht, as well as by the C14 dating for a layer with shells of the brackish form of *Cardium edule* of 1350 B.P. (i.e. A.D. 600) (personal communication D. P. Hal-lewas).

Little is known about the environment of Schagen at the time of the early medieval occupation. The palaeobotanical and geological investigations are still in progress. The preliminary results of the palaeobotanical investigation carried out by Mrs. Buurman indicate that both peat-bog and salt-marsh elements are present in the sample. This peat is presumably part of the extensive area of peat-bog that covered Holland in the Early Middle Ages (Pons & Van Oosten, 1974, p. 25, fig. 14). The remains of salt-marsh plants as demonstrated by Buurman could be an indication of marine influence in the surroundings of Schagen in the Early Middle Ages.

It is unlikely that forests with oak and beech were present in the surroundings of Schagen in the Early Middle Ages. The areas covered with marine sediment would have been devoid of trees, and the peat-bog areas too, except for a few patches of forest swamp. The Old Dunes, which had been thickly forested with beech and oak since Roman

times, were presumably too far away to graze pigs. It would therefore probably have been impossible to reach any sizeable area of forest for grazing pigs from Schagen. This may be the explanation for the low percentage of pig bones in this early medieval settlement (table 1). The pigs which were kept would have had to have fed upon organic refuse, of which the available quantity was presumably a limiting factor for pig-keeping.

The percentage of sheep (/goat) bones was very high in the early medieval settlement near Schagen. Only late medieval Alkmaar had percentages of sheep (/goat) that were almost as high. The percentage of cattle was relatively low in this early medieval settlement (table 1, 2, 3), as was the case in Alkmaar. It has been stated above that this early medieval settlement near Schagen possibly lay within a region that was saline to some extent at least due to the influence of the sea. The high percentage of sheep remains suggests that sheep were kept in large numbers in this saline environment, as sheep have a high salinity tolerance, while in a saline environment there is no chance of liver-fluke infestation, to which sheep are highly susceptible. Caution is necessary, however, in attributing the high percentage of sheep (/goat) remains in this case to the presence of a saline environment, because due to lack of data the presence of such a saline environment in the surroundings of the early medieval settlement near Schagen is hypothetical.

Sheep would have been kept in this early medieval settlement mainly for their wool, as well as for meat and milk. In the Early Middle Ages woven lengths of wool, the so-called *pallia*, were important export products of the Netherlands (Niermeyer, 1964). Some of the exported *pallia* may have originated from the surroundings of Schagen.

The finds of cattle bones indicate that there would have been suitable pasture for cattle around Schagen, excluding the possibility of total import. This means that there must have been local areas of lower salinity.

3.2.4. *Late Medieval Alkmaar*

Medieval Alkmaar is situated on the northern extremity of a coastal barrier ridge covered by Old Dunes (Pons & Van Oosten, 1974, p. 51). Between

this and the more extensive region of Old Dunes further to the west there is only a narrow gap, which was bridged at the end of the 12th century by a dike (the *Zanddijk*). This large area of dunes would have been readily accessible from Alkmaar in the Late Middle Ages.

The Old Dunes in North-Holland, like those near Rijnsburg, had been covered with forest since Roman times. Especially the oak and the beech would have made this region attractive for keeping swine. The region did not remain uninhabited, however, but was gradually reclaimed: the forest was cleared for the purpose of establishing settlements and laying out fields for cultivation and pasture.

In the Old Dunes near Alkmaar reclamation was already taking place in the 7th and 8th centuries, as is evident from place-names. Some place-names were already in existence by around A.D. 800 (Blok, 1957). The suffix *-loo* in Heiloo, a place near Alkmaar, is indicative of a reclaimed settlement in woodland (Pons & Van Oosten, 1974, p. 50). De Jong and Van Regteren Altena (1973, p. 46) are of the opinion that the forest on the Old Dunes had hardly been affected by reclamation before A.D. 1000. After this date the process of forest clearance increased rapidly, so that by about 1100 deforestation was extensive and pastures which had developed on deforested land were already being overgrazed. These factors, in addition to climatological conditions, contributed to the formation of the Young Dunes, as a result of which part of the Old Dunes became covered by wind-blown sand (Pons & Van Oosten, 1974, p. 32). While this took place the Old Dunes upon which Alkmaar lies remained intact.

