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Deer ghosts: Invisible bone tools from the Vlaardingen Culture (3400–2500 BCE), bone-working, toolkits, and cultural preferences

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ABSTRACT

This paper explores the application of use-wear analysis on flint tools for the reconstruction of bone-working toolkits. Lithics from three Neolithic Vlaardingen Culture (3400–2500 BCE) sites were analysed. We successfully identified toolkits used in the production of bone tools. Combining our results with zooarchaeological data, we conclude that the metapodium technique was only practiced on sites where deer was hunted, and deer bones were thus available. When deer were not, or barely, hunted, bone-working was limited to *ad hoc* tool production. Widely available cattle metapodia, which could provide a substitute for deer metapodia, especially for the production of chisels, were generally not used to make tools using the metapodium technique. Culturally determined preferences, for the use of specific raw materials, thus determined technological choices made by the inhabitants of these sites.

1. Introduction

Use-wear analysis is ideally suited to give us indirect clues about past craft activities involving perishable materials like plants, bone, shell, and so forth. It thus provides valuable insights into the 'missing majority' of organic materials, which made up the material world of prehistoric societies (Hurcombe, 2008). This study will focus on three sites from the Neolithic Vlaardingen Culture (3400–2500 BCE). Sites attributed to this archaeological culture are found in different landscape settings with subsistence strategies closely linked to the different ecological conditions (Raemaekers, 2003; Van Gijn and Bakker, 2005).

This study is part of the NWO-funded project *Putting Life into Late Neolithic Houses, Investigating domestic craft and subsistence activities through experiments and material analysis* (NWO AIB.019.020). The project aims to gain insight into daily life in and around Neolithic houses, based on detailed reconstructions of object biographies and toolkits (Van Gijn, 2021b). The present study is focused on the interplay between toolkits, as recognised through use-wear analysis on flint tools, and the zooarchaeological evidence relating to subsistence strategies and bone tool production.

This study will present the results of the use-wear analysis of the lithic assemblages from three major Vlaardingen Culture (VLC) sites: Den Haag Steynhof, Vlaardingen Arij Koplaan, and Hekelingen III (see Fig. 1. for the locations of the sites). Den Haag Steynhof is situated in the coastal dune area, while Vlaardingen Arij Koplaan and Hekelingen III are located on river levees. The subsistence economy of Den Haag Steynhof was geared towards cattle herding, cereal cultivation, and the collection of wild plants (Kooistra et al., 2021; Kubiak-Martens and Oudemans, 2021; Van Dijk, 2021). At both Hekelingen III and Vlaardingen Arij Koplaan hunting and fishing played an important part in the subsistence economy (Prummel 1987, 193-217; Van Rechteren Altena et al., 1963). It should be noted that red deer was present both in the wooded parts of the coastal dune area, and in the wooded areas near the levees (Prummel 1987, 234-237; Van Dijk, 2021). It has been suggested that activities on the levees were related to specific food procurement strategies, such as fishing and hunting. The produce of these activities was thought to be transported to sites in the coastal dune area (Raemaekers, 2003). The present study demonstrates that, in addition to food procurement strategies, craft activities, notably the production of bone tools, were equally important on these levee sites.

2. Materials and methods

The results of the use-wear analyses for Hekelingen III are based on the thesis by Van Gijn (Van Gijn 1990, 99-132). For the sites Den Haag Steynhof and Vlaardingen Arij Koplaan the selection criteria, which Van Gijn applied to the assemblage of Hekelingen III are adopted. In addition to the retouched tools all artefacts with macroscopically visible wear

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traces, points, and/or edges with a straight cross-section > 1 cm were selected (Van Gijn, 1990). For Den Haag Steynhof the flint from zone five was selected for analysis. This included several borers and scrapers which were previously analysed. For these tools the results from the previous studies were included (Carter, 2021; Petrogiannaki, 2022; Van Gijn, 2021a). For Vlaardingen Arij Koplaan trench 15 and trench 17 were selected for analysis (Van Beek 1990, 171-214). In Table 1 the number of analysed tools, and the number of tools with wear-traces are listed per site.

The use-wear analyses were conducted in the Laboratory for Material Culture Studies at the Faculty of Archaeology in Leiden. The analyses were conducted using a Nikon SMZ-2 T stereomicroscope (7-63x) and a Leica DM6000 metallographic microscope (50-500x). The microscope photos of the use-wear traces were taken using the Leica DM6000 microscope. The network analysis is conducted using Visone, in the network degree centrality is used as an analytical tool to rank nodes (in this case sites and different actions) by the number of ties (relations) they exhibit. This allows us to visualise which *chaîne opératoires* are shared amongst different sites (Kroon et al., 2019). In Fig. 5 this is used to visualise bone- and antler-working activities on the three Vlaardingen Culture sites under study.

