Neolithic Human Diet Based on Studies of Coprolites from the Swifterbant Culture Sites, the Netherlands

Synthesis - Human versus community diet

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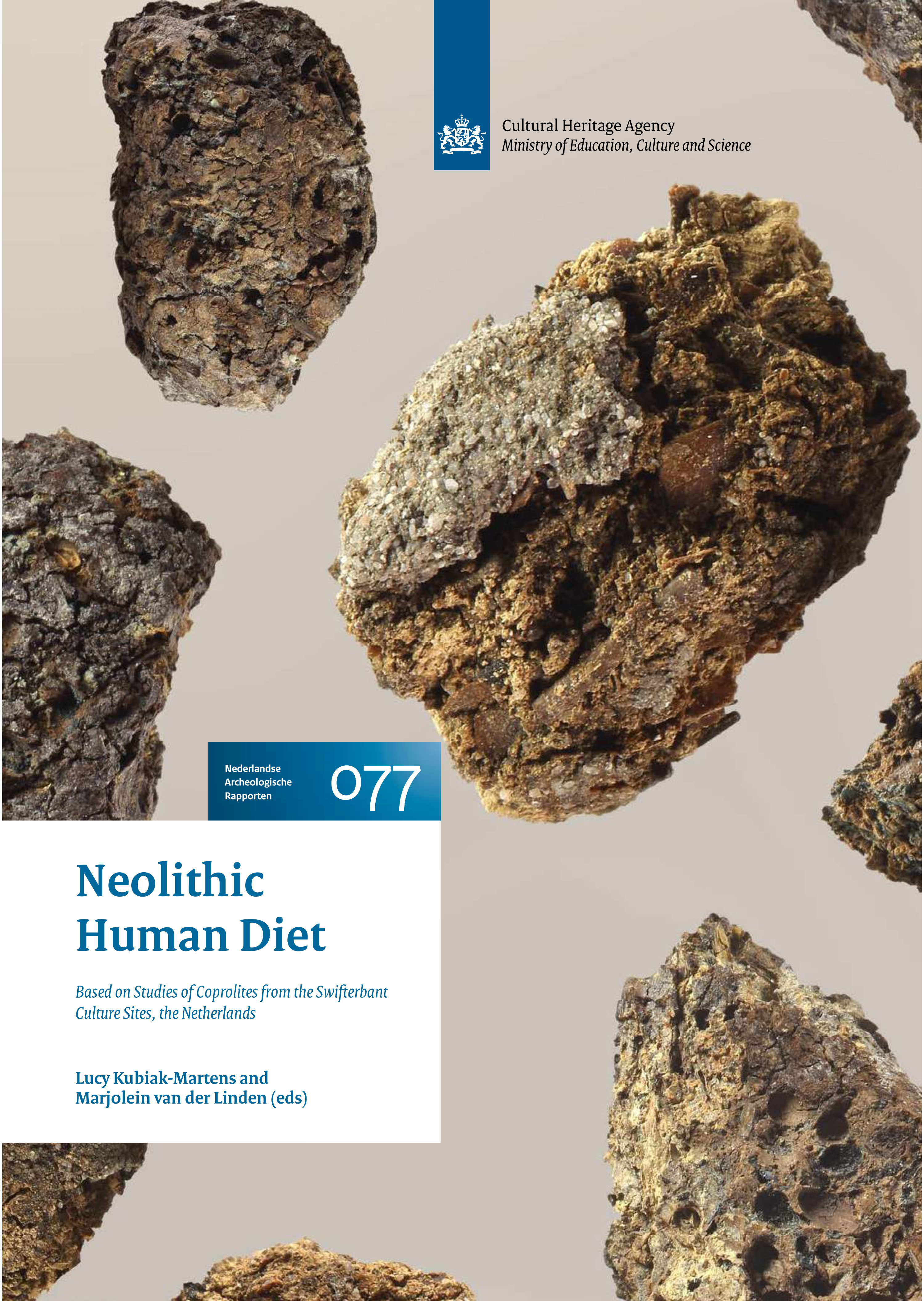
Publication date
2022

Document Version
Final published version

Published in
Neolithic Human Diet Based on Studies of Coprolites from the Swifterbant Culture Sites, the Netherlands

Citation (APA)
Kubiak-Martens, L., van der Linden, M., Hardy, K., Mackay, H., Ngan-Tillard, D. J. M., Shillito, L. . M., & Zeiler, J. T. (2022). Neolithic Human Diet Based on Studies of Coprolites from the Swifterbant Culture Sites, the Netherlands: Synthesis - Human versus community diet. In L. Kubiak-Martens, & M. van der Linden (Eds.), *Neolithic Human Diet Based on Studies of Coprolites from the Swifterbant Culture Sites, the Netherlands* (Vol. NAR077, pp. 119-139). (Nederlandse Archeologische Rapporten; No. 077). Cultural Heritage Agency of the Netherlands.



Cultural Heritage Agency
Ministry of Education, Culture and Science

Nederlandse
Archeologische
Rapporten
077

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Colophon
Nederlandse Archeologische Rapporten 77
Neolithic Human Diet Based on Studies of Coprolites from the Swifterbant Culture Sites, the Netherlands
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Cover design: J. Ranzijn (Happyfolio)

Illustration editors: M. Jórdeczka, K. Hardy, L. Kubiak-Martens, M. van der Linden, D. Ngan-Tillard, L.-M. Shillito & W. van der Meer

Design and layout: Xerox/Osage

ISBN/EAN: 978-90-76046-77-8

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13 Synthesis - Human versus community diet

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13.1 Introduction

The aim of this final chapter is to integrate the results obtained from the multi-disciplinary study applied to a series of coprolites from the Late Mesolithic and Early Neolithic Swifterbant Culture sites, to determine their role as a source of information about the prehistoric dietary tradition and health.

The study of coprolites provides a unique opportunity to reconstruct the most complete spectrum of the foods that were consumed in the past, both as cooked meals as well as foods that were eaten raw. In addition to the food remains, coprolites also contain intestinal parasites which affected the health of prehistoric populations. Coprolite studies can also provide information about palaeoenvironmental conditions through the types of microfossils and macrofossils they contain.

13.2 The project

The project 'Neolithic Human Diet Based on Studies of Coprolites from the Swifterbant Culture sites' was one in a series of studies referred to as Pre-Malta research. It was commissioned by the Cultural Heritage Agency of the Netherlands. BIAX Consult was honoured to take the lead in this project. It aimed to assess the diet and health of the Swifterbant populations through the analysis of coprolites from sites excavated before 2007. Four sites were selected, as they provided preservation of coprolites, including Hardinxveld-Giessendam De Bruin in the Lower Rhine-Meuse delta, and three sites in the province of Flevoland, including Swifterbant-S3 and -S4, and Emmeloord-J78-91 (the later site, however, was eliminated in the early stage of the project).

The first step in the project was to form a research team. We assembled a group of specialists from various countries to work together and contribute their highly sensitive research methods to the project. Multiple proxies were combined, including sterols and bile acids (together termed 'faecal steroids'), micro-CT scans, SEM images, animal bone remains, phytoliths, pollen, intestinal parasites and starch granules (see Table 13.1).

As with every project, this one also started on *Day* 1, on the 15th of July 2019 when the five coprolites recovered from Hardinxveld-Giessendam De Bruin were collected from the depot of the province of Zuid-Holland in Alphen aan den Rijn. Then, on the 22nd of July 2019 the coprolites recovered from the Swifterbant-S3 and -S4 sites and Emmeloord were collected from the archaeological depot of the province of Flevoland in Lelystad. It was beyond any expectation that as many as nearly 350 small paper bags with coprolites recovered from the S3 and S4 sites were stored in Lelystad archaeological depot.

13.3 The world of the Swifterbant Culture (c. 5000-3400 cal BC)

In the Netherlands, the Swifterbant sites were concentrated in two main areas: in the Lower Rhine-Meuse delta and the Swifterbant area in the province of Flevoland. The site of Hardinxveld-Giessendam De Bruin, located in the Lower Rhine-Meuse delta, witnessed the transition from the Late Mesolithic to the Early Swifterbant, while sites Swifterbant -S3 and S4 are dated to the classic Swifterbant Culture. The sites in the Swifterbant area were extensively excavated and studied, and only very recently was it concluded that the S3 and S4 sites would have functioned as one settlement in the Swifterbant period, perhaps only divided by a small creek. The neolithisation of the Swifterbant Culture is proposed as a long process that started around 5000 cal BC with the production of pottery, either invented or adopted. At around 4600 cal BC, there is some evidence that domesticated animals were incorporated into the Swifterbant economy. The introduction of small-scale cereal cultivation into the Swifterbant subsistence followed around 4300 cal BC and gradually gained more importance, but never seemed to become dominant before c. 4000 cal BC. The Mesolithic roots of the Swifterbant Culture are attested to in the reliance on hunting and fishing, and the gathering of wild plants for food. Perhaps the best way we could describe the economy of these people would be hunter-gatherers and farmers with an 'extended broad-spectrum economy'.[313]

[313] Louwe Kooijmans 2003; Raemaekers 1999; 2019.

13.4 Strategy for coprolite analysis

Although coprolites are generally a rarely encountered archaeological find, hundreds of coprolites were recovered at Swifterbant Culture sites as the result of suitable past burial conditions and the excavation methods. Only a fraction of these coprolites could be expected to be of human origin as coprolites produced by other omnivores such as pigs and dogs can be easily mistaken for human coprolites. As a result, the selection of the best coprolite candidates for detailed studies focusing on human diets cannot be guaranteed. The small size and heterogeneous nature of human coprolites render subsampling for a modern multi-disciplinary analysis very challenging. The fact that the least mineralised coprolites tend to crumble when they are manipulated while the most mineralised coprolites cannot be separated manually adds to the difficulty. The see-through (visually penetrating without damage) capacity of micro-CT can and should be exploited to outline the difficulties related to coprolite selection and subsampling for further study and to assess the representativeness of subsequent analyses. Coprolites containing only small bone fragments or bones without a specific shape can be deselected for zoological analysis. Plant tissues can be targeted during a scan-guided micro-extraction. The recovered tissues might then be identifiable at a very high taxonomic level using the SEM. One specimen could be selected for further analysis from a group of coprolites exhibiting similar scans. Micro-CT scanning can take place at the start with all of the other techniques to follow.