It can thus be assumed that the Old Dunes near Alkmaar were for the greater part still covered with forest in the 10th-12th centuries, and that deforestation steadily increased until the 14th century. For the inhabitants of medieval Alkmaar the only area of forest available for pannage would have been these Old Dunes. The fact that relatively more pig bones were found from the first period than from the second (the difference was only weakly significant, see table 2) may be connected with the more limited degree of deforestation of the Old Dunes during the first period.

Both periods of Alkmaar are characterized by

high percentages of sheep/goat bones. In the Middle Ages wool was an important commodity. This would undoubtedly have stimulated sheep-farming. It will be evident from the following that the environmental conditions prevailing around Alkmaar made sheep-farming possible on a large scale.

In the discussion of the Schagen results (3.2.3.3.) mention was made of the repeated medieval Dunkirk III floodings of the northern part of North-Holland. These floodings, which resulted in the deposition of marine clay, reached as far as Alkmaar via the river Rekere (Pons & Van Oosten, 1974, pp. 28, 52, 85). In the Late Middle Ages these marine deposits still formed an environment of mud-flats and salt-marshes (De Jong & Van Regteren Altena, 1972).

On the northern edge of this region that was flooded by the Dunkirk III transgression there was a settlement near Den Helder (Het Torp) (Van Es, 1973) between the 10th and the 12th century. Van Zeist (1973; 1974) made a palaeobotanical study of Het Torp, and came to the conclusion that the area immediately surrounding the settlement was unsuitable as pasture for livestock on account of the high salinity. This probably hindered keeping cattle and pigs, but not sheep.

Probably the same applied to the mud-flats and salt-marshes of medieval Alkmaar. It is assumed that, on account of the high salinity, the dwarf pond-snail was not present here, although no malacological studies have been carried out. Where there are no dwarf pond-snails, there are no liver-flukes, as is well known to sheep-farmers. Therefore the hypothesis is proposed that the many sheep of which bones have been found in medieval Alkmaar were kept in the areas to the north and east of the town which had been flooded by the Dunkirk III transgression and covered with a marine deposit. In these areas the salinity would have been generally too high for cattle, which therefore presumably grazed on the dunes and the high salt-marsh. The dunes were probably also grazed by sheep: the dryer areas of the dunes would have been free of liver-fluke infestation. Nevertheless it seems reasonable to look for an explanation for the high percentages of sheep/goat remains in Alkmaar mainly in the availability of brackish pastures.

4. THE METHODOLOGICAL BASIS OF THE INVESTIGATION

The differences between the settlement samples shown in table 1 have been tested on the basis of the numbers of fragments of domesticated mammals (cattle, sheep/goat, pig, horse, dog, cat); in each case the number of fragments of a certain species (pig, sheep/goat or cattle) is entered in a 2×2 table against the sum of the numbers of fragments of all the other domesticated species, i.e. including horse, dog and cat, species which have not been studied in any further detail as regards their frequency. In most of these samples the remains of horse, dog and cat together constitute less than 3% of all bone fragments, and have very little influence on the percentages of fragments of cattle, sheep/goat and pig. Only in Hoogkarspel-Watertoren is there a high percentage of remains of dog, almost 8% (neither horse nor cat are represented), and this has a moderating effect on the percentages of cattle, pig and sheep/goat, although not to such an extent that this sample would fall into a completely different category.