3. Bone tools in the Vlaardingen Culture

Most bone tools from VLC settlements are produced from metapodia of red deer (*Cervus elaphus L.*) and roe deer (*Capreolus capreolus L.*). The preference for these species is most clearly observed in the well-preserved assemblages of Hekelingen III and Vlaardingen Arij Koplaan (Maarleveld 1985, 14-15; see Table 2). At Hazendonk a similar preference for red deer and roe deer is apparent (Van den Broeke, 1983). Table 2 lists the main categories of species from which the bone tools were produced. Several minor groups are not listed separately in the table. These are included in the other/indet. category. This includes items such as pendants from dog teeth and hollow tubes made from bird bones (Van Dijk, 2009).

The strong preference for the use of deer bones for the production of bone tools is not directly related to a wide availability of deer (Brinkkemper et al., 2010). At Vlaardingen Arij Koplaan red deer (N = 700) and roe deer bone (N = 25) make up only 32 % of the total mammal bone assemblage (N = 2284). Yet, 74 % of the worked mammal bone assemblage consists of red deer and roe deer (Maarleveld 1985, 14-58; Van Rechteren Altena et al., 1963). A similar overrepresentation of

Table 1
Number of tools analysed and number of tools with wear-traces per site (after Van Gijn, 1990).

Site	Number of tools analysed	Number of tools with wear-traces
Den Haag Steynhof	230	158
Hekelingen III	337	136
Vlaardingen Arij Koplaan trench 15	252	117
Vlaardingen Arij Koplaan trench 17	69	33

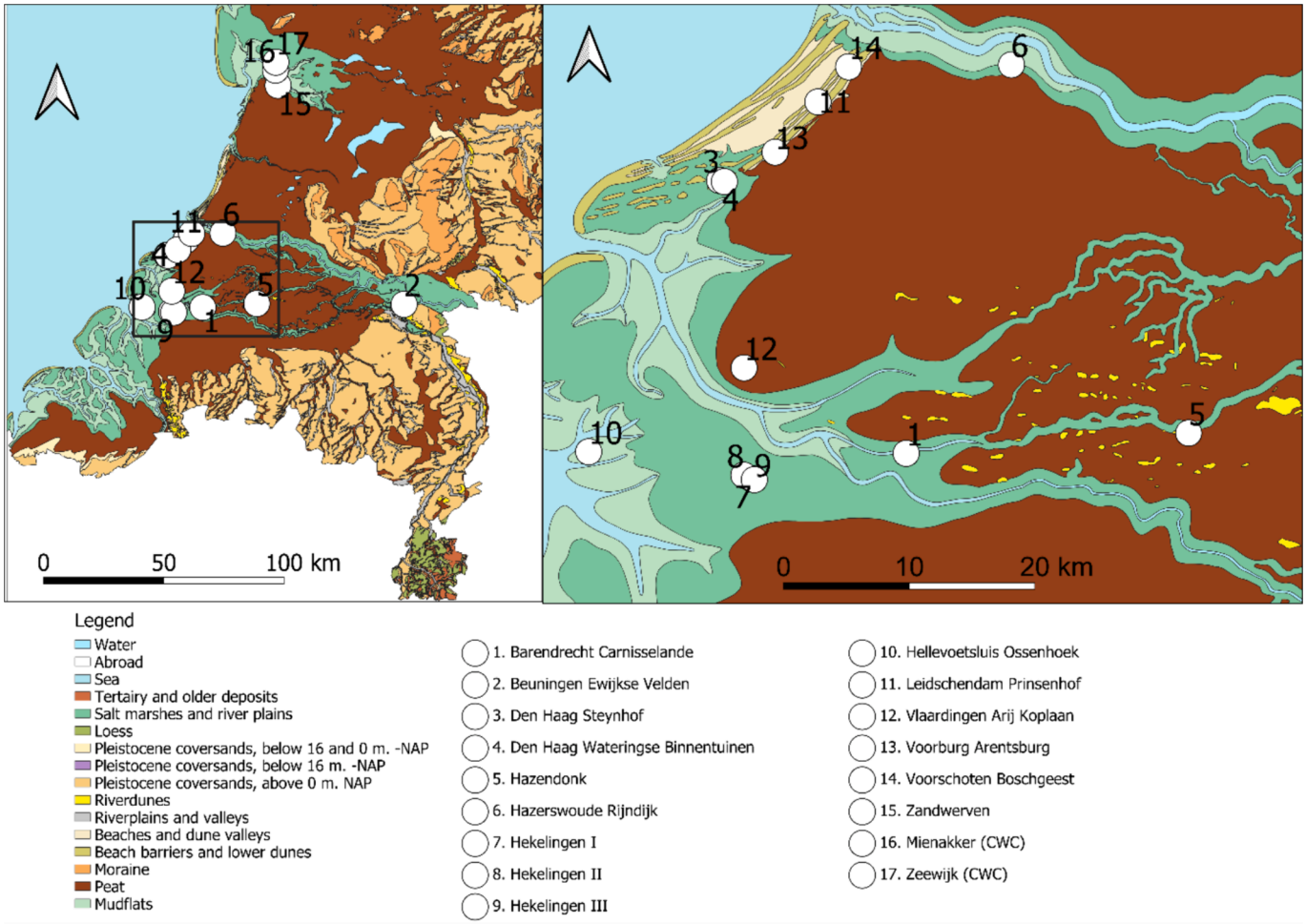

Fig. 1. VLC-sites mentioned in the text, also including the two Corded Ware Culture (CWC) sites Mienakker and Zeewijk, plotted on the paleographic map of the Netherlands ca 2750 BCE (after: Vos et al., 2020).