13.5 Integration of the multi-disciplinary evidence preserved in the coprolites

When we integrate the various lines of evidence and dietary components preserved in the studied coprolites, it seems that a more complete picture emerges for the individual coprolites (see Table 13.1). For example, the S3-2 coprolite shows a sausage-like shape with cracks on the surface (Appendix II, Plate IV). The determination of faecal steroids indicated human/pig as the producer organism. The plant component in this coprolite consisted of both emmer chaff and reed leaves and/or stems. Its internal matrix was also filled with both small and large fish bones, including vertebrae and teeth (some still embedded in the palate). The large chunks of fish bones in this coprolite, together with the large quantities of reed and other grasses (in phytolith remains) may speak in favour of the animal (likely pig) origin of this coprolite.

The S3-4 coprolite was defined based on faecal steroids as being of human/dog origin. Seeing the morphology of this coprolite, however, particularly its characteristic lumpy surface (Appendix II, Plate V) and the mainly small fish bone fragments (no vertebrae!) embedded in its matrix, one would argue for the human origin of this coprolite. The presence of a *Capillaria* egg suggests the consumption of infected meat (possibly freshwater fish). Numerous silicified epidermal tissue fragments from emmer chaff (lemma or palea) in the SEM images and the phytoliths of cereal husks (both *Triticum* and *Hordeum*) indicate cereals as a meal component. Charred emmer chaff epidermal tissue was found in the pollen slides as well. Leaf epidermal fragments of *Polygonum aviculare* embedded in the coprolite matrix suggest that the leaves of knotgrass were part of the meal.

In the assessment phase of the faecal steroids, it was suggested that coprolite S3-28 was of human origin. In the final analysis, however, human/ruminant origin was considered as the producer organism. The morphological appearance of S3-28 (Appendix II, Plate XIX, separated hard lumps) and the internal contents of this coprolite could speak in favour of human origin. Remains of silicified epidermal tissue from emmer chaff (lemma or palea) in the SEM images, accompanied by apple and white water-lily seeds and fine pike and perch bones, could all be interpreted as remains of a meal (or meals) consumed by a human rather than by a ruminant. Charred emmer chaff epidermis was also found in the pollen slides. Furthermore, coprolite S3-28 contains the highest concentration of intestinal parasite eggs; in particular, many eggs of whipworm (*Trichuris*) are present. Based on the size of these eggs it can be deduced that these probably belong to *Trichuris trichiura*, which has humans as hosts, but another possibility is that the eggs are *T. suis*, which has pigs as hosts. In addition, eggs of fish tapeworms (Diphyllobotriidae) and flukes (Opisthorchiidae) were found, indicating the consumption of freshwater fish. The composition of intestinal parasites therefore also points to human origin rather than ruminant.

The S3-10 coprolite was defined, based on faecal steroids, as being of dog/human origin. The pericarp tissue of likely barley (*Hordeum*) (on pollen side) offers a piece of strong evidence for the consumption of grain by the individual associated with this coprolite. The pollen assemblage and the composition of the intestinal parasites of S3-10 much resemble that of S3-11. Also, the morphologies of both S3-10 and S3-11 are very much alike, suggesting similar producers (see Appendix II, Plate VIII, and IX). In S3-11 charred emmer chaff epidermal tissue was found on the pollen slides as well. *Trichuris* eggs in both coprolites may point to a human (or pig) origin rather than a dog. The presence of a barbule in S3-10 and hair of likely red deer in S3-11 suggest the consumption of meat or the processing of animal products. White water-lily seeds were the dominant component in those two coprolites (S3-10 and S3-11). The overwhelming presence of the seeds throughout the matrices of both coprolites is well illustrated in the micro-CT scans. It is clear from these images that the seeds were the main component of the meal, consumed, possibly, with the addition of fish, as suggested by the fish bones and fish scales that accompanied the water-lily seeds. Usually, the testa of the empty seeds was preserved, often deformed but still revealing the outline of the individual seeds. Also, many seed fragments were embedded in both coprolite matrices. In S3-20 (human coprolite) and S3-28 (likely-human coprolite), the white water-lily seeds were also present, but were represented only by a few seed remains embedded in the coprolite matrices. In S3-11, as well as in S3-28 and S4-1, marsh mallow (*Althaea officinalis*) pollen suggests the consumption/use of this edible and medicinal plant (mild laxative and gentle purgative properties).

Fragments of silicified epidermal tissue from emmer chaff were detected in the SEM images from the S4-1 coprolite. Charred emmer chaff epidermis was found in the pollen slides. This coprolite revealed a very fragile and deteriorated internal structure (also shown in the micro-CT scan), very different from most of the S3 and S4 coprolites which were often hard and solid. Many small fish bones (including vertebrae) were present within the crumbling matrix of the S4-1 coprolite. Also, large quantities of melted silica were found in phytolith assemblages from this coprolite. One would wonder if the melted silica could actually be melted phytoliths, possibly representing the results of cooking for long times at high temperatures. This assumption is supported by finds of melted phytoliths that have been recovered in archaeological settings.[314] Coprolite S4-1 was indicated as being of human origin in the assessment phase of its faecal origin. However, this brief determination was not confirmed in the final analysis as no human faecal steroids were detected. The morphological appearance of this coprolite (a sausage shape with cracks on the surface, Appendix II, Plate XXI), its great similarity to S3-20 (human coprolite; contains *Triticum* grain pericarp tissue), and the food components found in its matrix suggest that it may well have originated from a human source. As already mentioned above, *Trichuris* eggs were also found in coprolite S4-1, suggesting a human origin. In addition, an egg of kidney worm (*Dioctophyma*) was present. Kidney worm has dogs as well as humans as final hosts. The indication for the consumption of freshwater fish is strengthened by the presence of Opistorchiidae (fluke) eggs. The composition of the intestinal parasite eggs of S4-4 suggests a similar origin as that of S4-1.

Five of the studied coprolites (S3-4, S3-5, S3-13, S3-18 and S3-20) share the presence of what are likely to have been knotgrass leaves. One of these coprolites (S3-20) (Appendix II, Plate XV) was defined as human in the faecal steroid analysis. This coprolite also contains remains of white water-lily seeds and fish and mammal bones. In addition, phytoliths of cereal husk (likely barley) were found in the matrix of this coprolite. In the assessment phase of the faecal steroid study, coprolite S3-18 was suggested to be likely a human/pig coprolite. Its definitive status, however, was not resolved as the biomarkers for faecal steroids were extremely low. Besides knotgrass leaves, this coprolite also contains phytoliths of cereal husk (likely barley) and fish remains (numerous tooth remains of pike). Judging by the morphological appearance of this coprolite (significant for

314 Scott Cummings, personal communication.

human coprolites: sausage shape and lumpy/ wrinkled surface; Appendix II, Plate XIII) and the fine internal matrix, human origin may be likely here. Two other coprolites with knotgrass leaf remains are likely of ruminant (S3-5) and carnivore/dog (S3-13) origin (Appendix II, Plates VI and XI, respectively). In addition to knotgrass leaves, coprolite S3-5 showed evidence both of silicified emmer chaff epidermis in the SEM images and phytolith microfossils of cereal husks (both *Triticum* and *Hordeum*). Also, numerous reed leaf/stem phytoliths and silicified epidermal tissue of reed stems (in the SEM images) were identified in this coprolite. Fish teeth and vertebrae accompanied the plant remains.

Coprolite S3-13 originated from a carnivore, likely a dog. This coprolite has an intriguingly smooth surface (Appendix II, Plate XI). Its morphological appearance seems to match its

Table 13.1 The combined results of various analyses applied in this study.

Coprolite code	Sample number	Charred particles emeded in coprolite matrices, observed during subsampling for microfossil anayses	Macroremains in residues from pollen preparations	Faecal steroids (1-assessment phase, 2-analysis phase, 3-revised)	Bone remains	micro CT-scan
Hardinxveld	19520	few Phragmites stem particles	.	1. indicates poor preservation so unable to determine source organism-2. not confirmed as faecal	perch (dentale, scale); fish indet.; mammal, indet.	perch dentale and scale; indet. Charred plant tissues?
Hardinxveld	19952	few small charcoal fragments, also few Phragmites stem particles	charred herbaceous particles	1. likely pig-2. pig	perch (vertebra, spine, scale); duck bone; mammal, indet.	fish scales, vertebras, finray; indet. Charred plant tissues?
S3-2	54516	numerous likely Phragmites stem particles	charred herbaceous particles	1. human – 2. pig	pike (vertebra, tooth, palatinum); fish indet.	fish vertebras, palatinum, pike teeth; fish indet. Charred plant tissues?
S3-4	54655	numerous Phragmites stem particles	charred herbaceous particles	1. human-2. human-3. dog/ human	fish, indet.	fishteeth, scales; indet. Indent. voids, possibly plant phantoms, many elongated, one sub-spherical, one stick-like
S3-5	51179	few reed stem particles	charred Phragmites stem particles	1. unlikely human, bile acids suggest most likely ruminant-2. ruminant?	pike (vertebra, tooth, spine); fish indet.	fish vertebras and teeth, fish indet. Many thin elongated voids, some large stem like plant voids
S3-8	53985	some large fragments of Phragmites stem, incl. nodium remains	.	1. indicates poor preservation so unable to determine source organism-2. pig	perch (vertebra, articulare, scale); fish indet.	"perch (vertebras, many with spines and scales), detached spines; indet. Many thin elongated voids and several large voids with distinct shape, possibly phantoms of rolled tissues, platy tissues with ribs and rounded seed fragment"

faecal steroid profile very well, both taken together suggesting a dog origin. Besides the knotgrass leaves, there are also cereal husk phytoliths (likely both wheat and barley) and numerous reed leaf/stem phytoliths.

We can conclude that knotgrass leaves were found in one human and one likely-human coprolite (S3-20 and S3-18, respectively), and in two animal coprolites, one of which is of ruminant origin (cattle and/or sheep/goat) and the other likely derived from a dog (S3-5 and S3-13, respectively). This indicates that the leaves of knotweed were consumed by people living on the S3 settlement, likely as green/leaf vegetables. The leaves and probably the complete young plants must also have been eaten by domestic animals wandering freely through the settlement.