The attempt to discover any possible relation between environment and the pattern of stock-raising described in section 3.2 is based on a number of postulates mentioned in section 1. One of these will be discussed here in further detail, namely the assumption that the numbers of excavated bones of the various domesticated mammal species is proportional to the numbers of individual heads of stock kept in former times. This postulate is based in turn upon two assumptions, the first of which is that all excavated bones originate not only from animals slaughtered on the spot, but also from animals kept on the spot or in the immediate neighbourhood, i.e. that there was no import of animals for slaughter in whole or in part from other types of environment further away. This assumption probably holds good to a large extent for the Bronze Age sites, but for the Middle Ages the possibility should be taken into account of trade in animals for slaughter over greater distances. Yet the late medieval towns would have been largely self-supporting or dependent on the immediately surrounding area as regards meat supply.

The second assumption is that the bones of slaughtered animals are proportionally represented

among the bones that are preserved and collected. In general this assumption will not hold good completely, either: sources of error in the sample of faunal remains collected may include differences in slaughter technique and manner of disposal for different species, different numbers of skeletal elements in the living animals (e.g. the varying numbers of fully developed metapodia in different species), differences in resistance to processes of weathering in the soil and possibly incompletely non-selective methods of collection. Various methods have been devised to evade these problems through eliminating these selective factors, e.g. by comparing the estimated minimum numbers of individuals, the weight of bone or the numbers of fragments of certain skeletal elements. These methods are of such questionable validity, however (see e.g. Uerpman, 1973; Grayson, 1978), that it was decided here to use the method of comparing "ordinary" numbers of fragments.

Combining these two assumptions in a more statistical context we can say that the samples of faunal remains listed in table 1 each represent a random sample of all the bones preserved in the settlement concerned (if the settlement has not been excavated completely), which together represents in turn a random sample of the population of animals slaughtered, which in turn can be regarded as a random sample of the animals kept in and around that settlement.

These assumptions are necessary for the χ^2 -tests carried out as described in section 1. For a critical consideration of the bias of completely random sampling in archaeology the reader is referred to Cowgill (1977), who maintains that this bias is generally not so big that statistical testing is undesirable and that an intuitive assessment is the only solution.

Cowgill (1977) discusses extensively the information that χ^2 values give us. In our case they say something about the samples of faunal remains from the settlements that are compared in pairs and about the chance that the members of each pair of settlements are alike in respect of the investigation (the null hypothesis), rather than that they differ significantly in this respect (the alternative hypothesis). The χ^2 values do not provide any evidence for the validity of either of these hypotheses. Values of χ^2 tend to increase as N increases (N = A

+ B + C + D), which makes it difficult to compare different χ^2 values. This problem can be solved by calculating a measure of association that is independent of N. Here the ϕ -value was chosen, which is calculated according to $\phi = \sqrt{\chi^2/N}$ (Blalock, 1960; Cowgill, 1977). When association is complete, i.e. in our case when in the sample of the first settlement only fragments of species a are found and none of species b-n while in the sample of the second settlement only fragments of species b-n are found and none of species a, then the ϕ -value is high; when the sample size of both settlements of the same order of magnitude, the value of ϕ will be higher, approaching the maximum value of $\phi = 1$.

If there is no association at all between the frequency of the number of fragments of a species and one of the two settlements concerned in the χ^2 estimation, then the value of ϕ is 0 (Blalock, 1960). All the intermediate values of ϕ represent different degrees of association. The association can also be expressed in a negative sense.

For the χ^2 values in tables 2, 3 and 4 the degree of association ϕ was found to be low: the highest values were around 0.24-0.30. This means that for each pair of settlement samples, even when the percentages of fragments of a species from both samples differed considerably and significantly, there is some third factor or several other factors determining the extent to which this species is represented in all the settlement samples. The method of Lasota-Moskalewska and Sulgostowska (1976/7) is of relevance here in my opinion. This method introduces an alteration in the χ^2 -test, in an attempt to ascertain exclusively the larger surpluses. Unfortunately it is impossible for me to understand the method completely and to apply it as I am unfamiliar with the Polish language, in which most of the relevant articles are published.

