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Pollen from coprolites and recent droppings: useful for reconstructing vegetations and determining the season of consumption?

An attempt has been made to infer the season of consumption and to reconstruct the former vegetation from the results of the analysis of the pollen contained in coprolites. A comparative analysis of recent droppings of foxes showed that it is not possible to infer the season of consumption from such results, except possibly in some special cases. The same analyses showed that it is possible to reconstruct the vegetation to a certain extent: all the species encountered in the droppings were present in the local vegetation, the species that were found to be dominant in most samples were also dominant in the vegetation and all of the species with high frequencies in the droppings were frequently occurring species in the vegetation.

Most of the coprolites were found to contain pollen of cultivated species; although this does not necessarily mean that those species were grown on the site itself, it does imply their presence there.

1. Introduction

Conditions for the preservation of pollen and (uncarbonised) seeds are often far from perfect at archaeological sites. Particularly on dry, sandy soils pollen is often absent. The consequence of this is that it is often very difficult to reconstruct the former vegetation of such sites. One of the alternative sources of information that have been considered in this context is coprolites. Coprolites are excrements which have been petrified due to particular local conditions (a dry matrix, the presence of large amounts of phosphate and chalk, the presence of a cover layer of drift sand). They are found in excavations relatively frequently. Coprolites often contain several zoological and botanical macro-remains. They also contain large amounts of pollen. To obtain pollen coprolites are scraped well to avoid the risk of contamination with pollen from the outer surface. They are then dissolved in phosphoric acid (85% for 3 to 4 hours), after which the resultant solution is separated with the aid of bromoform/alcohol (s.g. 2). Finally an acetolysis is carried out (Erdtman 1969).

In our case it was hoped that the pollen from coprolites would provide answers to two questions. The first of these concerned the environment. As already mentioned above, it was hoped that the information obtained from the coprolites would help us to reconstruct the former vegetation. The second question was whether some Neolithic sites in the western part of the Netherlands had been occupied on a seasonal basis. It has often been assumed that pollen contained in coprolites can be used to determine the season in which it was consumed (see Paap 1976).

Pollen can make its way into the intestinal system in two ways: via inhalation (Wilson *et al.* 1973) and via food and drink (Kowalski *et al.* 1976). The behaviour of the donor is an important factor in this respect. In our sites the donors of the coprolites were probably dogs.[1] In order to determine what information the pollen from the coprolites could provide about the vegetation or the season, comparative research was carried out using the droppings of foxes from the dunes west of Vogelenzang (Amsterdamse Waterleiding-duinen, fig. 1). Foxes were chosen because prehistoric dogs are probably more comparable with present-day foxes than with present-day dogs. Moreover, the vegetation of the territories of the foxes was well known. A practical reason was that we were able to collect the droppings there. Fresh droppings were collected in part of the area once or twice a month for two consecutive years. They were analyzed for pollen and macroremains using the usual laboratory procedures, with the difference that a tablet containing *Lycopodium* spores was added.

2. The analysis of the fox droppings

The collected droppings were described and prepared for pollen analysis. An example is shown in figure 2. The excrements yielded macro-remains besides pollen[2]. After the droppings had been prepared the pollen was counted. The taxa present, their numbers and the preservation of the pollen varied considerably. In some exceptional cases the foxes in question had eaten butterflies. The scales of the wings were found and enormous amounts of pollen from plants that are visited by butterflies, such as *Anchusa*, *Echium vulgare* and *Solanum dulcamara* (fig. 3).

The presence of large numbers of small black particles (probably bacteria) often made it difficult to count the