SEM	**Phytolith qual assessment**	**phytolith counts (for cereal husk & Phragmites)**	**Pollen and other microfossils**	**Helminths**	**Starch granules (Group) shape**
herbaceous stem tissue (possibly grass)	no data	no data	no data	no data	no data
likely Phragmites stem epidermis with long cells accompanied by gramineous type stomata and few papillae	no phytoliths, some minerals	no phytholits	Alnus, Artemisia, Chenopodiaceae, Filipendula, Nymphaea seed testa fragment, likely apple epidermis/ parenchyma, Foraminifera, fine wool	97 eggs/ml: 97 trematode eggs > 86 µm	(3) angular, four starch granules (12.58 µm, 18.5 µm, 17.3 µm, 14.2 µm)
silicified epidermal tissue likely of emmer chaff acompanied by numerous papillae/trichome scars; epidermal surface, likely from emmer glumes, showing numerous papillae accompanied by gramineous-type stomata; numerous fragments of herbaceous leaves/stems (includind some parenchyma)	large quantity of highly silicifed, large conjoined reeds, grasses	reed leaf/stem 116x	no pollen, only charred plant remains including cf. Cereal epidermis	no data	(1) very small starch granule (2-3µm)
silicified epidermal tissue from emmer chaff (lemma or palea); Phragmites leaf (epidermal tissue); herbaceous leaf fragments (indet.), leaf fragments of cf. Polygonum aviculare	lots of reeds etc but seem to be more fragmented. More noticeable number of shirt cells than others	Cereal husk ?Triticum 3x, Cereal husk ?Hordeum 1x, reed leaf/stem 120x	very poor in pollen, Cerealia pollen, , Chenopodiaceae, Typha angustifolia, T. dicoccum, epidermis (C)	14 eggs/ml: Capillaria sp.	no starch granules
silicified emmer husks (imprints of epidermal cells), silicified epidermal tissue-likely Phragmites stem (culm) with numerous papillae and gramineous type stomata (the same tissue as in S3-2), herbaceous leaf fragments (cf. Polygonum aviculare - the same tissue as in S3-13 and S3-18)	large quantity of highly silicifed, large conjoined reeds, grasses	Cereal husk ?Triticum 2x, Cereal husk ?Hordeum 3x, reed leaf/stem 153x	Artemisia, Humulus, likely apple epidermis/ parenchyma	no data	(2) lightly oval, two starch granules (42.41 µm and 26.48 µm)
leaf remains of Viscum album with epidermal tissue and stomata (the same tissue as in S4-4); herbaceous leaf fragments with trichomes and trichome scars (the same tissue as in S4-4)	no data	no data	no data	no data	no data

Coprolite code	Sample number	Charred particles emeded in coprolite matrices, observed during subsampling for microfossil anayses	Macroremains in residues from pollen preparations	Faecal steroids (1-assessment phase, 2-analysis phase, 3-revised)	Bone remains	micro CT-scan
S3-10	54845	few herbaceous particles	Nymphaea alba-seed testa fragments, charred herbaceous particles	1. human-2. human-3. dog/ human	pike (vertebra), cyprinid (vertebra, spine); fish indet.	distal finray, vertebras and scales, indet. Numerous water-lily seeds, one phantom of apple seed plus a few large unidentified tissues or voids.
S3-11	54827	.	Nymphaea alba-seed testa fragments	1. indicates poor preservation so unable to determine source organism-2. not confirmed as faecal	.	fish vertebras and indet. Numerous water-lily seeds.
S3-12	53842	numerous Phragmites stem fragments & small herbaceous particles	.	1. indicates poor preservation so unable to determine source organism-2. not confirmed as faecal	fish, indet.++	.
S3-13	53814	some large fragments of Phragmites stem	charred herbaceous particles	1. indicates poor preservation so unable to determine source organism-2. unknown source-3. unknown, possible carnivore	.	fish vertebras, fish jaw bone; indet. Long rolled plant tissue (leaf?).
S3-15	43716	some fragments of Phragmites stem	charred herbaceous particles	1. likely human-2. pig	pike (vertebra, spine); fish indet.	fish vertebras ,spines, scales, fin; indet. One large spherical plant phantom (?)
S3-18	54752	some fragments of Phragmites stem	few charred herbaceous particles	1. 'likely human and have good concentrations' in first round, while in second attempt 'likely pig', 2. in final results - n.d. faecal steroids not detected	pike (vertebra); fish indet.	fish vertebras, scales, pike teeth; indet. Long rolled tissues (leaf?); possibly Cereal chaff
S3-20	57443	some fragments of Phragmites stem	charred herbaceous particles	1. human-2. human	pike (vertebra, tooth, quadratum, spine); cyprinid (vertebra); fish indet.; mammal, indet.	fish vertebras, at least one cyprinid vertebra, pike teeth; indent. One water-lily phantom.
S3-26	53954	fragment of reed stem(?) embedded in the matrix	.	1. indicates poor preservation so unable to determine source organism-2. human-3. dog/ human	pike (vertebra), perch (vertebra, scale); fish indet.	fish vertebras, at least one pike vertebra, scales, fish skulls; indent. Phantoms of seeds (tri-facet seed and water-lily)
S3-28	54488	some small fragments, possibly Phragmites stem, also other herbaceous particles	charcoal particles	1. human-2. unknown (human/ruminant)	pike (vertebra), perch (scale), fish indet.	perch (scale), vertebras, fin; indet. Phantoms of apple seeds

SEM	Phytolith qual assessment	phytolith counts (for cereal husk & Phragmites)	Pollen and other microfossils	Helminths	Starch granules (Group) shape
numerous seeds of white water-lily (Nymphaea alba)	large quantity of phytoliths, fragmented and broken, brown staining	Cereal husk ?Triticum 1x, Cereal husk ?Hordeum 2x, reed leaf/stem 7x	Cerealia pollen, cereal pericarp likely Hordeum, Polygonum aviculare-type, Lathyrus-type, cf. Rubus, Filipendula cf. vulgaris, Mentha-type, Solanum dulcamara, Typha angustifolia, Chenopodiaceae, Nymphaea, likely apple epidermis/parenchyma, Nymphaea seed testa fragments ++++, feather barbule	1103 eggs/ml: Trichuris trichiuria(-suis); Diphyllobotrium; Diphyllobotriidae	(2) lightly oval, one starch granule (38.19 µm)
numerous seeds of white water-lily (Nymphaea alba)	few, digested, grasses	reed leaf/stem 11x	Lathyrus-type, Filipendula, Solanum dulcamara, Typha angustifolia, Chenopodiaceae, Althaea officinalis, Nymphaea, likely apple epidermis/parenchyma, Nymhaea seed testa frag +++, cf. cereal pericarp (c), cf. T. dicoccum epidermis chaff , hair likely red deer	1396 eggs/ml: Trichuris trichiura(-suis); Diphyllobotrium; Diphyllobotriidae; Opistorchiidae	(2) lightly oval starch granule (58.25 µm)
herbaceous stem/leaf tissue; possible parenchyma cells, indet.	no data	no data	no data	no data	no data
numerous leaf fragments of cf. Polygonum aviculare, rolled (the same tissue as in S3-5, S3-18, S3-20)	large quantity, highly silicifed,	Cereal husk ?Triticum 1x, Cereal husk ?Hordeum 1x, Reed leaf/stem 180x	hardly any pollen, Poaceae, Matricaria-type, cf. Cereal epidermis (c), likely apple epidermis/ parenchyma, fine wool	27 eggs/ml: Trichuris trichiura(-suis)	no starch granules
silicified epidermal tissue, likely of Phragmites stem (culm); indet. herbaceous leaf/stem	large quantity of highly silicifed, large conjoined reeds, grasses. Very clean sample.	Cereal husk ?Triticum 2x, Cereal husk ?Hordeum 2x, reed leaf/stem 85x	Artemisia, Typha angustifolia, Chenopodiaceae, likely apple epidermis/ parenchyma, fine wool	no data	(1) very small starch granule (9µm)
leaf fragments of cf. Polygonum aviculare (the same tissue as in S3-5, S3-13, S3-20)	large quantity of highly silicifed, large conjoined reeds, grasses, charcoal. Very clean.	Cereal husk ?Hordeum 6x, reed leaf/stem 156x	very poor in pollen, Alnus, Poacaea, epidermis T. cf. dicoccum chaff	no data	no starch granules
white water-lily (Nymphaea alba), leaf fragments of cf. Polygonum aviculare (the same tissue as in S3-5, S3-13 and S3-18); indet. herbaceous stem/ leaf tissue	large quantity of highly silicifed, large conjoined reeds, grasses, husks? Very clean.	Cereal husk ?Hordeum 2x, reed leaf/stem 99x	Filipendula cf. vulgaris, Chenopodiaceae, cereal pericarp likely T. dicoccum (c)	no data	no starch granules
herbaceous stem/leaf tissue, indet.; diatoms	no data	no data	no data	no data	no data
silicified epidermal tissue-likely emmer chaff epidermis, crab apple (Malus sylvestris) and white water-lily (Nymphaea alba) seeds; diatoms	large quantity, highly fragmented, some eroded, brown staining	reed leaf/stem 50x	Cerealia, Artemisia, Rosaceae cf. Rubus, Filipendula cf. vulgaris, Mentha-type, Solanum dulcamara, Typha latifolia, Chenopodiaceae, Althaea officinalis, Nymphaea, Nymphaea seed testa fragments +, cf. apple epidermis, T. cf. dicoccum epidermis chaff (c), cf. cereal pericarp (c)	3880 eggs/ml: Trichuris trichiura(-suis); cf. Diphyllobotrium; Opistorchiidae	no starch granules

Coprolite code	Sample number	Charred particles emeded in coprolite matrices, observed during subsampling for microfossil anayses	Macroremains in residues from pollen preparations	Faecal steroids (1-assessment phase, 2-analysis phase, 3-revised)	Bone remains	micro CT-scan
S4-1	1420	few herbaceous particles	charred herbaceous particles	1. human-2. n.d. = faecal steroids not detected	pike (vertebra); fish indet.	fish vertebras; indet.
S4-4	629	few herbaceous particles	herbaceous particles	1. likely human-2. n.d. = faecal steroids not detected	.	spongious fish bones?