Table 2
Worked animal bone on VLC-sites in the Netherlands (Asmussen and Moree 1987, 166-167; Boomert, 1974, 221; Clason, 1962, 217; Grimm, 2010, 166; Groenman-van Waateringe et al., 1968, 118; Maarleveld 1985, 14-58; Moree et al., 2011, 42; Van den Broeke, 1983, 182; Van Dijk, 2009, 130; Van Dijk et al., 2017; Van Rechteren Altena et al., 1963, 41; Zeiler 2014, 288-299).

Site	Red deer	Roe deer	Cattle	Sheep/goat	Pig/wild boar	Antler	Large mammal	Medium mammal	Other/ indet.
Barendrecht Carnisselande	–	–	–	–	1	1	–	–	–
Beuningen Ewijkse Velden	–	–	–	–	–	1	–	–	2
Den Haag Wateringse Binnentuinen	–	–	–	–	–	–	1	–	3
Hazendonk VL 1a	–	–	–	–	–	2	–	–	–
Hazendonk VL 1b	2	2	–	–	–	1	–	3	5
Hazendonk VL 2b	1	11	–	2	–	3	7	4	2
Hazerswoude Rijndijk	1	3	2	–	–	–	–	–	24
Hekelingen I	–	1	–	–	2	4	–	–	2
Hekelingen II	–	–	–	–	–	1	–	–	1
Hekelingen III	42	30	3	–	9	–	–	–	23
Hellevoetsluis Ossenhoek	1	–	3	2	1	1	5	–	7
Leidschendam Prinssenhof	–	–	–	–	–	–	–	–	2
Vlaardingen Arij Koplaan	81	16	6	–	8	–	–	–	21
Voorburg Arentsburg	–	–	2	–	–	2	–	–	–
Voorschoten Boschgeest	1	–	1	–	–	–	–	–	4
Zandwerven	–	–	1	–	–	–	–	–	–
Total	**129**	**63**	**19**	**4**	**6**	**16**	**13**	**7**	**82**

deer in the worked bone assemblage can be observed in Hekelingen III. Here 34 % of the total mammal bone assemblage (N = 1255) consists of red deer (N = 274) and roe deer (N = 151). Yet, they make up 69 % of the worked mammal bone assemblage (Maarleveld 1985, 14-58; Prummel 1987, 193-217). It thus seems that deer bones, notably metapodia, were specifically selected for bone tool production. In total 59 % (N = 192) of the worked bone tools (N = 323), from VLC settlements consist of tools made from red- and roe deer (see Table 2).[1]

4. Toolkits and the metapodium technique

An important contribution of micro-wear analysis to our understanding of the past is the reconstruction of toolkits. Toolkits can be conceptualized in various ways. They can refer to all tools used for a single type of craft activity. For example, all woodworking tools in a modern carpentry workshop can be seen as a woodworking toolkit. These broader toolkits can also be subdivided to refer to specific activities; for example, a toolkit for making wooden shoes (Van Gijn, 2010a). Organic materials are generally poorly, if at all, preserved in the archaeological record. But for many craft activities the toolkits used to produce organic artefacts can be reconstructed through use-wear analysis. This was for example demonstrated for the Middle Neolithic site of Schipluiden (3600–3400 BCE) where several toolkits were reconstructed, based on detailed use-wear analysis of artefacts made of a range of raw materials (Van Gijn, 2008). A recent study on Mesolithic antler, bone and flint tools also successfully led to the reconstruction of toolkits related to antler and bone-working (Kabaciński and Winiarska-Kabacińska 2023, 15-16).

Based on previous experiments, studies of bone tool production waste, and use-wear analysis the toolkit which was used for the metapodium technique has been reconstructed (Maarleveld, 1985; Van Gijn, 1990; Van Gijn 1994, 263-264). The metapodium technique is a standardised technique which was applied to create bone chisels and awls. The *chaîne opératoire* of this technique will be briefly described here, as this allows us to deduce the toolkit involved in the production of these tools (see Fig. 2). First, the natural grooves, present on the anterior and posterior of the metapodia are deepened by carving, or graving, up and down the shaft. Next, the distal end of the metapodium is sawn, and broken off. After this the bone is split in halves along the deepened grooves. These halves are used as blanks, or occasionally new grooves are made after which these halves are split again into two smaller blanks. The blanks are ground, on a grinding stone, shaping them into chisels or awls. Some tools are polished after grinding, giving them an intense lustre.

Two of these steps involve flint tools which are used in specific motions. The deepening of the grooves is done with a sturdy flint point. Use-wear analysis on experimental tools used in this manner indicates that the point becomes rounded and that a smooth and reflective polish with characteristic striations or 'comet tails' develops (Van Gijn 1990, 32-34). The second motion relates to the sawing of the distal end of the metapodia. For this a retouched flake or blade can be used. This motion causes edge removals, and on the protruding points of the retouched tool isolated spots of domed smooth and matt polish with parallel striations develop (Van Gijn 1990, 32-34).