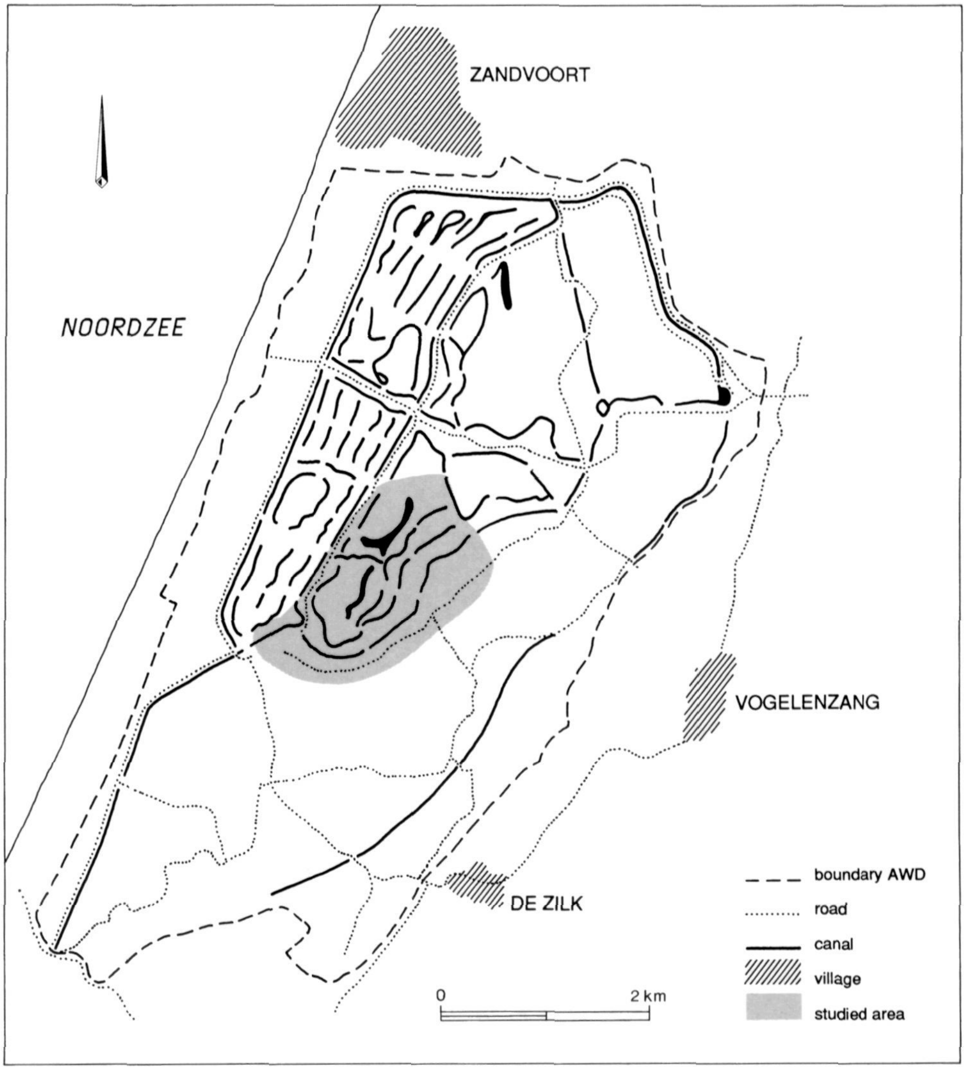

Figure 1. Position of the investigated area in the Netherlands.

pollen. In some cases they covered the pollen completely. A sieving experiment was carried out using a sieve with meshes of 9 μm to see whether the particles could be removed[3]. The sieving of the samples of fox droppings did not lead to a spectacular reduction in the number of bacteria. It was therefore decided to stop sieving and to make the most of the black slides. The result is shown in figure 4.

3. Vegetation reconstruction on the basis of the fox droppings

The composition of the local vegetation (fig. 5) was determined via observations in the area and from maps by Doing (1988). The vegetation resulting from the data obtained for the fox excrements was compared with the actual vegetation. A vegetation can be reconstructed in two ways: qualitatively and quantitatively. The qualitative reconstruction was found to be quite reliable in the sense that all of the species encountered in the fox excrements indeed occurred in the dune area. However, it was not possible to reconstruct the entire vegetation from the data obtained because the donor had not ingested pollen from all the species present (for instance because some species produce only little pollen).

The quantitative reconstruction was reliable to a certain extent only. A distinction was made between dominant and frequently occurring species. There were two dominant taxa in the vegetation: *Hippophae rhamnoides* and Gramineae. In the excrements the first species was regularly found to dominate, followed by Gramineae. In the case of some samples, however, other species dominated, for example *Prunus serotina*, *Alnus*, *Betula*, *Pinus*, *Crataegus*,

Figure 2. Example of a fox dropping. 1:1. Amsterdamse Waterleidingduinen.