13.6 Answering the research questions

For this project, our focus was mainly concerned with the dietary diversity and preparation of food in the Swifterbant tradition, with attention to both plant and animal components. The evidence for the consumption of plant foods in general, and cereals in particular, was of great interest. Also, the health conditions of the Swifterbant people were studied in terms of the presence of intestinal parasites. During our research, we encountered a large amount of plant and animal remains. The observed taxa of the Swifterbant coprolites are summerised in Appendix XIII. In the following sections the research questions which were formulated at the start of the project are answered in a summarizing way:

1. Who or what was the producer of the coprolites? See Section 13.7;
2. What were the Swifterbant peoples' typical meals? See Sections 13.8 and 13.9;
3. How much cereal did they eat? See Section 13.8;
4. Can the crucial dietary shift, the introduction of cereals to the Swifterbant diet, be identified and evaluated more accurately? See Sections 13.8 and 13.14;
5. What natural environment did the Swifterbant people live in? See Sections 13.10 and 13.11;
6. What can be said about seasonality? See Section 13.12;
7. What were the health conditions of the Swifterbant populations? See Section 13.13;
8. NOaA 2.0 question 7: How did the way of life change during the Late Mesolithic until the Late Neolithic? See Section 13.14;
9. NOaA 2.0 question 8: Which landscape zones were used in the Late Mesolithic and Early Neolithic for habitation, hunting, arable farming and livestock? See Section 13.15;
10. NOaA 2.0 question 22: What role did the exploitation of natural food resources play after the introduction of agriculture? See Section 13.16.

13.7 Faecal biomarker results and coprolite origins

In archaeological studies, the coprolites of human origin and the domesticated animals associated with them are usually of great interest. It was not different in this project, except that with this project the primary focus was to be on human coprolites. Human faecal remains are often difficult to identify with certainty. In particular, distinguishing human from dog coprolites can be challenging because they are often similar in size and shape, and they tend to occur together at archaeological sites.

There are several methods available to and applied in coprolite analysis that help to define their faecal origin, each with its advantages and limitations. aDNA and GC-MS are the most commonly used. The method used in this project

SEM	Phytolith qual assessment	phytolith counts (for cereal husk & Phragmites)	Pollen and other microfossils	Helminths	Starch granules (Group) shape
silicified epidermal tissue from emmer chaff (lemma or palea); Phragmites leaf (epidermal tissue with gramineous type stomata)	lots of melted silica, large quantity silicifed phytoliths, some appear eroded, staining	reed leaf/stem 87x	Cerealia pollen, Artemisia, Filipendula cf. vulgaris, Solanum dulcamara, Typha angustifolia, Chenopodiaceae, Althaea officinalis, Nymphaea seed testa (v), likely apple epidermis/parenchyma, epidermis cf. Triticum cf. dicoccum (c)	54 eggs/ml Dioctophyma sp; Trichuris trichiura(-suis); Opistorchiidae	(2) lightly oval starch granule (21.25 µm)
leaf remains of Viscum album with epidermal cells and multiple stomata (the same tissue as in S3-8); indet. herbaceous leaf fragments with trichomes and trichome scars	very few, digested, grasses	no cereals, no Phragmites	very poor in pollen, Poacaea, Lemnaceae, Armeria/Limonium, Nymphaea, cf. cereal epidermis	282 eggs/ml: Dioctophyma sp.; Trichuris trichiura(-suis); Opistorchiidae	no starch granules

to help to identify the producer organism for 25 of the selected coprolites was GC-MS (gas chromatography mass spectrometry). With this method, the sterol and bile acid fractions in the coprolites were analysed.

Faecal lipid biomarkers (steroid compounds) have been used as diagnostic tools to identify the producer organisms of coprolitic deposits across a range of environmental and temporal settings, successfully discriminating between herbivore, carnivore, porcine, and human sources.[315] Species-specific coprolitic identification requires a combination of the analysis of sterol compounds, the characterising of major dietary profiles, and the identification of bile acids to facilitate inter-species discrimination.

The identification of the coprolitic source organisms in this study has, however, been limited by low concentrations of both sterols and bile acids in the majority of the samples, which either precluded source identification or presented multiple possible source organisms. In some coprolites, the low steroid concentration could not even confirm that the samples were of faecal origin. No steroids detected does not necessarily mean 'not of faecal origin' - but it could not be proved using the lipids. This technique will likely have different outcomes when used to distinguish human from non-human coprolites in drier environments since sterols and bile acids contain a region that is water soluble.

According to the GC-MS assessment of the initial lipid extractions, there were some traces of possible bile acid compounds in several of the samples, suggesting a human or likely-human origin for eight coprolites and an animal origin for three (including two pigs and one ruminant). The concentrations of lipids in 14 coprolites were too low to enable the determination of the source organisms. Due to time constraints, we had to use the tentative source identifications that were available to allow other multi-proxy analyses to be completed as part of this project, while we continued to extract and analyse more lipids from additional sample material. Unfortunately, even with this additional material, the concentrations from the combined extracts were too low to detect sufficient bile acid compound concentrations in many of the samples by GC-MS analysis, thus explaining the number of coprolites that were finally attributed to an unconfirmed source. Even though the samples were run twice, and while some were initially classified as a 'best fit' for human origin on the assessment run, the sterol and bile acid concentrations were too low to give a firm species identification in the analysis phase. Therefore, the lipid data/ratio calculations should be treated with caution. However, given the results from the multi-proxy analyses, the combination of data strongly suggests a human origin for many of the studied coprolites.

What was clear from the biomolecular analysis was that animal coprolites were present in the Hardinxveld-Giessendam De Bruin assemblage, and that both human and animal coprolites were represented in the assemblages from both of the S3 and S4 sites. The faecal

315 Bull *et al.* 2002.

origin of the Emmeloord-J78-91 coprolites could not be specified. The summary of coprolite likely-producer-organisms based on faecal steroid analyses suggests that pigs, humans, and carnivores (likely dogs) were the dominant producer organisms of the confirmed coprolites, accounting for ten of the 25 analysed coprolite samples. Unfortunately, many of the coprolites presented multiple possible source organisms.

The first set of results, referred to as initial runs, was often confirmed in the final analyses, but some differed, and for these identifications, some explanations are proposed. For example, S3-2 was initially identified as a human coprolite, but in the final analysis as a pig. A possible explanation can be that Ratio 3 is 0.4, which is on the borderline for pigs (since ratios <0.4 signify pigs). Human ratios are usually 0.6+ and that is why this coprolite was attributed to a pig in the final analysis, but it is at the upper limit of the identification. The S3-15 coprolite was initially assessed as 'likely human,' but in the final analysis as a pig coprolite. Two other coprolites, S4-1 and S4-4, were assessed in the initial run as likely human; however, in the final analysis faecal steroids were not detected in those coprolites. The same occurred with S3-18, which in the initial run was defined as a likely pig coprolite, but did not yield any faecal steroid signature in the final analysis. The explanation, perhaps, of the discrepancy between the assessment runs and the analysis phase, lies in the possibility that different portions of coprolites were provided for each phase. Given the problems with low concentrations of faecal sterols, it might be more appropriate to assess this qualitatively using combined data.

Other studies have also reported examples of coprolitic samples that yielded inconclusive results, attributed to low faecal lipid preservation and the presence of multiple source organisms. The distribution of faecal biomarkers indicative of a mixed human/carnivore origin, for example, is explained by the coprophagy of human faeces by carnivores.[316] Coprophagy in canids (particularly in dogs) is a well-recognised phenomenon and could explain the presence of both carnivore-derived lipids and human biomarkers in some coprolites. The presence of coprolites with a dog/human faecal signature (possibly dog coprolites with a human element) in the coprolite assemblage studied in this project may possibly be explained by dogs eating human faecal remains. Future lipid work should adapt the methods to account for low concentrations and the fact that these are discrete coprolites rather than dispersed sediment samples.[317]

Before subsampling the coprolites for SEM and various microfossil analyses, the morphology of 16 coprolites was digitally documented. Their internal content was also documented in the form of micro-CT scans. We concluded that even though we could agree on the composition of the food remains within individual coprolites (plant versus animal food), we could not absolutely determine, based on the micro-CT scans, whether the producers of the studied coprolites were humans, dogs or pigs.

13.8 The plant component in the diet of the Swifterbant Culture

13.8.1 Cereals

Some of the research questions of the project were related to the consumption of cereals, as we wanted to know how much cereal the Swifterbant people ate and whether or not we could more accurately identify and evaluate the crucial dietary shift: the introduction of cereals into the Swifterbant diet. We definitely can present multiple lines of evidence for the consumption of the cereals at the Swifterbant sites in Flevoland (see Table 13.2). However, no evidence for cereal consumption was found in the coprolites from Hardinxveld-Giessendam De Bruin (Late Mesolithic-Early Neolithic).

The evidence for the presence of cereals is found in phytolith remains. The phytoliths of *Hordeum* (barley) husk were indicated in coprolites S3-18 and S3-20, and both *Hordeum* and *Triticum* (likely emmer) husks were represented in the phytolith assemblages from S4-4, S3-5, S3-10, S3-13 and S3-15. While these were only present in small numbers, this would be expected if cereals were de-husked as part of the preparation process (in the case of emmer) or entered the cooking pots as clean grain (in the case of naked barley). The few emmer and barley husks that were present were very well silicified, indicating that they were formed under conditions of high water availability and silica-

316 e.g. Shillito *et al.* 2020b.
317 e.g. as in Shillito *et al.* 2020a.

Table 13.2 Overview of cereal remains and other monocotyledons found in the Swifterbant coprolites.