From the above we can conclude that on sites where the metapodium technique was applied we find: 1. Sawn-off distal ends of metapodia; 2. Pointed flint flakes or blades with use-wear traces from carving bone; 3. Retouched flakes or blades which are used to saw-off the distal ends of the metapodia; 4. Grinding stones with bone-working traces. We can expect that the sawn-off distal ends of metapodia are only preserved on sites where animal bones are well preserved. The flint tools with use-wear traces from carving and sawing bone will be preserved on most sites. The grinding stones can also be expected to be preserved. In fact, one such tool was found at the Middle Neolithic site of Schipluiden (Van Gijn and Houkes, 2006, fig. 8.17). However, linking these grinding stones specifically to the metapodium technique is problematic as grinding stones are likely also used to resharpen bone awls and chisels. As such they can thus be indicative of either production, or maintenance of bone tools.

5. Use-wear results

Both Hekelingen III and Vlaardingen Arij Koplaan yielded extensive evidence for bone tool production (Table 3). The use-wear traces related to carving and sawing bone were often found on multifunctional tools of which the retouched sides were used for sawing bone, while the pointed distal ends were used for carving bone (see Fig. 3). Traces related to carving bone were absent at Den Haag Steynhof (see Fig. 4). The toolkit, used to produce bone tools using the metapodium technique, is thus only present in Hekelingen III and in Vlaardingen Arij Koplaan. Both sites also yielded multiple sawn-off distal ends of metapodia (Maarleveld, 1985).

The bone assemblage from Den Haag Steynhof is unfortunately poorly preserved. Bone tools or distal ends of metapodia are not found on the site, but it cannot be ruled out that this absence is related to the

[1] This excludes the antler artefacts in the assemblage.

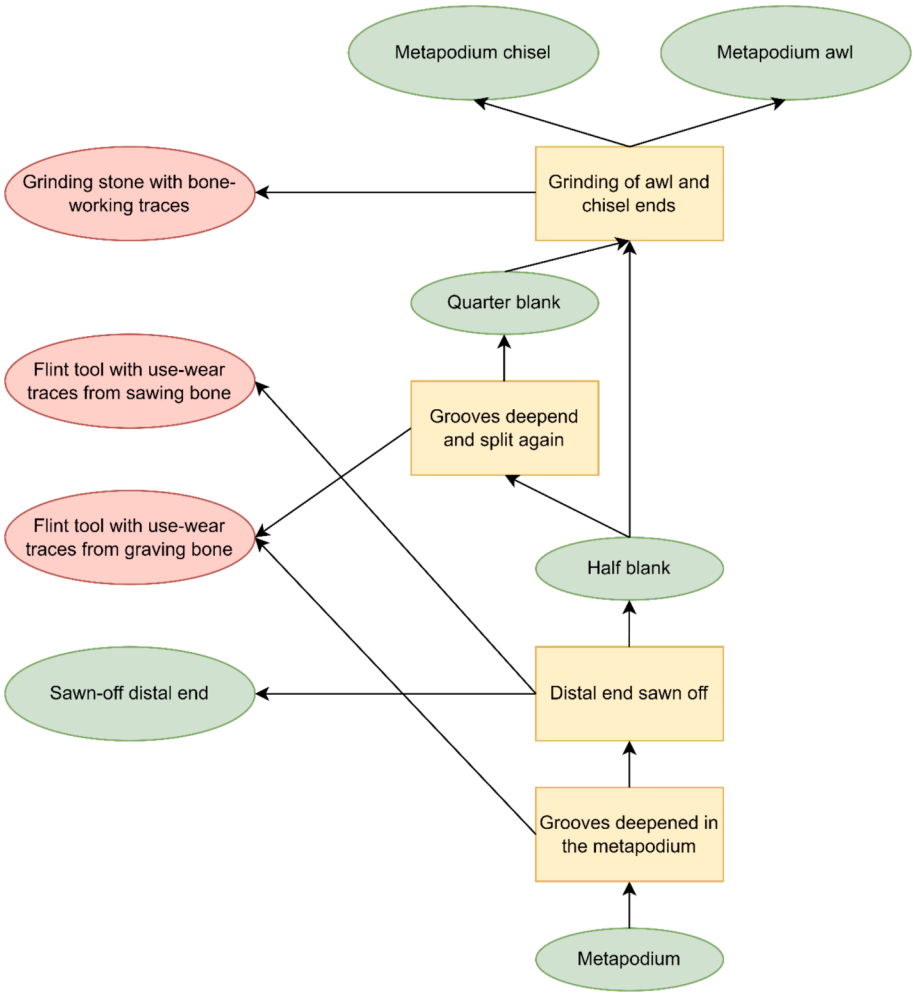

Fig. 2. Flowchart for the chaîne opératoire of the metapodium technique. In yellow steps of the chaîne opératoire, in green organic artefacts related to different steps, in red inorganic artefacts. The left of the diagram shows the waste products, the top shows the end products.