Some mention was made above of communal factors which would have influenced the frequency of (the fragments of) a species in the total number of (fragments of) domesticated species. From table 1 it is evident that in all settlement samples investigated cattle represent the most abundant species in terms of numbers of fragments. This applies to many other West-European settlements dating from the periods in question. The reason for this is not certain. There was possibly a distinct

preference for cattle, a species which provided milk, meat, hides, fat and traction power. It seems that among the settlements investigated here, it was only in those settlements in the proximity of a saline environment, namely Schagen and Alkmaar, that sheep were kept in large numbers, presumably, in view of the periods from which these settlements date, for the purpose of providing wool.

Dorestad and Rijnsburg are more or less contemporary with Schagen, but the percentages of bones of sheep/goat are much lower, perhaps because there was no brackish environment in the locality. In the West-Frisian Bronze Age settlements the percentages of fragments of sheep/goat were low, as indicated in 3.2.2, presumably in connection with an environment free of liver-fluke infestation. The reason why sheep were nevertheless kept everywhere, even if in very small numbers, may be because they provided meat, milk, wool and skins. Pigs form an important supply of meat and were therefore probably kept in all the settlements investigated, even where forest was locally scarce as they could be fed upon organic refuse.

5. ACKNOWLEDGEMENTS

I should like to express my gratitude to all those who have contributed towards the realization of this article: to Dr. A. T. Clason who helped to identify the remains and who made some useful comments on the text; to Mr. J. F. van Regteren Altena and Mr. D. C. Brinkhuizen who read through the text and commented upon it; to Mr. D. P. Hallewas who criticized the part about Schagen and who provided me with much useful information on the geology and archaeology of North-Holland; to Mrs. S. M. van Gelder-Ottway M.Sc. for translating the text; to Mrs. E. Rondaan-Veger for typing the texts and to Mr. J. M. Smit for drawing fig. 1.

6. LITERATURE

AITKEN, F. C., 1976. *Sodium and potassium in nutrition of mammals*. Commonwealth Agricultural Bureau, Technical Communication no. 26.

- BAKELS, C. C., 1974. Enkele milieu-aspecten van grasheuvel late Hoogkarspel. *West-Frieslands Oud en Nieuw* 41, pp. 259-261.
- BAKKER, J. A., R. W. BRANDT, B. VAN GEEL, M. J. JANSMA, W. J. KUIJPER, P. J. A. VAN MENSCH, J. P. PALS & G. F. IJZEREFF, 1977. Hoogkarspel – Watertoren: towards a reconstruction of ecology and archaeology of an agrarian settlement of 1000 B.C. In: B. L. van Beek, R. W. Brandt & W. Groenman-van Waateringe (Eds.), *Ex Horreo*. Amsterdam, pp. 187-225.
- BLALOCK, H. M., 1960. *Social statistics*. New York.
- BLOK, D. P., 1957. Het goederenregister van de St. Maartenskerk te Utrecht. *Mededelingen van de vereniging voor naamkunde te Leuven en de commissie voor naamkunde te Amsterdam* 33, pp. 89-104.
- BOTTEMA, S. & A. T. CLASON, 1979. *Het schaap in Nederland*. Zutphen.
- CASPARIE, W. A. & J. E. J. SWARTS, 1978. Hout. *Spiegel Historiaal* 13 (nr. 4, Speciaal Dorestad), pp. 267-281.
- CATE, C. L. TEN, 1972. *Wan god mast gift...*, *Bilder aus der Geschichte der Schweinezucht im Walde*. Wageningen.
- CLASON, A. T., 1967. *Animal and man in Holland's past, I, II*. Groningen.
- CLASON, A. T., 1972. Dieren in middeleeuws Alkmaar. In: E. H. P. Cordfunke (Ed.), *Alkmaar, van boerderij tot middeleeuwse stad* (Alkmaarse studiën 1), pp. 98-104.
- CLASON, A. T. & D. C. BRINKHUIZEN, 1978. Dieren in middeleeuws Alkmaar (II). In: E. H. P. Cordfunke (Ed.), *Alkmaar in Prehistorie en Middeleeuwen, tien jaar stadskernonderzoek* (Alkmaarse historische reeks II). Zutphen, pp. 118-133.
- CLASON, A. T. & W. PRUMMEL, in druk. Faunaresten uit vroeg-middeleeuws Schagen (Waldervaart). *Westerbeem*.
- COWGILL, G. L., 1977. The trouble with significance tests and what we can do about it. *American Antiquity* 42, pp. 350-368.
- ES, W. A. VAN, 1973. Early-Medieval settlements. *Berichten R.O.B.* 23, pp. 281-287.
- ES, W. A. VAN, 1973. Terp Research; with particular reference to a medieval terp at Den Helder, Province of North Holland. *Berichten R.O.B.* 23, pp. 337-345.
- GRAYSON, D. K., 1978. Minimum numbers and sample size in vertebrate faunal analysis. *American Antiquity* 43, pp. 53-65.
- HERWEYER, C. H., 1978. Schapeziekten. In: M. Bekedam & C. H. Herweyer, *Schapeenteelt en schapeziekten*. Zutphen. 240 pp.
- JELGERSMA, S., J. DE JONG, W. H. ZAGWIJN & J. F. VAN REGTEREN ALTENA, 1970. The coastal dunes of the western Netherlands; geology, vegetational history and archaeology. *Mededelingen Rijks Geologische Dienst* N.S. 21, pp. 93-167.
- JONG, J. DE & J. F. VAN REGTEREN ALTENA, 1973. Enkele geologische en archeologische waarnemingen in Alkmaars oude stad. In: E. H. P. Cordfunke (Ed.), *Alkmaar, van boerderij tot middeleeuwse stad* (Alkmaarse studiën 1), pp. 25-64.
- KUIJPER, W. J., 1977. Molluscs. In: J. A. Bakker *et al.*, Hoog-