Compositae and the species visited by butterflies. These species were present in the vegetation, but not as dominant elements.

The species frequently encountered in the droppings were all frequently occurring species in the vegetation. The opposite, however, did not apply: there were certain species in the vegetation which, for various reasons, were hardly, if ever, encountered in the droppings.

The overall conclusion is that it proved possible to reconstruct the vegetation to a certain extent: all the species that were encountered in the fox excrements actually grew in the dune area, the species that were found to be dominant in many samples were also dominant elements in the vegetation and all the frequent species in the excrements were frequently occurring species in the surroundings.

4. Season of consumption as reflected in the recent fox droppings

The absolute numbers were plotted on a logarithmic scale (see fig. 5) to enable comparison of the results with Spieksma's pollen calendar (Driessen *et al.* 1988, 105).[4] At first sight there seemed to be no connection between the two. It appeared to be impossible to infer the season of consumption from the data obtained for the excrements. However, this changed when the species were divided into two groups, one of species of which pollen were to be found in the area for part of the year only and one of the species of which pollen were present on the plants throughout the year. In the case of the last group some correspondence with the calendar was observed for the flowering period (in particular in the case of the samples of the 'butterfly foxes' of August 1987 and August 1988) and in some cases for the fruiting season (species that were eaten as fruit, such as *Prunus serotina*, in October 1987, and *Rubus fruticosus*, in August 1988).[5]

With the possible exclusion of the exceptional samples, such as those of the 'butterfly foxes' and those containing the remains of Rosaceae fruit, which provided indications of the flowering and fruiting season, respectively, the samples did not provide any information on the season of consumption.[6]

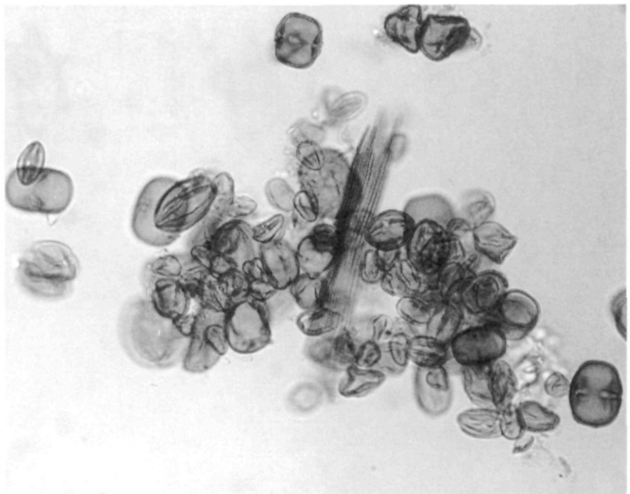

Figure 3. Pollen and wing scale of a butterfly. Amsterdamse Waterleidingduinen. 1:200.

5. Results of the analysis of the coprolites

Over the past few years several coprolites have been analyzed (fig. 6). The macroremains usually encountered are bones, including those of fish, sand, small pieces of charcoal, the odd seed (*Juncus*, *Poa* and *Phragmites*) and pollen, usually well preserved (tab. 1).

The dominant species in two Neolithic coprolites from Hekelingen (western Netherlands) was *Alnus*. Species with high frequencies were *Hedera helix* and *Corylus avellana*. Together with the other species encountered they were indicative of a dry place bordered by an alder carr, which was in excellent agreement with the other botanical evidence from this site.[7] The question concerning seasonal occupation raised in the introduction, could not be answered, as will have become clear from the results of the fox-dropping research.

The dominant species in the twelve coprolites dating from the Roman period that were found in The Hague (western Netherlands) were *Myrica gale* (1×) and Gramineae (11×). On the basis of the results obtained in our fox research they would indicate a vegetation dominated by grasses. This is in accordance with other evidence obtained for this region.[8] The large amount of *Myrica gale* pollen can be understood by assuming that the dog drank water from a dune lake at the time when the shrubs surrounding it were in flower. Enormous amounts of pollen would then have floated on the surface of the water.