Table 3
Use-wear results main categories of contact materials per site (after: Carter, 2021; Petrogiannaki, 2022; Van Gijn, 1990, 104; Van Gijn, 2021a).

	Antler	Bone	Bone/ antler	Hide	Mineral	Plant	Pottery	Wood	Other/indet.	Total
Den Haag Steynhof	0	7	0	117	4	7	9	4	46	**194**
Hekelingen III	8	27	0	41	1	16	0	21	51	**165**
Vlaardingen WP15	14	22	2	31	9	34	10	5	17	**144**
Vlaardingen WP17	2	4	1	8	0	4	1	5	21	**46**
Total	**24**	**60**	**3**	**197**	**14**	**61**	**20**	**35**	**135**	**549**

poor preservation of organic materials (Van Dijk, 2021). Because of the absence of production waste, we depend on use-wear analysis for our understanding of bone-working activities on this site. Six of the tools which were used in a longitudinal motion had traces related to both contact with bone and hide. It cannot be ruled out that these were multi-purpose tools, but it seems more likely that these tools represent butchering tools.

Bone-working on Vlaardingen Culture sites does not represent a monolithic activity. While the metapodium technique is ubiquitous on the levee sites of Hekelingen III and Vlaardingen Arij Koplaan, it is apparently absent in Den Haag Steynhof. Different bone- and antler-working activities can be represented as a network (see Fig. 5). The network illustrates not only a quantitative difference between these sites, in terms of bone-working frequency, it also visualises a qualitative difference in terms of the specific activities at these sites. At Vlaardingen and Hekelingen III a much wider range of activities is present; these also include antler-working and the use of the metapodium technique. The activities at Steynhof are limited, presumably these are related to *ad hoc* bone tool production. The drilling of bone could potentially be related to ornament production.

At Den Haag Steynhof deer make up only 1 % of the faunal remains (Van Dijk 2021, 188-189). Antler-working is absent at the site, which arguably can be seen as a logical consequence of the scarcity of deer at the site. It was previously noted that deer were preferred for the production of bone tools, using the metapodium technique. Deer hunting hardly played a role in the subsistence strategies at Den Haag Steynhof. This meant that deer metapodia were virtually absent at the site, which in turn determined the technological choices made by the inhabitants. Because of the scarce availability of deer bones, bone-working at Steynhof was not geared towards tool production using the metapodium technique. Cattle metapodia were abundant at Steynhof, in theory they would provide a suitable substitute for deer metapodia. They could

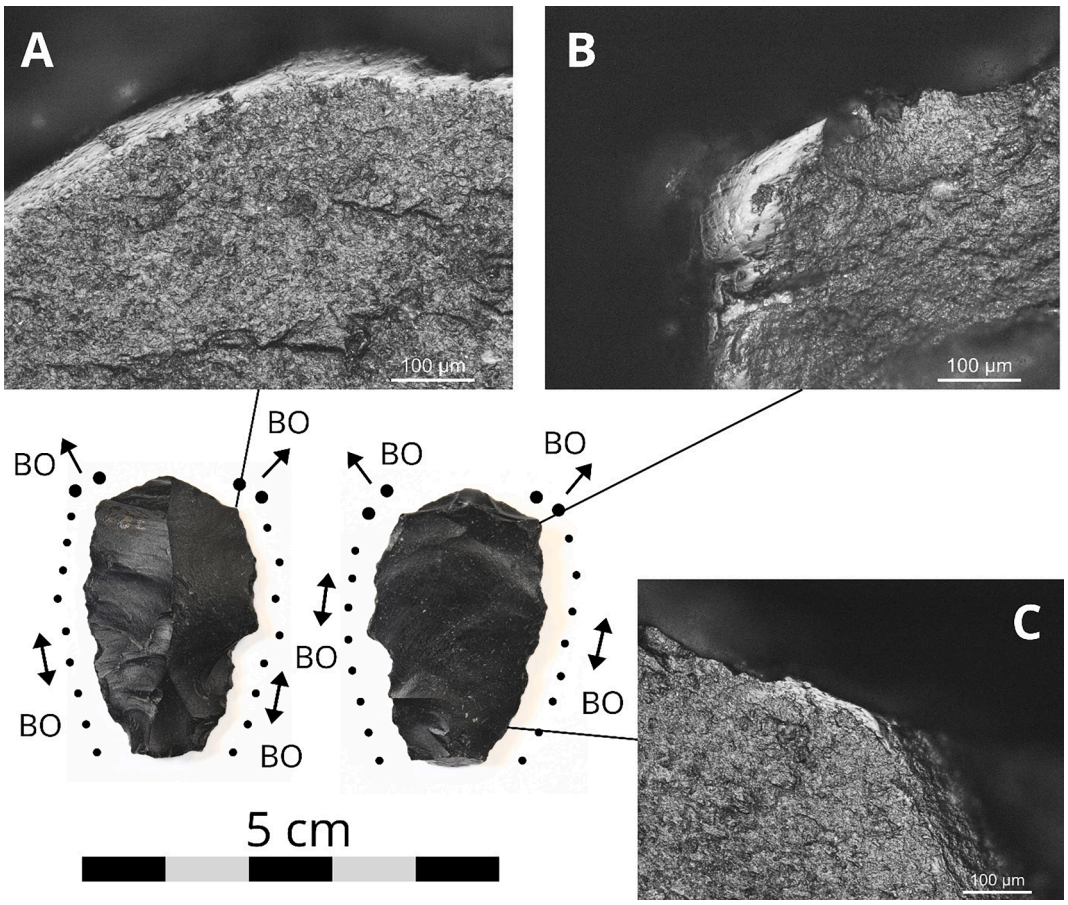

Fig. 3. Multifunctional tool (383.1), a retouched blade from Vlaardingen Arij Koplaan trench 15 which was used on two sides for carving (A + B) and sawing bone (C).

