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Ungulates exploitation for subsistence and raw material, during the Maglemose culture in Denmark: the example of Mullerup site (Sarauw's Island) in Sjælland

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This article presents results from recent re-analysis of the faunal remains from Mullerup (Zealand), the first excavated site attributed to the Maglemose Culture (9600–6550 cal BC) in Denmark. All faunal remains and fragments related to the bone tool industry (pieces and waste) were studied together, in order to reconstruct the total exploitation of animal resources for dietary as well as 'technical' (non-dietary) purposes by Maglemosian groups. The detailed quantification of species, individuals, skeletal elements, as well as marks on the bone surfaces provides relevant data to reconstruct the relative contributions of the five main hunted species (ungulates) to subsistence and technical activities, such as bone tool production. The ungulates were exploited in different ways, depending on species, transport strategies, and raw material needs. This article particularly focuses on the acquisition of raw material for making bone tools and its influence on the whole carcass treatment. The reconstruction of the total exploitation of animal resources thus addresses important issues in Maglemose socioeconomic organization.

Keywords: Maglemose culture; early Mesolithic; Denmark; archaeozoology; animal exploitation; Carcass processing; bone tool industry

1. Introduction

The Maglemose culture was named after the excavation of Mullerup,[1] located in the 'Magle Mose' peat bog in Zealand (Denmark), in 1900 by G.F.L. Sarauw (Sarauw *et al*. 1903). Mullerup was, at that time, attributed to a period preceding the *køkkenmøddinger* or shell midden period (Sarauw 1906) that was first attributed to the Neolithic and then to the Late Mesolithic Ertebølle culture (Brinch Petersen and Meiklejohn 2007). The Maglemose culture was then more precisely defined, thanks to important excavations in Denmark (Figure 1): Sværdborg I (1918–1919) (Friis Johansen *et al*. 1919), Holmegård I (1923–1924) (Broholm *et al*. 1924), Holmegård IV, V, and VI (Becker 1945), Sværdborg I (1943) and Lundby II (Bille Henriksen *et al*. 1976, 1980), Ulkestrup I and II (Andersen 1951, Andersen *et al*. 1982) and particularly in Åmosen bog (Mathiassen *et al*. 1943); and on the basis of synthetic work concerning the lithic industries (Becker 1945, 1953, Brinch Petersen 1966, 1973).

The Maglemose culture is now considered the first Mesolithic culture in Denmark and southern Scandinavia, lasting from 9600 cal BC[2] to 6500 cal BC (Brinch Petersen 1973, Møller Hansen *et al*. 2004) and preceding the Kongemose and Ertebølle cultures. The Maglemose sites located in Zealand (Figure 1) mainly dated to the Boreal period, yielded very well-preserved faunal remains

and an abundant and diversified bone tool industry. This bone tool industry appears to be homogeneous, in terms of typological composition, as well as in terms of raw materials used (species and anatomical parts) and manufacture techniques (David 1999, 2003a, 2003b, 2004). Bone points are predominant (straight and barbed points), alongside heavy tools (hammer-axes, adzes, handles/sheaths, blade axes) from cervid antlers, mainly elk and red deer. Such an industry is now considered one of the main components of the Maglemose culture (David 1999, 2003a, 2003b, 2004). Thus, the acquisition of raw materials for its manufacture was very likely a key issue for Maglemose hunter-gatherers in animal exploitation.

Animal resource exploitation for subsistence and raw materials involves choices in the way animals were selected and how their carcasses were processed. Which species were mainly hunted? For what resources or raw materials were they exploited? Were they all exploited in the same way?