Species with high frequencies in the samples from The Hague were *Corylus avellana*, *Plantago lanceolata*, *Myrica gale*, *Filipendula*, *Alnus*, *Rumex*, Cyperaceae, Ericaceae, Cruciferae, Compositae liguliflorae, Monoletae and Cerealia. These and the less frequent species grow in small

Table 1. Pollen from coprolites.

site	Hekelingen		Villeneuve St. Germain			Uitgeest	The Hague												The Hague				
sample number	12C-291	12D-288	F4.C.19B	142	249	20-3-53	301	323	345	356	522	688	698	1100	1103	2258	4367	4382	98	283	303	417	3
period	Neolithic		late Iron Age			Roman	Roman												Middle Ages				
Cerealia	4	1	114	4	53	18	-	3	15	10	3	13	5	4	2	7	19	-	84	52	71	17	10
Juglans regia	-	-	-	-	-	-	-	-	-	-	-	1	4	1	-	1	-	-	-	-	-	-	-
Pisum sativum	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-
trees and shrubs:																							
Alnus spec.	672	91	13	-	22	18	-	1	6	15	8	6	10	17	2	6	2	9	7	38	11	9	8
Betula spec.	6	-	1	-	2	7	-	-	2	3	2	1	2	7	2	-	1	1	1	3	3	2	1
Corylus avellana	76	22	1	-	11	3	-	20	10	64	18	5	13	10	5	7	2	3	-	33	6	8	4
Hedera helix	108	4	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	7	-
Hippophae rhamnoides	-	-	-	-	-	-	-	2	1	5	-	1	1	3	1	-	-	1	-	-	-	-	-
Juniperus communis	-	-	-	-	-	-	-	-	1	-	1	24	3	7	1	1	-	1	-	-	-	-	-
Myrica gale	5	-	-	-	-	-	500	2	8	14	3	1	3	1	17	3	-	2	-	3	-	2	1
Pinus spec.	2	3	1	1	1	4	-	-	1	1	1	1	2	1	-	1	-	-	-	-	2	-	1
Quercus spec.	24	5	1	-	4	4	-	1	2	6	-	2	1	4	1	3	2	2	1	4	1	4	2
Salix spec.	8	-	-	-	-	-	-	-	2	3	10	2	2	1	2	-	1	1	6	27	2	4	-
Ulmus spec.	34	4	-	1	-	-	-	-	1	2	-	-	-	1	-	-	-	-	-	-	-	-	1
other taxa	16	8	1	-	-	-	-	-	1	1	-	-	-	-	-	-	1	1	1	18	-	-	2
herbs:																							
Artemisia spec.	-	-	2	2	1	-	1	3	7	19	6	1	5	4	2	6	6	4	1	-	6	4	-
Caryophyllaceae	-	-	1	1	2	1	-	2	-	14	6	4	4	4	3	4	2	5	3	4	1	-	-