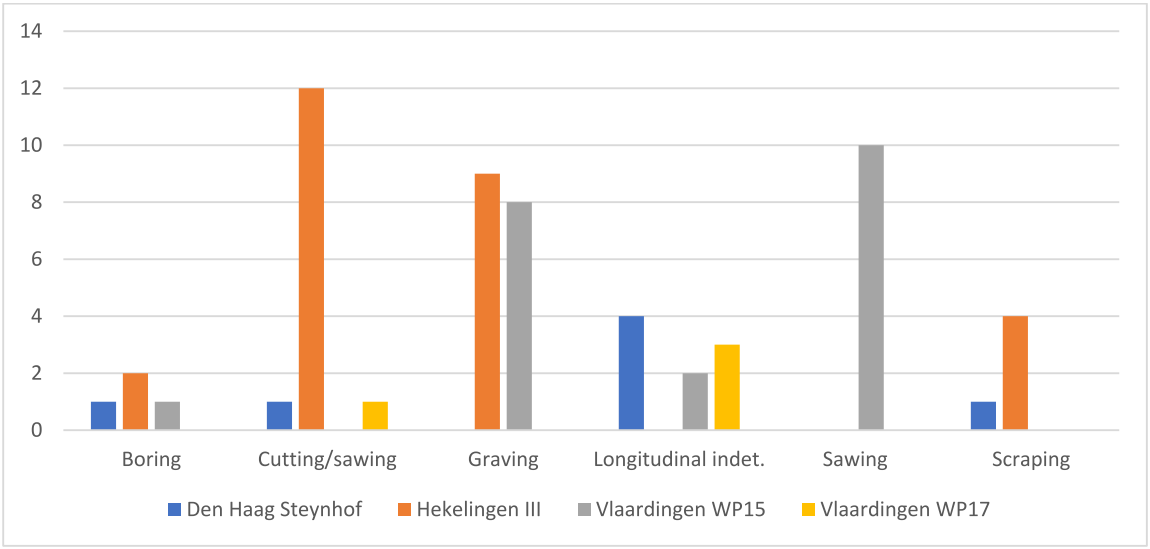

Fig. 4. Motions for bone-working tools per site (after: Van Gijn, 1990).

especially have been used for the production of bone chisels. Such chisels have occasionally also been found in other sites (Maarleveld 1985, 59-83). Yet, at Den Haag Steynhof, cattle metapodia were not utilised for this technique, presumably because of the previously mentioned preference for the use of deer metapodia.

6. Discussion

Bone-working, on Late Neolithic sites in the western Netherlands, is mainly a prominent activity on sites where deer bones were abundantly available (see table 4). Because a distinction between bone- and antler-working is not always made, and is not always possible, both

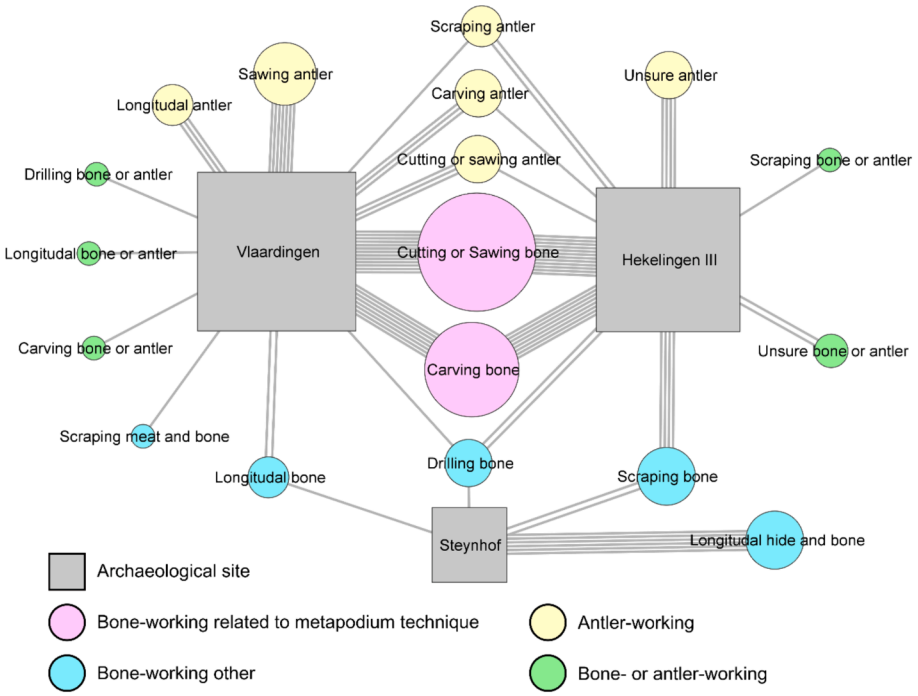

Fig. 5. Network representing the three sites and different bone- and antler-working activities. Bone-working at Hekelingen III and Vlaardingen is clearly geared towards tool production using the metapodium technique (see pink nodes). At Steynhof, boneworking activities represent only a limited spectrum, presumably indicative of ad hoc tool production.