The main faunal assemblages from Maglemose sites have rarely been studied from this specific perspective and in detail. Most are short studies, part of the (sometimes old) monograph publications (e.g., Sarauw *et al*. 1903, pp. 194–199). Maglemose faunal assemblages also provided material for specific studies, such as fauna history reconstruction, notably after the deglaciation of Denmark
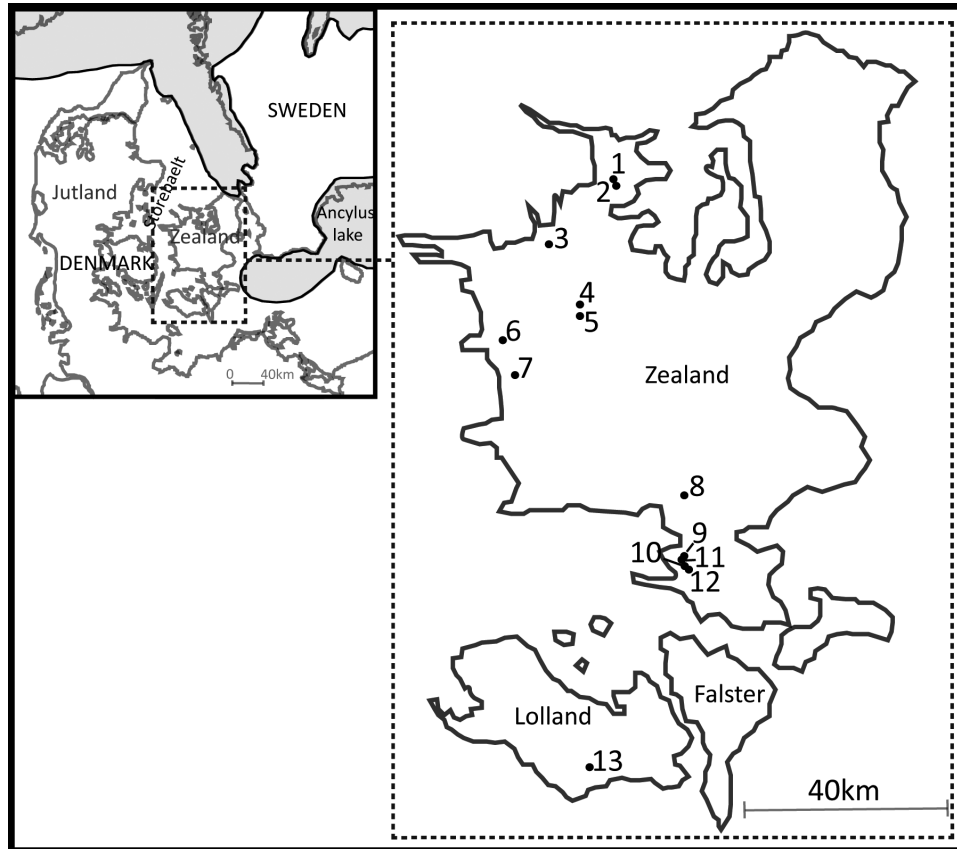
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Figure 1.   Distribution of the main Maglemosian sites from Zealand (Denmark) with faunal remains: 1, Vig; 2, Prejlerup; 3, Favrbo; 4, Ulkestrup I and II; 5, Verup; 6, Vinde Helsinge; 7, Mullerup; 8, Holmegård I, IV, and V; 9, Lundby I and II; 10, Sværdborg I and II; 11, Lundby Mose; 12, Barmose I; 13, Skottemarke.

(e.g., among many, Degerbøl and Fredskild 1970, Aaris-Sørensen 1992, 1999, 2009) or seasonality of occupations (e.g., Rowley-Conwy 1993, Carter 2001, 2009, Carter and Magnell 2007). We can, however, mention pioneering work on cut-mark analysis and exploitation reconstruction using Mesolithic bone assemblages, including Maglemose sites (Noe-Nygaard 1977, 1987, 1995) and the first synthesis concerning Maglemose subsistence economy (Blankholm 1996) that raised the question of the overlapping between exploitation for dietary purposes and exploitation for raw material.

This article presents the main results from the re-analysis of the faunal assemblage from Mullerup (Sarauw *et al.* 1903), which is the reference site for the Maglemose culture. This analysis was part of a doctoral thesis (Leduc 2010b) that specifically focused on the question of 'total' animal exploitation (see Fontana *et al.* 2009) and the management of animal resources by Maglemosian groups, i.e., the exploitation of all the animal resources and its consequences on the way different species were hunted and processed.

Therefore, one of the purposes of the study was to decipher how carcass exploitation and raw material

selection for bone tool manufacturing were articulated at Mullerup. Were they priorities in resource exploitation? Were these priorities the same for each species?

This article will focus only on the exploitation of the five ungulates which dominate the Mullerup faunal assemblage (89% of the number of identified specimens NISP): wild boar (*Sus scrofa*), elk (*Alces alces),* red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), and aurochs (*Bos primigenius*). These examples will emphasize the fact that animal resources were exploited in different ways, notably based on raw material needs.

2.   The Mullerup site

Mullerup is located in the north-western part of Zealand (Denmark), a few kilometers from the western coast (Figure 1). At the time of occupation, Mullerup was an inland site located less than 50 km from the outlet of the Ancylus Lake (Sarauw *et al.* 1903).

The site is dated to the Boreal period according to pollen analysis (Jessen 1935) and was later attributed to an early phase (phase 2) of the Maglemose culture based on the lithic industry (Brinch Petersen 1973, 1993).

Several radiocarbon dates (Tauber 1972, 1973) situate the occupations, after calibration, between 8225 and 6828 cal BC (calibration with Calib Rev. 6.0.1© (Stuiver and Reimer 1993, Reimer *et al.* 2009) Leduc 2010b, p. 121). A recent Accelerator Mass Spectrometry radiocarbon date result on a human femur (Fischer *et al.* 2007) provides a similar age: 7510–7187 cal BC (AAR-8554/NM1 A18269: 8310 ± 55 BP).