Environment and stock raising in Dutch settlements

- karspel – Watertoren... In: B. L. van Beek, R. W. Brandt & W. Groenman-van Waateringe (Eds.), *Ex Horreo*. Amsterdam, pp. 198-200.
- LASOTA-MOSKALEWSKA, A. & Z. SULGOSTOWSKA, 1976/7. The application of contingency table for comparison of archaeozoological materials. *Ossa* 3/4, pp. 153-168.
- MENSCH, P. J. A. VAN & G. F. IJZEREFF, 1975. Animal remains from a Bronze Age settlement near Andijk, Province of North Holland. *Berichten R.O.B.* 25, pp. 55-68.
- MENSCH, P. J. A. & G. F. IJZEREFF, 1977. Animal and human remains. In: J. A. Bakker *et al.*, Hoogkarspel – Watertoren... In: B. L. van Beek, R. W. Brandt & W. Groenman-van Waateringe (Eds.), *Ex Horreo*. Amsterdam, pp. 204-208.
- MODDERMAN, P. J. R., 1964. Middle Bronze Age graves and settlement traces at Zwaagdijk, gemeente Wervershoof, Prov. North Holland. *Berichten R.O.B.* 14, pp. 27-36.
- NIERMEYER, J. F., 1964. De Friese handel. In: *Wdvaart in wording. Sociaal-economische geschiedenis van Nederland van de vroegste tijden tot het einde van de middeleeuwen*. Den Haag.
- NOBIS, G., 1955. Die Entwicklung der Haustierwelt Nordwest- und Mitteldeutschlands in ihrer Beziehung zu landschaftlichen Gegebenheiten. *Petermanns geografische Mitteilungen* 99, pp. 2-7.
- PALS, J. P., 1977. Seeds and fruits. In: J. A. Bakker *et al.*, Hoogkarspel – Watertoren... In: B. L. van Beek, R. W. Brandt & W. Groenman-van Waateringe (Eds.), *Ex Horreo*. Amsterdam, pp. 200-204.
- POELMAN, J. N. B., 1973. *Bodemkaart van Nederland, schaal 1:50000, toelichting bij de kaartbladen 39 West Rhenen en 39 Oost Rhenen*. Wageningen.
- PONS, L. J. & M. F. VAN OOSTEN, 1974. *De bodem van Noordboland. Toelichting bij blad 5 van de bodemkaart van Nederland schaal 1:200000*. Wageningen.
- PRUMMEL, W., 1978. Vlees, gevogelte en vis. *Spiegel Historiae* 13 (nr. 4, Speciaal Dorestad), pp. 282-293.
- REGTEREN ALTENA, J. F. VAN & J. A. BAKKER, 1961. De neolithische woonplaats te Zandwerven (N.H.). In: W. Glasbergen & W. Groenman-van Waateringe (Eds.), *In het roetspoor van A. E. van Giffen*. Amsterdam, pp. 33-40.
- REGTEREN ALTENA, J. F. VAN, 1970. Archeology. In: S. Jelgersma *et al.*, The coastal dunes... *Mededelingen Rijks Geologische Dienst* N.S. 21, pp. 93-167.