Centaurea jac./prat. type	-	-	1	1	-	-	-	-	-	-	-	-	-	2	6	2	-	2	-	-	-	-	-
Chenopodiaceae	4	2	3	1	2	8	-	2	4	24	5	-	8	3	1	7	4	2	2	6	4	6	1
Compositae lig. type	1	-	9	11	5	2	1	10	12	42	22	55	22	30	15	27	13	5	8	58	18	12	4
Compositae tub. type	2	1	14	6	10	7	-	6	1	21	12	7	13	7	3	3	5	2	4	47	24	6	1
Cruciferae	-	-	-	5	-	11	-	1	-	-	4	112	1	2	-	-	-2	-	28	5	2	-	
Cyperaceae	5	6	1	2	-	26	-	4	13	32	21	34	15	6	17	15	6	3	3	32	2	-	8
Ericales	3	-	-	-	-	1	1	8	15	45	9	9	13	9	5	10	4	2	2	26	-	10	11
Filipendula spec.	3	6	1	1	-	3	-	2	1	60	6	6	3	2	2	1	-	3	-	1	3	30	-
Gramineae	42	1	80	21	151	160	1	91	145	516	235	244	371	105	185	132	72	74	218	187	86	208	35
Lotus uliginosus	-	-	-	-	-	1	-	-	-	1	3	-	-	3	1	1	-	1	-	-	-	-	-
Mentha type	-	-	-	-	-	-	1	1	1	1	-	-	-	1	-	-	-	-	-	-	-	-	1
Monoletae psilatae	36	18	-	1	-	1	-	2	2	18	4	1	106	7	5	3	5	9	9	23	11	20	12
Papilionaceae	-	-	-	-	-	-	-	1	1	6	3	16	7	14	3	4	-	4	3	-	-	-	-
Plantago lanceolata	-	2	9	2	13	1	-	13	6	87	20	23	20	22	19	13	11	11	7	10	8	6	-
Plantago major/media	-	-	-	-	-	-	-	3	-	1	1	-	1	1	-	-	-	-	-	-	1	1	6
Polygonum aviculare	-	-	1	-	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	3	2	-	-
Polypodium	2	-	-	-	-	-	-	1	1	1	2	-	-	-	-	-	-	-	-	-	-	-	-
Ranunculus spec.	-	-	-	3	-	4	1	3	2	30	5	9	13	4	6	3	2	4	6	8	1	13	2
Rubiaceae	1	-	1	-	-	-	-	4	10	11	-	5	4	6	3	5	1	3	6	4	3	6	-
Rumex acetosa type	-	-	2	-	7	7	-	11	5	20	16	9	32	6	4	4	5	10	2	9	1	12	-
Sanguisorba minor	-	-	-	-	-	-	-	3	-	1	-	4	-	-	2	2	-	3	1	-	-	-	-
Sphagnum spec.	1	-	1	-	-	4	1	3	3	7	1	1	2	5	3	1	2	1	-	16	2	1	3
Triletae psilatae	1	2	4	2	3	-	-	-	1	-	4	1	1	-	-	-	-	-	-	-	1	-	-
Umbelliferae	-	1	12	10	10	7	-	3	3	11	11	7	2	4	3	2	1	-	2	6	2	-	-
Urtica spec	2	1	2	-	2	1	-	6	1	4	-	1	2	-	-	-	-	-	6	1	1	-	-
other taxa	5	57	28	6	26	72	-	11	7	109	7	21	12	8	1	3	5	7	11	16	9	11	17