The archaeological material was all recovered from the same peat layer. Although the duration and number of occupations at Mullerup are not known, the lithic assemblage (Brinch Petersen 1973) and bone tool industry (David 1999, 2004) are homogenous and typical of the early Maglemose period (lithic phase 2). This enabled study of the excavated bone material as a single unit, resulting from occupation(s) by the same group(s) of people. Despite the early date of the excavation (1900), fairly good recovery of faunal remains was done, as many bone splinters are present. However, analysis of the size distribution of bone fragments shows that bone fragments less than 2 cm are under-represented (Leduc 2010b, p. 148), which is likely due to the lack of sieving.

Based on the abundance and diversity of archaeological material, the site was interpreted as a settlement site (Sarauw *et al.* 1903) involving a wide range of activities such as lithic production, bone tool manufacture, and subsistence activities. The spatial distribution of lithic waste (Grøn 1995, Blankholm 1996) led to the hypothesis of a small inhabitation for a small group of people on an islet in the middle of a former lake, with a large refuse area in the lake (Figure 2, Leduc 2010b, p. 127–129), as described at Ulkestrup I and II (Andersen 1951, Andersen *et al.* 1982, Grøn 1995).

3. Materials and methods

The former study of faunal remains, undertaken by H. Winge (Zoological Museum, Copenhagen), led to the determination of around 30 species (13 mammal species, 15 bird species, and one fish species). No new species were identified during the re-analysis. Winge's work pointed to a summer occupation, based on the presence of very young individuals, unshed roe deer antlers, and migratory bird species nesting in Denmark during the warm months, such as the common crane (*Grus grus*). Later, Carter (2001) X-rayed the dental remains from young red deer and roe deer from Mullerup in order to very precisely describe the tooth development stages, also concluding a summer, possibly spring, occupation. The re-analysis by the author also led to an occupation period during the warmer months of the year, from April to October (Leduc 2010a, 2010b, pp. 244–245).

The Mullerup site yielded 4515 bone and antler fragments, waste, and pieces from tool manufacture included. Mammals are widely predominant (Table 1). They account
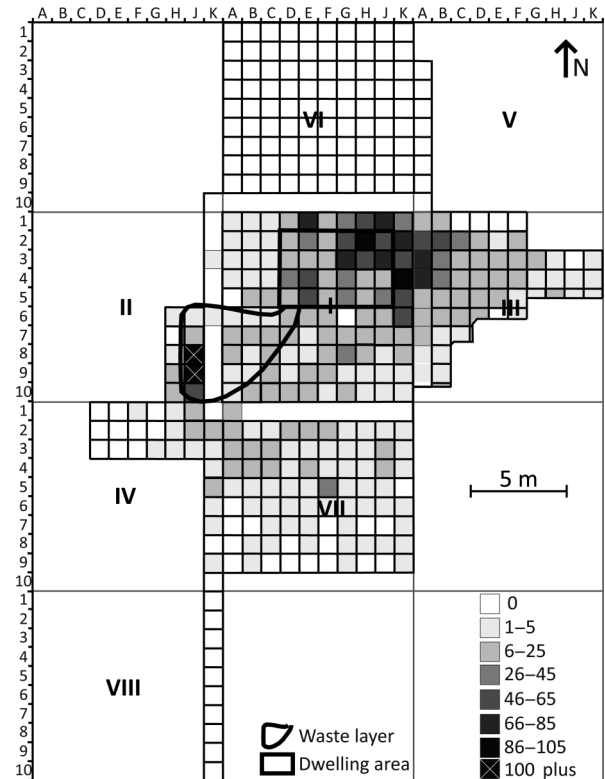

Figure 2. Map of the Sarauw's excavation at Mullerup (Sarauw *et al.* 1903, fig. 2, p. 156 and fig. 8, p. 188), showing the repartition of faunal remains, per density (number of specimen/m²; Leduc 2010b). One square = 1 m². The restitution of the dwelling area and the waste layer position is after Grøn (1995, p. 77) according to the lithic waste distribution.

for 92.4% of the NISP and 99.8% of the number of unidentified specimens (NUSP). The five ungulates are the main hunted species (Table 1; Figure 3): wild boar, elk, red deer, roe deer and aurochs. They account for more than 89% of the total NISP and 96.9% of the mammal NISP while other mammals (mainly fur-bearing mammals) are represented by a small number of fragments and individuals. There are only a few bird bones (NISP = 128), but they belong to 15 species, mainly aquatic birds. Finally, fish bones are all from one species, pike (*Esox lucius*), mostly large individuals, due to the lack of sieving during the excavation (Leduc 2010b, pp. 249–251).