Sample		Hardinxveld 19952	S3-2	S3-4	S3-5	S3-10	S3-11	S3-13	S3-15	S3-18	S3-20	S3-28	S4-1	S4-4
GC-MS (producer)		pig	pig	dog/human	?ruminant	dog/human	n.d.	?dog	pig	n.d.	human	human/ ruminant	n.d.	n.d.
Cereals:														
Cerealia husk (likely emmer)	phytoliths	.	.	3	2	1	.	1	2	.	.	.	.	.
Cerealia husk (likely barley)	phytoliths	.	.	1	3	2	.	1	2	6	2	.	.	.
Triticum dicoccon (emmer), chaff (lemma, palea, and/or glumes)	SEM	.	+	+	+	.	.	.	.	.	.	+	+	.
Cerealia-type, pollen	pollen & intestinal parasite slides	.	.	1	.	4	.	.	.	.	.	9	2	.
Cerealia-type?	pollen & intestinal parasite slides	.	.	.	.	.	.	.	.	.	.	5	.	.
Charred epidermis cf. Cerealia	pollen & intestinal parasite slides	.	+	.	.	.	.	+	.	.	.	.	.	.
Triticum cf. dicoccum, charred epidermis	pollen & intestinal parasite slides	.	.	+	.	.	+	.	.	+	.	+	+	.
Cerealia, pericarp (likely emmer)	pollen & intestinal parasite slides	.	.	.	.	.	.	.	.	.	+	.	.	.
Cerealia, pericarp (likely barley)	pollen & intestinal parasite slides	.	.	.	.	+	.	.	.	.	.	.	.	.
Monocots:														
Phragmites leaf/stem	phytoliths	.	116	120	153	70	11	180	85	156	99	50	87	.
Phragmites stem epidermis	SEM	+	.	.	+	.	.	.	.	.	.	.	.	.
Phragmites leaf epidermis	SEM	.	.	+	.	.	.	.	.	.	.	.	+	.
Monocot leaf/stem	phytoliths	.	100	70	23	110	5	42	56	125	103	46	86	2
Monocot husk	phytoliths	.	2	4	1	.	.	2	.	10	5	1	4	.
Charred epidermis Poaceae/Cyperaceae	pollen & intestinal parasite slides	+	+++	+	+	+++	++	++	+++	++	++	+	+	+
Charred epidermis Poaceae/Cyperaceae with stomata	pollen & intestinal parasite slides	+	++	+	.	.	++	+	+++	+++	++	+	+	+
Charred epidermis, Cyperaceae	pollen & intestinal parasite slides	.	++	+	.	.	.	+	++	+	+	.	.	+
Charred epidermis cf. Phragmites	pollen & intestinal parasite slides	.	.	.	+	.	+	+	+	.	.	.	+	+

rich substrate. These conditions likely favoured the preservation of phytoliths in general. The phytoliths embedded in coprolite matrices were exceptionally well preserved and were present in large quantities, which is not often the case in coprolites. The SEM images also demonstrated cereal components in five coprolites (S3-2, S3-4, S3-5, S3-28 and S4-1). The cereal tissue embedded in the matrices of these coprolites was assigned to the epidermal tissue of emmer light chaff (husks), which would have survived the de-husking process and, possibly still attached to the grain, entered the cooking pots. The waste from threshing cereals, if scattered through the Swifterbant settlement, could also have been eaten by animals (dogs and pigs in particular) scavenging around the food preparation areas or it was deliberately fed to the animals. The evidence for the consumption of cereals was also detected on pollen and intestinal parasite slides. Interestingly, on some of the microscopic slides from S3-10 and S3-20, fragments of cereal pericarp (also referred to as bran) from resp. *Hordeum* (barley) and *Triticum* (likely emmer) grain were found. The grain pericarp tissues embedded in coprolite matrices offer the best possible evidence for the consumption of cereals.

The evidence for the consumption of cereals is omnipresent. It comes from different proxies, including SEM, phytoliths, pollen and intestinal parasite samples. Cereals - emmer and barley - were likely used as an addition to other foods and were eaten together with other foods. From studies on food crusts preserved on pottery from Swifterbant -S3 and -S4 sites, we know that both emmer and barley were cooked as a porridge-like food, sometimes with the addition of fish or green vegetables.[318] This composition of ingredients is now mirrored in the coprolites.

13.8.2 Green vegetables

Also exceptional were the large quantities of reed (*Phragmites*) phytoliths, representing both leaves and stems of this marsh plant. The silicified epidermal remains of reed were also indicated in the SEM analysis. Both reed phytoliths and their presence in the SEM images are good direct indicators that reed (probably young reed shoots) were eaten. Usually, it is difficult to distinguish whether these had been consumed, or if they derived from fuel or craft activity, but their presence in coprolites is a clear indicator of consumption, likely by both humans and animals.

Even though leaf or stem tissues of herbaceous plants are occasionally found in charred food crusts on ceramics and, as such, they indicate that green vegetables were cooked, a much larger variety of plants and their green parts would have been eaten raw. In five of the studied coprolites, leaf remains of likely knotgrass (*Polygonum aviculare*) were preserved as rolled or scroll-like fragments embedded in coprolite matrices (well observed in SEM images and micro-CT scans). The knotgrass leaves would have likely been used by people as leaf vegetables. The leaves, and perhaps the complete young plants, must also have been eaten by domestic animals. Knotgrass also has medical properties. It can be used for the treatment of parasitic diseases because of its laxative effect.[319]

Interestingly, two coprolites, S3-8 (pig) and S4-4 (likely human/no definitive origin of faecal steroids) revealed the presence of mistletoe (*Viscum album*) leaves embedded in their matrices. The leaves of mistletoe were also found earlier in animal dung at Neolithic wetland settlements in Germany (Alleshausen) and Switzerland (Arbon Bleiche 3) where it has been suggested that animals (cattle) were fed the evergreen leaves and stems of mistletoe. Obviously, in the Swifterbant tradition, the pigs were also fed mistletoe greens. If the animal dung from the S3 and S4 sites (which is now stored in the archaeological depot in Lelystad) were at some later point analysed, the issue of animal fodder and animal husbandry, in general, could be presented in a much broader sense. The possibility that mistletoe was used as a medicinal plant during the Swifterbant period cannot be completely excluded. At the same site of Arbon Bleiche 3, ivy (*Hedera helix*) leaves were also suggested as having been used as animal fodder. In the natural deposits from Hardinxveld-Giessendam De Bruin, *Hedera* pollen was present in high quantities. In one of the coprolites of Hardinxveld Giessendam De Bruin, the ivy pollen was also found. At Swifterbant, a pollen grain of *Hedera helix* is present (S3-15), but no leaf tissue could be identified.

13.8.3 Wild seeds, fruits and berries

It seems that seeds of water-lily were appropriated in Swifterbant tradition as the source of food. Two of the studied coprolites, S-10 and S11 revealed large amount of white water-lily seeds embedded in their matrices. One of the micro-CT scans provides the best picture for how densely coprolite S3-10 is packed with the remains of white water-lily seeds

[318] Raemaekers, Kubiak-Martens & Oudemans 2013.
[319] Chiej 1984; 242.

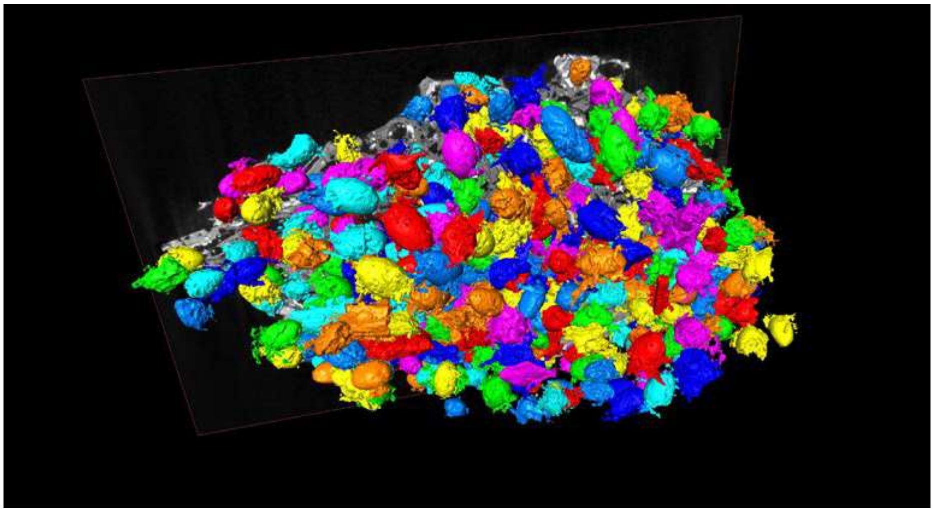

Figure 13. 1 Micro-CT scan showing white water-lily seeds embedded in the matrix of the S3-10 coprolite. The botanical identification of the species was based on the stereomicroscope (source: D. Ngan-Tillard).

Figure 13.2 Small portion of white water-lily seeds (c. 2.2 x 1.5 mm in size), representing a handful of seeds usually obtain from one seed capsule (source: BIAX).

(see≈Fig. 13.1). In both coprolites, S3-10 and S3-11, an unusually large amount of *Nymphaea* pollen and fragments of *Nymphaea* alba seed testa are present as well. Also, the starch granules preserved in both coprolites, S3-10 and S3-11, are most likely from *Nymphaea* sp. seeds. The remains of water-lily seeds are also embedded in yet another (likely human) coprolite, S3-28, where they were accompanied by fish bones, apple seeds, and emmer chaff remains, all indicating the complexity of the Swifterbant diet. Rich in oil, starch and protein white water-lily seeds were likely used as food. Many small seeds would have been obtained just from one seed capsule (see Fig. 13.2). Whether however they were processed/cooked or what kind of food was produced from them cannot be concluded from the remains preserved.