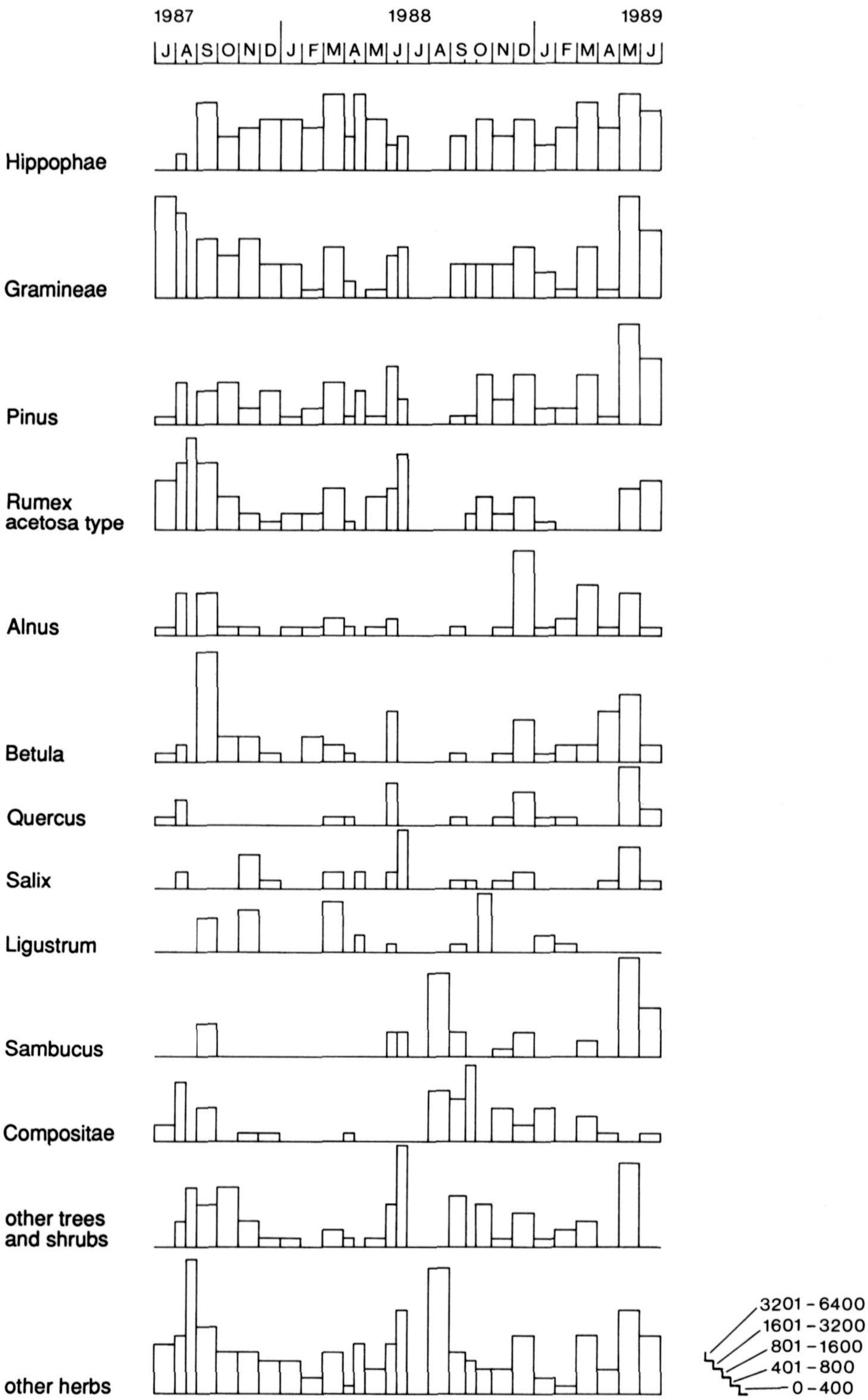

Figure 4. Absolute numbers of pollen from fox excrements (log. scale).

Figure 5. Vegetation of the studied area. Amsterdamse Waterleidingduinen.

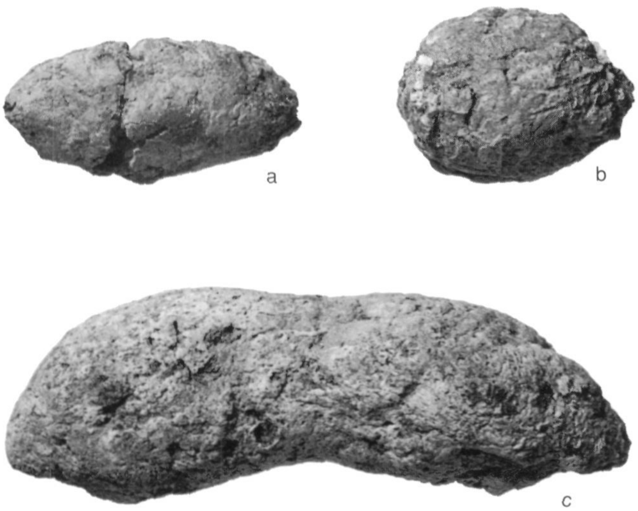

Figure 6. Coprolites from: a - Hekelingen (Neolithic), b - Villeneuve Saint Germain (Late Iron Age), c - Uitgeest (Roman Period). 1:1.

woods and brushwood, grasslands of varying moisture contents and in aquatic and ruderal environments. The cereals are a special case. Although they were frequently encountered in the excrements they were not necessarily common species in the former vegetation. They may have been leftovers that were fed to the dogs. The cereal pollen included pollen of oat (*Avena*), barley (*Hordeum*) and wheat (*Triticum*). Other pollen of cultivated species encountered besides that of cereals was pollen of walnut (*Juglans regia*) and pea (*Pisum sativum*). Such pollen of cultivated species provides information on the food consumed by the occupants of the site. It cannot prove that the species in question were grown on the site itself, but it does imply that those species were present there, for instance as supplies.[9]

Coprolites from (around) the same period from Uitgeest (western Netherlands, 1×) and from the Late Iron Age site Villeneuve Saint Germain (northern France, 3×) yielded roughly the same results. Gramineae regularly dominated and the other species represented an open landscape closely resembling that inferred from the results of the analysis of the coprolites from The Hague. Cereals were frequently found.