The data presented here are based on the study of the entire faunal assemblage. This means that not only were remains commonly interpreted as resulting from butchering activities taken into account but also all remains attributed to the bone industry, i.e., manufactured pieces (tools, weapons, ornaments) and waste (fragments showing marks from *debitage* and/or related to the manufacture of pieces).

This new analysis is based on the detailed quantification of bone material, using several criteria: NSP, NISP and NUSP; a derived 'bone industry NISP', i.e., the NISP

Table 1. Taxinomic composition of the Mullerup assemblage.

Taxa	NSP	MNI	NSP (%)	MNI (%)	NSP Bone industry	NSP Bone industry (%)
Sus scrofa scrofa – Wild Boar	938	21	29.9	18.6	17	6.7
Alces alces – Elk (included unshed antlers = 71)	624	7	19.9	6.2	87	34.5
Cervus elaphus – Red Deer (shed antlers exluded)	477	4	15.2	3.5	71	28.2
C. capreolus – Roe Deer (included unshed antlers = 16)	445	13	14.2	11.5	56	22.2
Bos primigenius – Aurochs	326	5	10.4	4.4	13	5.2
Martes martes – Pine Marten	23	6	0.7	5.3	–	–
Castor fiber – Castor	21	2	0.7	1.8	–	–
Meles meles – Badger	12	2	0.4	1.8	–	–
Canis familiaris – Dog	11	2	0.4	1.8	2	0.8
Ursus arctos – Brown Bear	10	3	0.3	2.7	1	0.4
Vulpes vulpes – Red Fox	8	2	0.3	1.8	–	–
Felis silvestris – Wild Cat	4	1	0.1	0.9	–	–
Sciurus vulgaris – Squirrel	1	1	0.03	0.9	–	–
Total identified mammals	2900	69	92.4	61	247	98
Cygnus olor – Mute Swan	46	4	1.5	3.5	3	1.2
Anas platyrhynchos – Mallard	22	7	0.7	6.2	–	–
Anas acuta – Northern Pintail	15	4	0.5	3.5	–	–
Podiceps cristatus – Great Crested Grebe	14	2	0.4	1.8	1	0.4
Phalacrocorax carbo – Great Cormorant	9	1	0.3	0.9	–	–
Haliaeetus albicilla – White-tailed Eagle	7	2	0.2	1.8	1	0.4
Botaurus stellaris – Eurasian Bittern	3	1	0.1	0.9	–	–
Clangula hyemalis – Long-tailed Duck	2	2	0.1	1.8	–	–
Gavia arctica – Black-throated Loon	2	1	0.1	0.9	–	–
Grus grus – Common Crane	2	1	0.1	0.9	–	–
Milvus milvus – Red Kite	2	1	0.1	0.9	–	–
Ardea cinerea – Grey Heron	1	1	0.03	0.9	–	–
Larus ridibundus – Black-headed Gull	1	1	0.03	0.9	–	–
Dryocopus martius – Black Woodpecker	1	1	0.03	0.9	–	–
Garrulus glandarius – Eurasian Jay	1	1	0.03	0.9	–	–
Total identified birds	128	30	4.1	26.5	5	2
Esox lucius – Pike	109	13	3.5	11.5	–	–
Emys orbicularis – European Pond Turtle	1	1	0.03	0.9	–	–
Total identified	3138	113	100	100	252	100
Large Cervids (*Alces/Cervus*)	76	–	6	–	36	16.2
Antlers from Large Cervids	21	–	2	–	9	4.1
Large ruminants (*Alces/Cervus/Bos*)	583	–	45	–	101	45.5
Mammals of Wild Boar/Red Deer's size	143	–	11.1	–	–	–
Large ungulates	327	–	25.4	–	28	12.6
Middle size mammals	54	–	4.2	–	6	2.7
Small mammals	5	–	0.4	–	1	0.5
Mammals	76	–	6	–	40	18
Total unidentified mammals	1285	–	99.8	–	221	99.5
Unidentified birds	3	–	0.2	–	1	0.5
Total unidentified	1288	–	100	–	222	100
Total	4426	113	98	–	474	84.6
Red deer shed antlers	89	–	2	–	86	15.4
Total	4515	113	100	–	560	100

Notes: NSP, number of specimen; MNI, = minimum number of individuals.

related to the bone industry; minimum number of individuals (MNI), according to right and left skeletal part fragments, after Poplin (1976a, 1976b); minimum number of elements (MNE, Lyman 2008). The relationship between the frequency of anatomical parts identified (MNE) and the MNI leads to reconstruction of the distribution of skeletal parts, presented in percentages (%PO) – the ratio of 'found/expected' skeletal elements (Grigson and Mellars 1987, Bridault 1993) – which shows over- or under-representation of body parts relative to taphonomy, or carcass transport and/or processing.