- REGTEREN ALTENA, J. F. VAN, P. J. A. VAN MENSCH & G. F. IJZEREFF, 1977. Bronze Age clay animals from Grootebroek. In: B. L. van Beek, R. W. Brandt & W. Groenman-van Waateringe (Eds.), *Ex Horreo*. Amsterdam, pp. 241-254.
- REICHSTEIN, H., 1975. Die Vegetationsverhältnisse und die relativen Haustieranteile in vor- und frühgeschichtlichen Siedlungen. In: A. T. Clason (Ed.), *Archaeozoological Studies*. Amsterdam, pp. 219-224.
- SARFATIJ, H., 1975. Rothulfaasem, de voorloper van Rijnsburg. In: *Archeologen werken in Zuid-Holland*, Rijksmuseum van Oudheden, tentoonstellingscatalogus nr. 11. Leiden, pp. 37-39.
- SARFATIJ, H., 1977. Die Frühgeschichte von Rijnsburg (8.-12. Jahrhundert), ein historisch-archäologisches Bericht. In: B. L. van Beek, R. W. Brandt & W. Groenman-van Waateringe (Eds.), *Ex Horreo*. Amsterdam, pp. 290-302.
- SIEGEL, S., 1956. *Nonparametric statistics for the behavioral sciences*. Tokyo, pp. 104-111.
- SLICHER VAN BATH, B. H., 1967. L'Histoire des forêts dans les Pays-Bas Septentrionaux. *A.A.G. Bijdragen* 14, pp. 91-104.
- SMITS, F., 1978. *Archeozoologisch onderzoek van een Bronstijd nederzetting bij Hoogkarspel* (N.H.). Doctoraal scriptie, Groningen.
- TENT, W. J. VAN, 1978. De landschappelijke achtergronden. *Spiegel Historiae* 13 (nr. 4, Speciaal Dorestad), pp. 205-214.
- UERPMAAN, H.-P., 1973. Animal bone finds and economic archaeology: a critical study of osteo-archaeological method. *World Archaeology* 4, pp. 307-322.
- WOLTERING, P. J., 1978. Archeologische kroniek van Noord-Holland. *Holland* 10, pp. 250-276.
- IJZEREFF, G. F., 1977. Bottenonderzoek. In: J. Schimmer, Opgravingen in de voormalige Bank van Lening. *Haarlems Bodemonderzoek* 5, p. 14.
- ZAGWIJN, W. H., 1970. Vegetational history. In: Jelgersma *et al.*, The coastal dunes... *Mededelingen Rijks Geologische Dienst* N.S. 21, pp. 93-167.
- ZEIST, W. VAN, 1969. Agriculture in Early-Medieval Dorestad: A preliminary report. *Berichten R.O.B.* 19, pp. 209-212.
- ZEIST, W. VAN, 1973. The environment of "Het Torp" in its early phases. *Berichten R.O.B.* 23, pp. 347-353.
- ZEIST, W. VAN, 1974. Palaeobotanical studies of settlement sites in the coastal area of the Netherlands. *Palaeohistoria* 16, pp. 223-383.