percentages for bone-working and a combined percentage for bone- and antler-working are provided in Table 4. In addition to the Vlaardingen Culture sites two contemporary Corded Ware Culture (2900–2500 BCE) sites are also included: Mienakker and Zeewijk (Garcia-Diaz 2017, 105-205). The table only includes sites where a representative selection was made for use-wear analysis. Sites where only specific tool types were studied are excluded. Furthermore, sites were only included if a minimum of twenty artefacts yielded use-wear traces. Lastly, sites where no zooarchaeological data was available have been excluded from the table.

In addition to deer, cattle, sheep/goat, and pig bones were occasionally also worked, especially on sites where deer was absent. However, these bones were generally worked more crudely. This can for example be observed on the *ad hoc* chisel found at Zandwerven which was made from a cattle radius (see figure 6).

The dataset is too small to be suitable for statistical analysis. Yet, it seems that frequency in bone- and antler-working traces is related to the presence of deer. Unfortunately, not all publications made a distinction between bone- and antler-working traces. For the sites Hazendonk and Leidschendam Prinsenhof it was not always possible to distinguish bone and antler working traces, due to the condition of the material (Bienenfeld 1986, 257-268; Van Gijn, 1990). The scatterplot in Fig. 7 therefore includes both bone- and antler-working traces. For the other sites it can be noted that sites with high frequencies of bone/antler-working traces also had high percentages with bone-working traces (see Table 4). Sites with low frequencies in bone/antler-working traces generally only had bone-working traces.

Bone- and antler-working are related to the presence or absence of deer hunting. For antler-working this co-dependency with deer hunting is to be expected, because other animals do not have antlers. For bone-working this co-dependency seemingly results from cultural notions about appropriate raw materials. It is possible that this cultural preference represents a continuation of previous Mesolithic traditions. It has been noted that red deer bones and antlers were specifically selected for tool production because of the special significance attributed to these animals (Conneller 2004, 52-53). Recent analysis of Mesolithic bone points from the submerged coastal area of the Netherlands indicated that most of these points were made from deer bone. It was suggested that these animals were not selected for utilitarian purposes, rather it seemed that these preferences were culturally determined (Dekker et al., 2021). It has also been suggested that white tailed eagles (*Haliaeetus albicilla*) were hunted in the Rhine-Meuse Delta during the Mesolithic and Neolithic because of the symbolic significance of this animal (Amkreutz and Corbey 2008, 176-178). Similarly, cultural preferences for the selection of certain species, and skeletal parts, for bone tool production have been documented ethnographically in central Europe. It has been noted that these traditions are usually conservative in nature

Table 4
Percentages of deer bone, as part of the mammal bone assemblage, and bone/antler-working on different VLC and CWC sites. AUA stands for 'Actually Used Areas, which refers to zones on tools displaying use-wear traces (Bienenfeld 1986, 257-274; Brinkkemper et al., 2010, 32; Carter, 2021, 91; Garcia-Diaz 2017, 105-205; Van Dijk, 2009, 119; Van Gijn 1990, 18-19; Groenman-van Waateringe et al., 1968, 113; Metaxas 2010, 105-106; Petrogiannaki, 2022, 56; Prummel, 1987; Van Gijn, 1990; Van Dijk, 2021; Van Gijn, 2021a; Van Rechteren Altena et al., 1963, 40; Zeiler and Brinkhuizen, 2013, 157; Zeiler and Brinkhuizen, 2014, 180; Zeiler, 1997, 102).

Site	Artefacts with use-wear traces	Nr. of AUAs	Bone-working %	Bone- and antler-working%	Deer bone %
Den Haag Steynhof	173	194	4	4	0.13
Hazendonk	20	20	0	10	10.86
Hekelingen III	139	165	16	21	34.69
Hellevoetsluis Ossenhoek	59	81	7	15	14.11
Leidschendam Prinsenhof	28	32	0	22	10.78
Mienakker	34	40	3	3	0.22
Vlaardingen trench 15 and 17	150	190	14	24	31.74
Zeewijk	65	89	1	1	0.01

Fig. 6. Crudely shaped bone chisel made from a cattle radius found at Zandwerven.

(Choyke, 2013). The use of the metapodium technique dates back to the Mesolithic (Louwe Kooijmans et al., 2001). Both the technique, and the preferences for certain raw materials thus seem to be rooted in Mesolithic traditions. For the Middle Neolithic site of Schipluiden (3600–3400 BCE) Van Gijn also argued that the bone-working traditions represented a continuation of Mesolithic traditions. Here red deer bones were also mainly selected for the production of awls and chisels using the metapodium technique (Van Gijn, 2006).