Gramineae also dominated in some medieval coprolites (5×) from The Hague.[10] Rye (*Secale cerale*) was a frequent species in these coprolites.

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notes

1 We did not identify the donor on the basis of the colour, odour and distribution of the coprolites on the site as has been done in some other studies. We believe that the shape (oval/cylindrical with long thin ends, as with all carnivores) and the dimensions are important criteria. In our case this left us with two possibilities: human beings or dogs. This had to be solved by inspecting the contents. The presence of sand, charcoal and bones pointed to dogs.

2 regularly encountered:
sand, fragments of leaves, moss, seeds (*Urtica dioica, Prunus serotina, Polygonum, Sambucus nigra, Betula, Rubus fruticosus, Rubus caesius, Rumex acetosella, Hippophae rhamnoides, Senecio, Viola, Carex, Moehringia trinervia, Lycopus europaeus, Typha, Sagina, Veronica, Poa, Crataegus monogyna, Gramineae*), stellate hairs of *Hippophae rhamnoides*, hairs of rabbits, fragments of bones, remains of insects, different species of larvae and caterpillars.
occasionally encountered:
fragments of flowers, fragments of twigs, spores of fungi, spiders, puparia of flies, fragments of feathers and nails of birds, eggs of water fleas, fleas, fragments of shells, lice, ticks, scales of butterfly wings, eggs of Bryozoa, fragments of birds' eggs.

3 The sieving experiment comprised two samples of the fox droppings and two samples from a peat layer not connected with the study presented here. The results obtained for the samples from the peat appeared promising at first: the small mineral parts had been removed almost completely. However, closer inspection showed that the pollen content had changed. The disappearance of pollen of small species like *Urtica* and *Solanum* seemed acceptable in view of the improved and more reliable countability of the slides. However, large amounts of pollen from larger species like *Alnus, Salix, Corylus*, Gramineae, Rubiaceae, Chenopodiaceae, Umbelliferae and Monoletae had also disappeared, which was more serious.

4 Absolute numbers were obtained by the addition of *Lycopodium* tablets. The pollen calendar provides the pollen content of the air in the Netherlands.

5 Pollen is known to adhere to fruits. Moreover, Mulder (1988) discovered that several of the foxes he studied buried food and left it in the ground for a short time, which makes it still more difficult to ascribe the pollen to a specific season.

6 It is possible that more positive results would be obtained if more data were to be collected (more droppings per month over a period of several years) and compared with the results of a similar study in another area (with a different vegetation). A study of the droppings of herbivores would involve other problems, such as the possibility of cattle having been fed summer hay in the winter time.

7 Pollen and seeds were studied (Bakels 1988).

8 Evidence obtained in archaeobotanical research of remains from the Scheveningse weg (Vermeeren, unpublished) and pollen research (Jelgersma *et al.* 1970; De Jong/Zagwijn 1983).

9 It is always very difficult to ascertain whether or not a cultivated species was grown on the site itself. It has long been believed that the presence of pollen of a species constitutes evidence that that species was grown on the site but we do not agree. With the exception of the pollen of rye, virtually all cereal pollen is released from the chaff in threshing. The assumption that cereals were traded and stored in the chaff is gradually winning ground; that would mean that small amounts of cereal pollen discovered at a site would not constitute evidence for the cultivation of the species on the spot, but would simply indicate its presence there. We initially thought that we would be able to prove whether or not peas had been cultivated at a site. Peas were stored after they had been removed from their pods. We assumed that any pollen that may have been present on the outside of the pods would have disappeared by the time they were stored. If that were true, the discovery of pea pollen at a site would mean that peas were grown on the site itself. Unfortunately, however, recent peas that were shelled and prepared for pollen analysis were found to contain pollen.

10 Four of these have already been published in Magendans and Waasdorp 1989.

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