Van Zeist and Palfenier-Vegter noticed that white water-lily (*Nymphaea alba*) seeds were remarkably well represented in macroremains assemblages from S3 and that most of the seeds were seriously damaged.[320] The *Nymphaea alba*

320 Van Zeist & Palfenier-Vegter 1981.

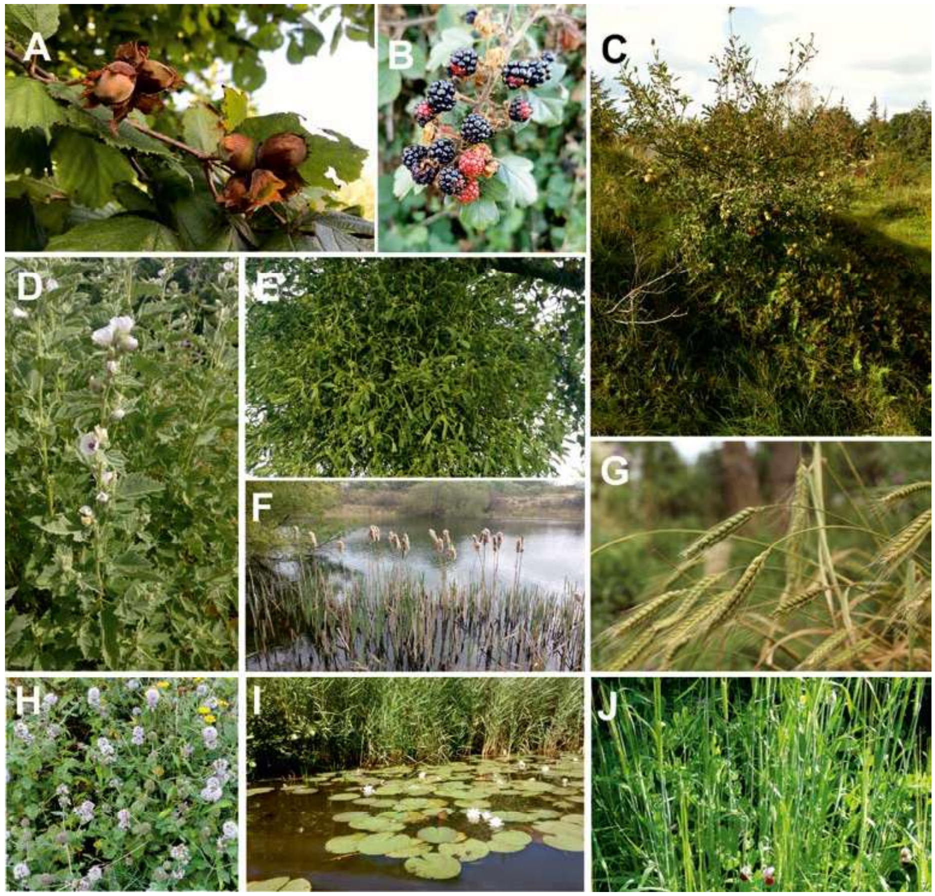

Figure 13.3 Examples of food plants of which remains were present in the Swifterbant coprolites. a: hazel, b: bramble, c: apple tree and polypody ferns in the undergrowth, d: marsh mallow, e: mistletoe, f: bulrush, g: emmer wheat, h: water mint, i: white water-lily with reed vegetation in the background, j: naked barley field (source: BIAX).

seeds were not present in or near (domestic) activity areas but were only found outside these areas. This might suggest some method of processing water-lily seed capsules in the area or areas dedicated to this work.

Palynological analysis showed that the pollen of food plants that would have been gathered was present in the coprolites. In addition to pollen, many microscopic fragments of (charred) epidermal tissue of leaves and, possibly, fruits were present. The presence of *Sorbus*-type pollen (including apple (*Malus*), hawthorn (*Crataegus*), and mountain-ash (*Sorbus aucuparia*)) and bramble (cf. *Rubus*) shows that trees and shrubs with edible fruits and berries were most likely eaten since pollen also sticks to the berries and fruits.[321] Probably the food plants were growing near the site. Some of the epidermal tissue found resembles that of apple (*Malus*) and bramble (*Rubus*). In the micro-CT scan of coprolite S3-10, an impression of an entire seed is visible and in the micro-CT scan and SEM image of coprolite S3-28, fragments of seeds of *Malus* were discovered, which confirms the consumption of crab apple. Both species are well known plant foods gathered in the Mesolithic and Neolithic.

In almost all of the coprolites, pollen of the food plant hazel (*Corylus*) is present. There shouldn't be any doubts that hazelnuts were gathered for food. At both the S3 and S4 sites, numerous finds of charred hazelnut shells were reported, which indicates that the nuts were processed.[322]

In the coprolites, pollen is also present of species of which no seeds were found during the earlier excavations. Of course, this may mean that these species were just not present in the

321 Personal communication Linda Scott Cummings (1-10-2021) paper in prep. The author also observed strawberry pollen on fruit epidermis tissue when preparing collection material.

322 Van Zeist & Palfenier-Vegter 1981; Schepers & Bottema-Mac Gillavry 2020; Schepers 2014.

archaeological samples - but were present in the local natural environment. For example, vetchling (*Lathyrus*) may have grown nearby the site or in the backswamps. But, for some taxa, the natural habitat differs from the reconstructed freshwater environment of the Swifterbant settlement. Two taxa marsh mallow (*Althaea officinalis*) and thrift/ sea lavender (*Armeria/Limonium*) for which pollen is present grow in a brackish to the marine environment. This may imply that the creeks near the settlement were, occasionally, slightly brackish. These conditions may have occurred - temporarily - after a marine flood. Or, this may imply that parts of these plants were - incidentally - gathered for consumption or consumed at other locations than the settlement site, in this case in a coastal environment. While people were traveling or collecting food, pollen of another vegetation type than at the settlement may have been inhaled. This may apply to marsh mallow and thrift/sea lavender which both have edible plant parts. The leaves, seeds, and tubers of marsh mallow are edible. An infusion of the flowers may be drunk as herbal tea. The leaves of *sea lavender* are also edible.

Honeysuckle (*Lonicera periclymenum*) pollen may point to the practice of sucking nectar from the tubular flowers. Perhaps, the presence of some pollen types e.g. heather (*Calluna vulgaris*) may point to the use of honey. Possibly, also the fruits of Ericaceae (e.g. blueberry) were gathered for food.

13.8.4 Roots and tubers

In many coprolites, vascular tissue (often charred), sponge parenchyma (probably of a leaf or stem tissues), and periderm (probably of roots and tubers) were found. These remains were difficult to assign to a single taxon. The presence of pollen of bulrush (*Typha latifolia*), water-lily (*Nymphaea*), and polypody (*Polypodium*) shows that plants with edible roots and tubers were growing in the nearby surroundings. The young leaves and the tubers of dropwort (*Filipendula* cf. *vulgaris*) may also have been collected. The tubers were likely consumed. Furthermore, many of these plants are used in herbal medicine. This will be discussed further in the health section below. The charred epidermal tissue of likely leek, onion or garlic (*Allium*) bulb found in one of the coprolites suggests that some species of wild onion or garlic would have been gathered for its bulbs and perhaps for its greens.

13.9 The animal component of the Early Swifterbant Culture diet

What we have learned from the micro-CT scans is that all 16 coprolites contained fish remains (Table 13.3). In only two cases were the fish bones accompanied by mammal bones and, in one case, duck bones. Interestingly, fish bone remains included vertebrae, fish scales, and head bones (including teeth). In all cases, the remains came from very small individuals (mainly pike but also cyprinid fish) of no more than 10 cm long. This, taken all together, would suggest that the whole fish was eaten. It was probably cooked in the vessels, which would have softened the bones. We have good evidence for this method of cooking fish from charred food residues, often filled with fish scales, encrusted on Swifterbant pottery.[323]

The bone analysis and CT-scans of the Hardinxveld coprolites (19520 and 19952) showed fish remains of mainly perch and of mammals. Duck bones could also be identified in Hardinxveld (19952). This indicates that perch and other fish, as well as ducks and mammals, were part of the diet at the Late Mesolithic-Early Neolithic Hardinxveld-Giessendam De Bruin. Hairs (fine wool) may point to the processing/ consumption of sheep meat or the use of sheep wool clothing or fabric. In addition to the bone data, the presence of helminths eggs of (possible) Fasciolidae family (in Hardinxveld 19952) points to the consumption of the meat of a herbivorous mammal (or possibly of the herbage). The lipid analysis showed that the coprolite itself was produced by a pig.

Also at Swifterbant, the main components of all of the studied coprolites were fish bones. This would suggest that fish was frequently eaten, perhaps on daily basis. Pike (*Esox lucius*), perch (*Perca fluviatilis*), and cyprinids (sometimes combined) were part of the diet. In coprolite S3-20, mammal bones were also found. The finds of hairs of sheep (fine wool in S3-13 and S3-15) and likely red deer (S3-11) may point to the processing/consumption of the meat of these animals or the processing of wool or fur. In

[323] Raemaekers, Kubiak-Martens & Oudemans 2013.

coprolite S3-10, a small fragment of a feather (barbule) from either a perching bird or a wader shows that these birds also formed a part of the diet or that feathers were used for other purposes like bedding or ornamentation. In addition to the bone data, the presence of parasite eggs of Diphyllobotriidae (fish tapeworms), Opisthorchiidae (liver flukes), *Dioctophyma* (kidney worm), and, possibly, also of *Capillaria* (hairworm) point to the consumption of freshwater fish and frogs. The consumption of entire small fish may have promoted infections with fish tapeworms. The diversity of animals processed either for their meat, fur, or wool is well-documented for the Swifterbant settlement. At both the S3 and S4 sites, bones from the domestic pig (and/or wild boar), cattle, sheep and/or goat, aurochs, beaver, otter, red deer, and other wild animals were documented.[324] The presence of dogs is also confirmed by their bone remains in archaeozoological assemblages from both the S3 and S4 sites.

In all the coprolites from S3 and S4 that were studied for intestinal parasites (S3-10, S3-11, S3-13, S3-28, S4-1, S4-4; except S3-4), *Trichuris trichiura/suis* eggs were present, implying human (or pig) component in all of these coprolites. *Trichuris* is a good indicator for faeces in the soil.[325] It is associated with the consumption of cultivated plants and with animal husbandry.[326] As for the Swifterbant Culture, the frequent presence of *Trichuris* may be seen as an indication for long-termpresence of animals and humans at one location. The composition of the intestinal parasites found in the Hardinxveld coprolite (19952) differed from the Swifterbant coprolites. At Hardinxveld, only large trematode eggs were present.

13.10 Drinking Water

In all of the coprolites, freshwater microfossils (green algae and diatoms) and marine microfossils (foraminifera and diatoms) are found. This may suggest that the drinking water was slightly brackish or that microfossils that

[324] Zeiler 1997; Kranenburg & Prummel 2020.
[325] Le Bailly & Bouchet 2005.
[326] Ledger *et al.* 2019; Reinhard *et al.* 2013.

Table 13.3 Overview of animal remains found in the Swifterbant coprolites.