Quantification of the material was thus conducted at different levels: species, individuals, anatomical parts, fragments and even at the level of cut-marks or
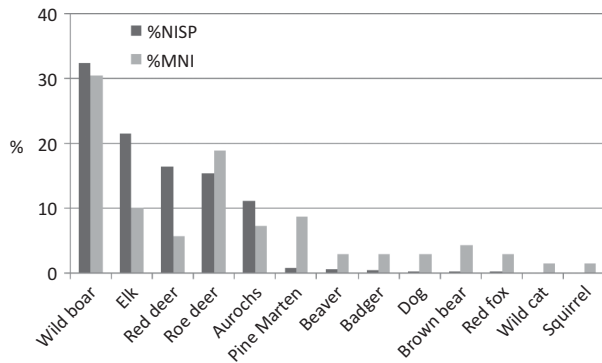
Figure 3.   Species composition of the Mullerup mammal bone assemblage, worked pieces included (Total NISP = 2900, shed antlers excluded).

manufacturing marks. The status of each species could thus be analyzed and described: establishing their frequency in the assemblage (number of fragments and number of individuals), evaluating the integrity of carcasses (skeletal part distribution), and reconstructing their exploitation through the reconstruction of the frequency of identified activities (analysis of butchery marks, bone breakage for marrow extraction, use of specific skeletal elements for bone tool manufacture, etc.). The latter issue requires identification of exploitation activities, from the interpretation of cut-marks, breakage marks and manufacture marks observed on bones.

Juvenile skeletal elements, mostly from very young animals, less than 6 months, are quite numerous as they account for 12.7% of the whole assemblage (NISP). These are mostly bone fragments belonging to the ungulate species in various proportions. Bone fragments from young individuals are more fragmented as a result of taphonomic processes because of their higher fragility than those from adults. This has consequences on the potential to identify the species (17.1% of the unidentified mammal bones and 32.1% of the unidentified fragments assigned to large ruminants are from young individuals) and sometimes the anatomical part itself. Moreover, considering each taxa separately, juvenile bones show fewer cut-marks than bones from adults. This can be due to taphonomic biases, resulting from biases observed in body part representation. In addition, most of the proximal and distal ends of juvenile long bones, which often have disarticulation cut-marks, are missing. This may also be due to specific transport strategies or butchering patterns for young individuals, perhaps less disarticulated than adults. Furthermore, young animals were never used as a source of raw material for bone tool manufacture (one exception being a metatarsal bone from a young elk with grooving marks), probably because very young bones, not completely grown, are more fragile and thus unsuitable for *debitage* or use. For these reasons, if both adult and

juvenile remains were used to compare the carcass exploitation of each species, they were considered separately for each taxon.

4.   Results

4.1.   Bone tool industry

4.1.1.   Species composition of the bone industry

About 12.4% of the whole faunal assemblage (identified or not) is related to the bone industry (Figure 4). These are complete or broken pieces (*n* = 240), including straight or barbed projectile points, fish hooks, various domestic tools made from bone (awls, points, hammers) or antler (axes, hammer-axes, adzes, punches) and personal ornaments made from teeth (David 1999, 2003a, 2003b, 2004), as well as waste (*n* = 306) and unidentified fragments (pieces or waste: *n* = 14) (Figure 5). This percentage must be considered a minimum as the manufacturing of an object does not necessarily leave traces on all the waste produced from one raw material.

Indeed, the important amount of waste (54.6%) suggests that production of bone tools took place on the site (David 1999, 2004). Mammal bones (antlers excluded) provided the majority of the raw material (69.5%). Since manufacturing processes often deeply modify the morphology of the bone matrix, specifically in projectile point manufacture (David 1999, p. 278, 2004 p. 264), many of the items cannot be attributed to one species or another (Figure 4; Table 2). However, for the most part, these unidentified pieces can be assigned to large mammals such as elk, red deer and aurochs (64.6%).
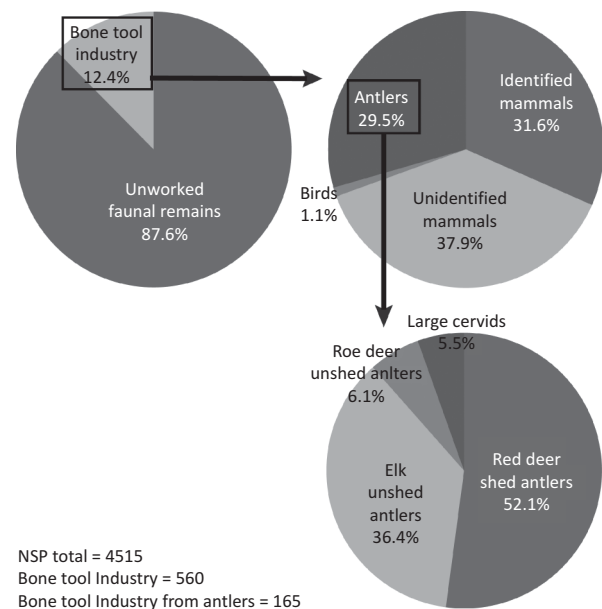