In terms of subsistence the importance of hunting gradually declined in favour of cattle herding throughout the Neolithic (Amkreutz 2013, 312-325; Raemaekers, 2003). During the Late Neolithic, cattle herding had largely replaced hunting as a main strategy for obtaining animal products. This is especially true for the coastal dune area (Raemaekers, 2003). Cattle was deemed a suitable replacement for the supply of meat and hides (see for example the high frequency in hide-working at Den Haag Steynhof). However, for the metapodium technique cattle were not considered to be a suitable replacement. On the levee sites, where hunting of deer took place, bone-working, using the metapodium technique, was abundant. It is possible that these sites also produced tools which were exported to other sites. This notion is supported by the Corded Ware Culture site of Mienakker, where two red deer bone tools are thought to have been imported to the settlement in a ready-made state (Garcia-Diaz, 2017). So far this could only be demonstrated for the Corded Ware Culture site of Mienakker. Because of the poor preservation of organic materials on the coastal dune sites it is difficult to assess whether this practice was widespread in this period. Yet, considering that flint axes were often imported in a ready-made-state for far away sources we could suggest that we should not ignore the possibility that organic materials were equally mobile (Amkreutz, 2013; Van Gijn, 2010a; Van Gijn, 2010b). It is possible that bone tools were exchanged in similar networks.

7. Conclusions

We were able to identify the toolkit used in the metapodium technique on both Hekelingen III and Vlaardingen Arij Koplaan. At Den Haag Steynhof this toolkit was absent. For the metapodium technique, a strong preference for the use of deer bones is apparent. It seemed that if

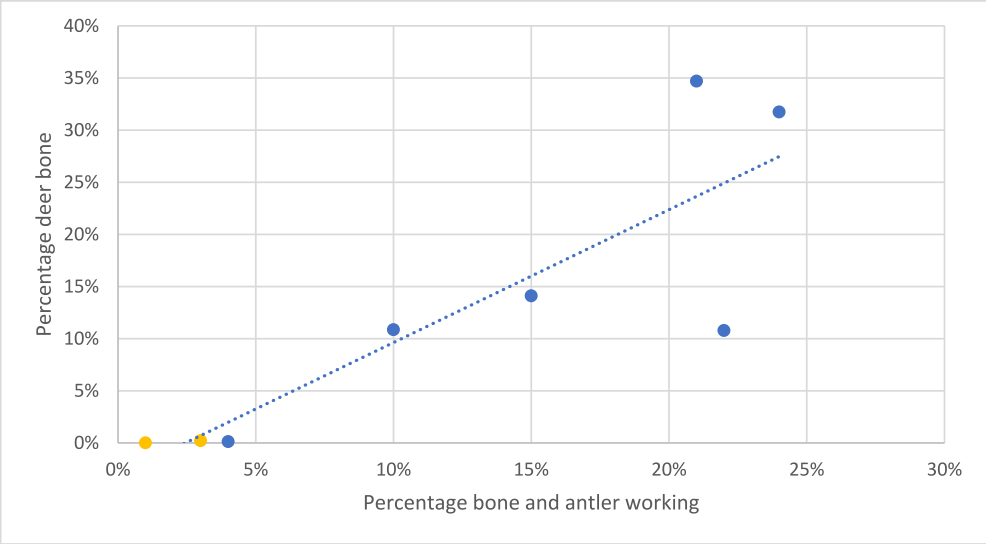

Fig. 7. Scatterplot with trendline, indicating that bone- and antler-working increases with the availability of deer on VLC (blue) and CWC (yellow) sites (see Table 4 for references).

deer were not hunted, and their metapodia therefore not available, bone-working was only practiced as a marginal activity, notably directed at *ad hoc* tool production. In addition to *ad hoc* tool production, the lack of suitable raw materials was possibly also compensated with the import of ready-made bone tools. The poor preservation of organic material in the coastal dune area makes it difficult to assess how widespread this phenomenon was. Nevertheless, despite the differences in preservation, we were still able to demonstrate different attitudes to bone tool production on different sites. It seems that subsistence strategies, craft activities and cultural notions regarding suitable raw materials were closely intertwined. The importance of red deer in the subsistence economy declined drastically in the Neolithic but their importance for bone- and antler-working remained unwavering. Red deer thus maintained a special position in these societies. In conclusion, this study shows that raw material availability and technological choices were intertwined with cultural notions, which were maintained even when subsistence strategies radically shifted during the Neolithic transition.

CRediT authorship contribution statement

Lasse van den Dikkenberg: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Annelou van Gijn:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: this research was funded by an NWO grant for the project *Putting Life into Late Neolithic Houses: Investigating domestic craft and subsistence activities through experiments and material analysis* (grant number: AIB.19.020). The authors report there are no competing interests to declare. The funding source was not involved in study design; in the collection, analysis, and interpretation of data; in the writing of the report; or in the decision to submit the article for publication.

Data availability

Data will be made available on request.

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