Site	Find	Labcode	CT-scan	Bones	Pollen/IP	Helminths
Hardinx.	19520	.	fish	fish, perch; mammal	n.d.	n.d.
Hardinx.	19952	BX9300	fish	fish, perch; duck; mammal	sheep	herbivorous mammal (or herbage)
S3-2	54516	BX9099	fish, mammals	fish, pike, cyprinid	.	n.d.
S3-4	54655	BX9295	fish	.	.	possibly freshwater fish (or meat)
S3-5	51179	BX9296	fish	fish, pike	.	n.d.
S3-8		.	fish, perch	fish, perch	n.d.	n.d.
S3-10	54845	BX9100	fish	fish, cyprinid	perching birds/ waders	freshwater fish
S3-11	54827	BX9101	fish	n.d	likely red deer	freshwater fish
S3-13	53814	BX9297	fish	n.d	sheep	.
S3-15	43716	BX9102	fish	fish, pike	sheep	n.d.
S3-18	54752	BX9103	fish, perch	fish, perch	.	n.d.
S3-20	57443	BX9104	fish, pike, cyprinid, mammals	fish, pike, cyprinid; mammals	.	n.d.
S3-26	?	.	fish, pike, perch	fish, perch	n.d.	n.d.
S3-28	54488	BX9298	fish, pike, perch	fish, pike	.	freshwater fish
S4-1	1420	BX9299	fish	fish, pike	.	freshwater fish, frogs
S4-4	629	BX9105	fish	.	.	freshwater fish, frogs

emerged from the reworked marine clay bedding of the creek were present in the drinking water. During the S4 excavation, the diatoms were studied, showing that marine species are broken and those from the fresh-water environment are not. This implies that the marine diatoms probably represent reworked microfossils. This would also apply to some of the pollen types present in the coprolites. Presumably, these would mostly represent aquatic plants and shore vegetation. Pollen of pine (*Pinus*) and alder (*Alnus*) and spores of buckler/male fern (*Dryopteris*) and peat moss (*Sphagnum*) are also easily transported by water. These pollen types may represent local vegetation or were present in reworked peat deposits or sediments.

13.11 Natural environment

The pollen and microfossil composition of both the Hardinxveld-Giessendam De Bruin and Swifterbant coprolites confirms that the Swifterbant people lived in a freshwater environment that was under marine influence. Near the settlements, open spaces were present in the wetlands and forests. Although a large part of the pollen present in the coprolites may be derived from food plants and does not reflect the actual vegetation, the pollen composition provides information about the surrounding vegetation in a general way (see section 10.4.3).

13.12 Seasonality

Based on the pollen composition of the coprolites no seasonality, the presence of pollen produced in a certain season could be demonstrated. On the contrary, pollen of species that bloom in different seasons was found in the same coprolite. This can be explained by the presence of pollen on various substrates and objects in a living area. When pollen is around it can be breathed in. Fruits may well have a bit of pollen on their parts which is consumed in another season than when the plant was flowering. Also if food plants were stored and consumed later, pollen of different seasons may end up in one coprolite. Leaves of knotgrass but also other green vegetables, for example, leaves of wild onion/garlic were likely gathered and consumed in spring through early summer. The best time of the year to collect seed capsules of the white water-lily would have been in late summer. Late summer would also be the right time of the year to collect crab apples, which would be followed by hazelnuts in early autumn.

The presence of bones of entire, small-sized fish (mostly pike and cyprinids) may be an indication of the season(s) the fish were caught. For example, the spawning season of pike is from February to May. Pike eggs hatch after 10-15 days. The young fish can already grow up to 10-30 cm in their first season. Cyprinids' spawning seasons are in spring and summer. These all would mean that the small-sized fish would have been available (in large numbers) from early spring through summer. Probably the small fish were consumed in their entirety in a soup or stew. Perhaps, the small fish were preserved in some way (dried or smoked?) for later use, but no indications were present to support this hypothesis.

13.13 Health and hygiene

The presence of eggs of different flatworm taxa at both Hardinxveld-Giessendam De Bruin and Swifterbant implies that raw or undercooked food of animal or plant origin was consumed. This led to worm infections of liver flukes at Hardinxveld-Giessendam De Bruin and flatworm and roundworm infections of fish tapeworms, liver flukes, hairworms, and kidney worms at Swifterbant. At Swifterbant, the presence of geohelminth whipworm (*Trichuris*) indicates that faecal matter was present in the soil. Overall, the hygienic conditions were poor at the Swifterbant settlement. Without treatment, these multiple parasitic worm infections probably led to serious health issues. Symptoms would have included abdominal pain, diarrhoea, obstruction of the intestines, liver and kidney damage. In the most severe cases, for example, infections of kidney worms could have led, ultimately, to death. In the coprolites, pollen and spores of several plants that can be used as herbal medicine to treat these symptoms were found. For example, infusions of the roots from buckler/male fern (*Dryopteris*), polypody (*Polypodium*), or dropwort

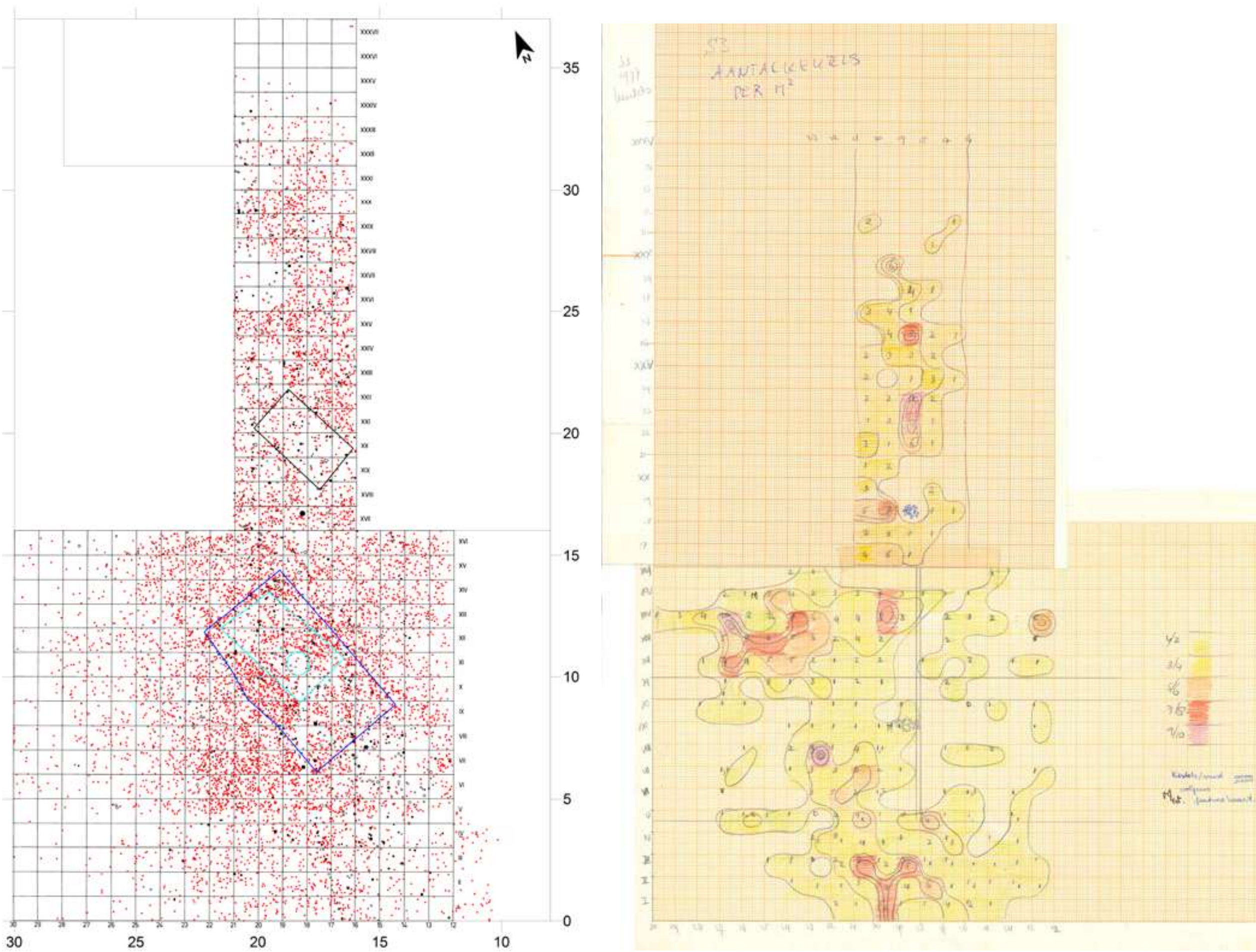

Figure 13.4 Swifterbant-S3 site, showing a. the outline of the houseplan postulated in the center of the site (c. 8 x 4.5-meter rectangular structure), and a possible small house in the north (after Devriendt 2014), and b. spatial distribution of coprolite clusters (as documented in the field, source: archaeological depot Province of Flevoland, Lelystad).

(*Filipendula vulgaris*) have anthelminthic properties (antiparasitic). Leaves from knotgrass (*Polygonum aviculare*), ivy (*Hedera helix*), and meadowsweet (*Filipendula ulmaria*) have medical properties that help against diarrhoea, mistletoe (*Viscum album*) leaves have diuretic properties (causing the increased passage of urine), and treatments with plant parts of marsh mallow (*Althaea officinalis*) help against abdominal pain (or dysentery).[327] It is unknown whether the Swifterbant people were aware of these remedies. Perhaps self-medication was practised. Self-medication is the consumption of plants not for their nutritional value but for their medicinal properties. The issue of self-medication has been studied in higher primates, revealing extensive evidence demonstrating the complex use of medicinal plants.[328] Some primates roll balls of leaves of specific plants and swallow these balls whole. Therefore, the faeces of primates sometimes contain unchewed leaves which points to the possibility that these leaves were not eaten for nutrition. Parasitic worms were found together with the leaves in the stool.[329] One may wonder if the preservation of knotgrass leaves as rolled or scroll-like fragments embedded in coprolite matrices in some of the studied coprolites indicates food or medicine. The consumption of plants without nutritional value is also witnessed in other animals. Common plant secondary compounds such as terpenes and anthraquinones may have a medicinal effect (diuretic and purgative, respectively) on animals and humans.[330] The study of the mummy of the iceman Ötzi, found in the Alps, suggested that 5300 years ago this

[327] Launert 1984; Chiej, 1984; Van Os 1974; Starý & Jirasék 1990; Moerman 2009; Prendergast *et al.* 1998.
[328] Cousins & Huffman 2002; Huffman 1997; Hardy *et al.* 2012.
[329] Fowler, Koutsioni & Sommer 2007.
[330] Huffman & Vitazkova 2011.

man was aware of the intestinal parasites (*Trichuris trichiura*) in his body and that he treated himself with measured doses of toxic resins of a bracket fungus.[331]

Although the ability to self-medicate among the Swifterbant populations must, of course, remain open to speculation, it is unimaginable to think that these groups did not have any knowledge of the medicinal plants within their environments. Ethnobotany studies have shown that indigenous peoples from the Americas use many herbal treatments.[332] Also, nowadays, in many traditional human societies around the world, people are still very much dependent on plants for both food and medicine. At Swifterbant, the presence of most of the plant taxa can also be explained as part of the regular diet. More research is needed on this subject to reach more clear conclusions.