Figure 4.   Bone tool industry frequency among the whole faunal assemblage and composition.
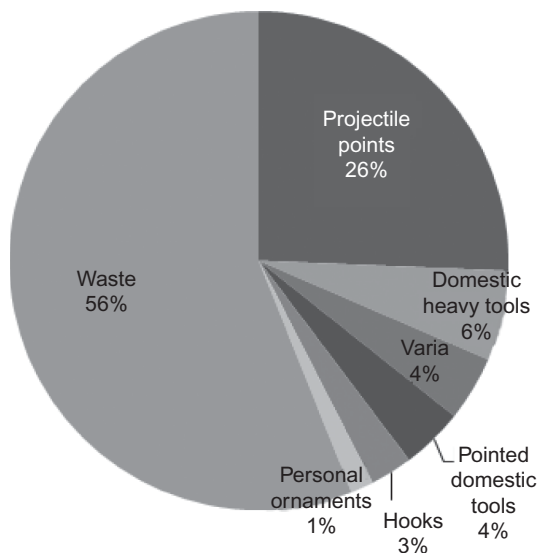
Figure 5. Composition of the bone tool industry, according to large typological categories (see David 1999, 2004, Leduc 2010b): domestic heavy tools refer to adzes, axes, and hammers; pointed domestic tools refer to awls and small points which are not interpreted as projectile points.

4.1.2. Antler exploitation

A third of the raw material used for the manufacture of tools is from cervid antlers (Figure 4; Table 2). Antler exploitation differs from one species to another. Red deer antlers are predominant (52.1%). Seven antler bases are present, all from shed antlers and the 89 fragments of red deer antler identified in the assemblage (96.6% are pieces or waste from the bone industry) could theoretically (Bridault *et al.* 2009) come from these seven antlers, from adult red deer, considering the size and the detailed origin (stump, tine, beam, crown, terminal tine, etc.) of each fragment (Figure 6). As red deer heads and unshed antlers are missing (see below), it can be assessed that only shed antlers were exploited on the spot, for making tools. These antlers were quite intensively exploited: mostly axes, adzes, and punches were made from the different antler parts, and the presence of abundant waste also suggests that manufacturing activities took place at the site.

In contrast, elk and roe deer antler fragments are very likely all from unshed antlers, i.e., removed from animals hunted and at least partially exploited on site. For elk antlers, 71 fragments are present and 84.5% of these are

Table 2. Taxonomic composition of the bone tool industry from Mullerup.

| Taxa	Piece	Waste	Unidentified	Total	%
Red deer	9	62	–	71	12.7
Roe deer	16	29	1	46	8.2
Elk	11	16	–	27	4.8
Wild boar	10	6	1	17	3
Aurochs	9	4	–	13	2.3
Dog	2	–	–	2	0.4
Bear	–	1	–	1	0.2
Castor	–	–	–	–	–
Total (identified mammals)	57	118	2	177	31.6
Large cervids	27	9	–	36	6.4
Large ruminants	60	34	7	101	18
Large ungulates	16	10	2	28	5
Mammal (middle size)	6			6	1.1
Mammal (small size)	1	–	–	1	0.2
Mammal (unidentified)	34	6	–	40	7.1
Total (unidentified mammals)	144	59	9	212	37.9
Red deer antlers (shed)	24	61	1	86	15.4
Elk antlers (unshed)	5	55	–	60	10.7
Roe deer antlers (unshed)	1	9	–	10	1.8
Large cervids antlers	8	1	–	9	1.6
Total (antlers)	38	126	1	165	29.5
Mute swan	–	1	2	3	0.5
White-tailed eagle	–	1	–	1	0.2
Great crested grebe	1	–	–	1	0.2
Birds (unidentified)	1	–	–	1	0.2
Total (birds)	2	2	2	6	1.1
Total	241	305	14	560	100
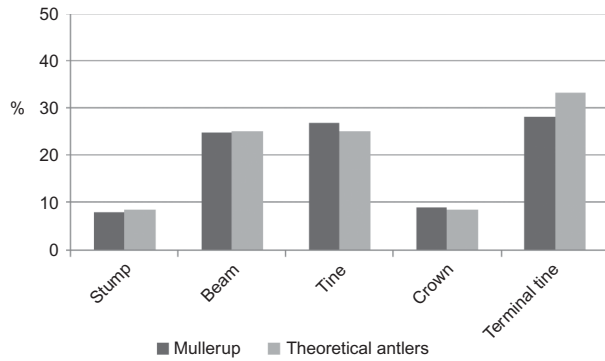
Figure 6. Repartition of the red deer antlers fragments from Mullerup, in comparison to the number of similar fragments from seven theoretical antlers (according to Billamboz, 1979, p. 96, i.e., one antler with two beams, three main tines, one crown with four terminal tines).