One of the questions related to the hygienic conditions on the Swifterbant sites is where the acts of defecation have taken place? If we look at the map of the spatial distribution of coprolites as they were plotted during excavation at the Swifterbant-S3 site, several small clusters can be observed. These were formed by the frequency of coprolite occurrences per one square meter (see Fig. 13.14 b).[333] If we compare the distribution of these coprolite clusters with the location of the houseplan in the center of the site postulated for the S3 site[334], it appears that they do not overlap with the outline of the house (see Fig. 13.14 a). This would further suggest that the acts of defecation would have taken place outside the house, and more specifically, south and northwest of the house. If yet another small house should be located more to the north (Fig. 13.14 a), also there (Fig. 13.14 b), the clusters of coprolites are found outside the outline of the house.

13.14 NOaA 2.0 question 7: How did the way of life change from the Late Mesolithic until the Neolithic?

From the mid-fifth millennium cal BC onwards, various aspects of a Neolithic lifestyle become apparent in the archaeological record, including a more settled way of life, animal husbandry, the consumption of cereals, and the cultivation of cereals on a structural, but small-scale basis.[335] During the Late Mesolithic and Early Neolithic people settled down and kept domesticated animals on the sites. Flesh, wool, and other animal products could be used. The consumption of animal meat resulted in zoonoses (infections caused by the spread of parasites from animals to humans). People were infected with intestinal parasites caused by the ingestion of undercooked meat. Faeces built up in the soil nearby the houses would have caused the whipworm infections. Cereals became part of the diet during the Early Neolithic Swifterbant Culture. Cereals such as barley and emmer wheat were an addition to gathered plant foods. Due to the finds of tilled fields at S4, it seems likely that the cereals were grown on the river banks near the settlement. Even though the micromorphological evidence attests to local cultivation, the introduction of cereals to the Swifterbant sites probably happened through contact with other farming groups. Van Zeist and Palfenier-Vegter have made a comparison between the cereal assemblage from the Swifterbant-S3 site and those from the Rössen culture in the German Rhineland area, highlighting similarities that would imply contact.[336] Archaeobotanical finds from the recently excavated Swifterbant settlement in Tiel Medel-De Roeskamp, suggest contacts with either the Bischheim groups in the Rhineland or with the early Michelsberg farmers.[337] The contacts between the Neolithic groups, however, concerned not only the cereals but also the trading of goods, also well-documented for Tiel Medel-De Roeskamp, and suggests contacts with the Rössen (or Epi-Rössen) and/or the Bischheim groups in the Rhineland area.[338] One of the most evident methods of transportation during the Neolithic, particularly through the wetland territories, would have been by canoe. Perhaps the people of the Swifterbant area were in contact via trading of goods with people living upstream of the Vecht River system in the Münsterland area. In this way, they could also have been in contact with other Neolithic groups from the Bischheim and/or early Michelsberg cultures living in the German Rhineland.[339]

A bead made of a single carbonised stone of sloe (*Prunus spinosa*) found at the Swifterbant-S4 site, may also suggest contact with other Neolithic groups.[340] Interestingly, sloe was not known from the Swifterbant archaeobotanical

331 Capasso 1998.
332 Moerman 2009.
333 As the spatial coordinates of the coprolite finds are not available, we use the field drawing for the purpose of this study. The darker colour the more coprolites were found within 1m².
334 Roever 2004, Devriendt 2014.
335 Raemaekers *et al*. 2021.
336 Van Zeist & Palfenier-Vegter 1981.
337 Kubiak-Martens (in prep.).
338 Ten Anscher & Knippenberg 2022.
339 Kreuz *et al*. 2014, Ten Anscher & Knippenberg 2022.
340 Schepers & Bottema-Mac Gillavry 2020.

record. Furthermore, it represented a tradition of bead making that was unknown in the Netherlands. However, it seems to be a phenomenon in the Neolithic period of middle and eastern Europe.[341] One of the best analogies for the Swifterbant S4 sloe bead is the finds from the Neolithic lakeshore settlements, Hornstaad Hörnle (3917-3905 cal BC) and Arbon Bleiche 3 (3385-3370 cal BC), both located on the shores of the Bodensee/Lake Constance.[342] The specialised production of sloe stone beads has been ascribed to Hornstaad Hörnle.[343] Even though both sites are quite a distance from the Swifterbant area, and Arbon Bleiche 3 is somewhat younger, the Rhine River as well as the Rhine delta and the Vecht river system (see figures 1.1 and 2.2) would have offered a geographical connection between various Neolithic groups.

Even though there was no direct connection between the Rhine system and the Swifterbant area in the Neolithic time, still, there may have been connections. Traveling by canoe via waterways such as the Rhine River and the Vecht River (considering Rheinland hinterlands are the source area of the Vecht river system) or via coastal navigation (from the Rhein delta to the North Sea) may have been a very logical way to establish contacts between peoples, migration, and perhaps even have offered a route of entry for the Swifterbant cereal cultivation, and perhaps also for the sloe bead. Interestingly, there are more similarities between the Swifterbant sites and Arbon Bleiche 3. At both sites, mistletoe leaves were used as animal fodder and the coprolites of both locations have a very similar intestinal parasite composition which suggests a comparable lifestyle and diet. Fish tapeworm, fluke and kidney worm infections show that (undercooked) freshwater fish was consumed. The frequent presence of the faecal-borne parasite *Trichuris* shows that this geohelminth proliferated in such living conditions.

Animal domestication and the consumption of the meat of infected animals increased the presence of zoonotic parasites. Adopting new food habits therefore also led to transitions in parasitic infections in humans. Migration or trade contacts between Neolithic groups may have, indirectly, promoted new parasitic infections. Since hardly any Neolithic coprolites (let alone Mesolithic ones) from Dutch prehistoric sites have been studied for intestinal parasites it is hard to conclude. It certainly raises new research questions.

13.15 NOaA 2.0 question 8: Which landscape zones were used in the Late Mesolithic and Early Neolithic for habitation, hunting, arable farming and livestock?

The Late Mesolithic-Early Neolithic Hardinxveld-Giessendam De Bruin site was located on a river bank, in a freshwater environment. Livestock was bred at the site. People were fishing in the nearby waters. The Early Neolithic sites Swifterbant -S3 and -S4 were situated in a freshwater environment. The river banks were used for habitation, arable farming and livestock. Hunting and fowling took place in the backswamp and possibly also on the coastal plains. Food plants were gathered from the nearby vegetation as well as from the coastal areas. Fishing activities mainly took place in a fresh water environment but possibly also in the coastal waters.

13.16 NOaA 2.0 question 22: What role did the exploitation of natural food resources play after the introduction of agriculture?

This research showed that cereals formed a small part of the finds in the Swifterbant coprolite. This however might be partially due to the preservation of cereal remains in coprolite matrices in general. The fact that the cereals were only presented in small numbers of chaff remains, would be expected if they were de-hushed as part of the food preparation process, which -at Swifterbant sites - would be the case of emmer wheat. Consequently, a small portion of emmer light chaff (or husks) would enter the cooking pots together with the grain. Naked barley would enter the cooking pots as true clean grain, giving even less chance to be represented by its chaff in the coprolites. Other remains than emmer or barley husks, for example, grain starchy endosperm, would likely not preserve in coprolites. Still, few fragments of

341 Schlichtherle 1988, after Schepers & Bottema-Mac Gillavry 2020.
342 Schepers & Bottema-Mac Gillavry 2020.
343 Maier 2001; Hosch 2004.

grain pericarp tissue from both wheat and barley were preserved on pollen slides, giving the best indication for consumption of both cereals. Adding up all the evidence, it can be concluded that cereals formed a regular and consistent contribution to the Swifterbant diet.

Natural food resources would have played a significant role. Food plants would have been gathered, for example, for starchy seeds (white water-lily), starchy roots and tubers (dropwort, marsh mallow, polypody), bulbs (leek, onion or garlic), greens (knotgrass and possibly leek), fruits (crab apples, berries) and hazelnuts. Furthermore, freshwater fish (pike, perch and cyprinids) formed a large part of the diet. Possibly game (red deer) and birds (waders) were eaten as well. Only a small portion of the bone material in the Swifterbant coprolites pointed to the consumption of mammals. See section 13.8 for a more detailed description.

13.17 Concluding remarks

Although this project aimed to reconstruct the Neolithic human diet based on human coprolites from the Swifterbant sites - and we integrated multiple research methods to achieve this - we may have to see our contribution as a reconstruction of the Swifterbant community diet. It seems that clarifying the diet on the level of individual species (humans, specifically) might be quite challenging, if not impossible. Particularly at archaeological sites where people were living together with their dogs (and pigs, nearby), the differentiation between human and dog (and pig) coprolites is complicated. It is likely that they all had a similar diet and that the people shared their space and the remains of food preparations with their animals.

Still, we feel that we have learned much about the dietary components of the Swifterbant culinary tradition as identified through multiple proxies. Furthermore, we have highlighted dietary trends in food preparations and indicated a highly variable diet. Based on the intestinal parasite study, it seems that the individual and community health at Swifterbant settlements would have been seriously compromised.