Figure 7. Taxinomic composition of the Mullerup bone assemblage (a, excluding European pond tortoise – *Emys orbicularis*, *n* = 1) and of the Mullerup bone industry (b).

related to the bone industry. Only two bases are present, both from unshed antlers from two different individuals. Elk antlers are highly fragmented, in very small fragments mostly coming from the palm, from upper or lower faces that are often separated. This is due to very high desiccation that occurred after the excavation and which preferentially affected flat elements, among them elk antlers. In consequence, it is more difficult to determine whether all of these antler elements came from these two unshed antlers or whether some pieces were from other antlers for which the bases are missing.

Roe deer antlers (*n* = 16) are more numerous in terms of individuals, as six right antlers and five left antlers are present (after refitting); all are unshed antlers. Nine can be considered as waste from *debitage*, showing a very specific breakage pattern, close to the base: 'flexion-break' or nicking for 'prepared breakage' (David 1999). Thus, the distal ends were the sought parts, but only one finished piece, a hook made from the distal end of a roe deer antler, has been discovered (n° M497, David 1999, pp. 178–179, fig. 51, 2004, pl. 5, n° 15). It is not possible to state with certainty that this piece was made on the site, from one of the unshed antlers discarded at Mullerup, and it appears that, except for this one, the distal ends are missing, perhaps transported to another site (as finished pieces?) or lost during utilization outside the site.

4.1.3. Bone and teeth exploitation

When we examine the industry made on bones and teeth (antlers excluded) and pieces that have been positively identified to species (Figure 7 and Table 2), we see that the cervids are the main species group used for the bone tools (81% of the bone industry NISP), mostly for straight or barbed projectile point manufacture from metapodials and ribs, or for hooks and awls from long bones. For this
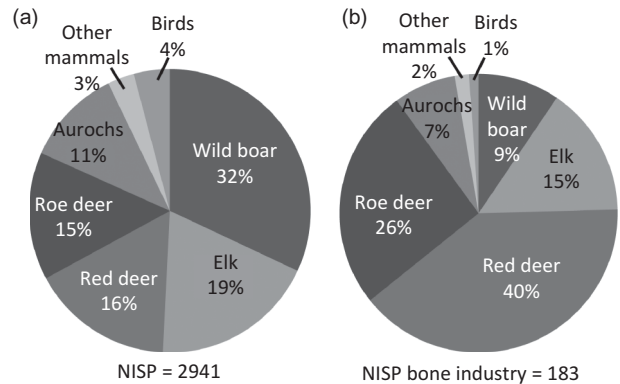
purpose, red deer, whose bones yielded 40% of the raw material, is the most commonly used species. Roe deer is also very well represented (26% of the bone industry NISP), notably because of the use of their metapodials and tibia for making tools or points, as is also seen for elk (15% of the bone industry NISP), for which the ribs were also used for barbed points and a couple of teeth for personal ornaments. Aurochs was used for a few worked pieces (9% of the bone industry NISP), mostly metapodials for heavy tools such as adzes and hammers (David 2002). Wild boar, while the dominant hunted species (Figures 3 and 7), was used for only a few finished pieces (9%), mostly tools made from male tusks and waste resulting from the *debitage* of a few tibias. The other mammal species are rarely used for making bone tools: two canines from dog (*Canis familiaris*) were perforated for making personal ornaments and one proximal end of an ulna from an adult bear, which is waste from *debitage*.

The use of bird bones also remains marginal (1.1% of the bone industry NISP). Only a few long bones from mute swan (*Cygnus olor*; *n* = 3), white-tailed eagle (*Haliaeetus albicilla*; *n* = 1), and great crested grebe (*Podiceps cristatus*; *n* = 1) and one piece from an unidentified species are present, mostly waste showing scraping or sawing marks. A humerus from mute swan with incisions forming a V-shaped design is also noted (Leduc 2010b, p. 166).

Thus, while mammals, and particularly ungulates, are the main species hunted and also the main species supplying raw material for the bone tool industry, the different species do not have the same value for this purpose. For instance, the mentioned opposition between the involvement of wild boar and red deer in hunting strategies and in the bone tool industry suggests different status of these species and different uses of their resources and may imply different exploitation patterns.

4.2. Hunting strategies for ungulates

This section, and before discussing the specific question of differential exploitation of species, focuses on the acquisition of animals, through the reconstruction of mortality profiles of the five ungulates, in order to identify possible differential hunting strategies. Unfortunately, the data allowing identification of age and sex are often scarce at Mullerup and the results are quite limited.

4.2.1. Wild boar

At Mullerup, a minimum number of 21 individuals were identified. Isolated teeth and mandible or maxillary fragments (number of teeth = 127) were used for age determination, using accurate references concerning tooth eruption and development (Matschke 1967, Carter and Magnell 2007, Magnell and Carter 2007), and use-wear patterns (Varin 1977, 1980, Iff 1978, Habermehl 1985). As precise age assessment of adults (more than 3 years) is problematic considering the large individual variation, the mortality profile (Figure 8) has been balanced for adults (division of larger age groups). It shows that the wild boar hunted population is divided in two categories of individuals (Leduc 2010a, 2010b, p. 204). First, very young individuals were hunted (44.4% of individuals are less than 6 months old; 31.5% of the number of teeth). Second, adults more than 3–10 years old are present (50% of the individuals; 63% of the number of teeth), mainly young adults from 3 and 5 years (five individuals).

The young individuals are mostly 2–5 months years old (M1 not yet erupting but present as complete crown in the cavity). Individuals from 6 to 12 months are absent, as well as from 14 to 24 months old (one individual was killed when 13 months old). Indeed, individuals aged from 6 to 12 months would normally be easily identified, showing erupted M1 with no wear or in a very early stage, but a not yet erupted M2, and also those from 18 to 24 months, showing erupted M2 and permanent premolars, and a not yet erupted or erupting M3. If we consider that there is no differential preservation between these individuals and the younger ones, we can thus argue for a real absence of individuals in these age classes. The lack of these age classes most likely reflects seasonal hunting, during the warmer half of the year.

The wild boar sex-ratio for adults, estimated from a combination of osteometric data from the scapula, compared to data from modern and Mesolithic wild boar (Magnell 2005, 2006), and canine[3] morphology, is six females to three males. At Mullerup, we can thus conclude that Maglemose people hunted mainly sounders, i.e., females with their offspring, and a few solitary adult males.

4.2.2. Red deer and elk

The red deer yielded very few teeth remains. Three individuals have been identified: one juvenile between 3 and 6 months old (one mandible fragment with deciduous P3 and P4 without wear, cf. Riglet 1977, Habermehl 1985) and two adults between 6 and 7 years old (three complete mandibles) according to the wear stages (Habermehl 1985, p. 29, Brown and Chapman 1991). As teeth are rare,
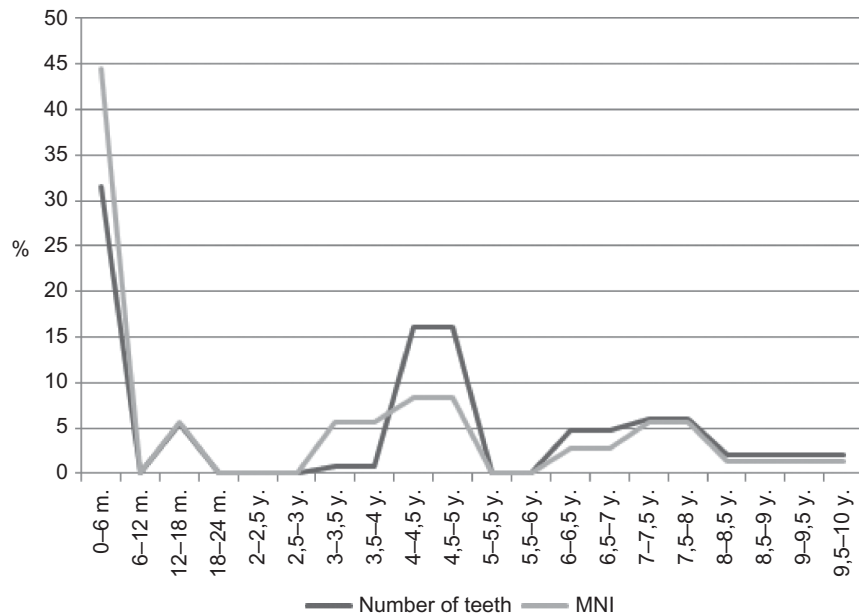

Figure 8. Wild boar mortality profile at Mullerup (number of teeth = 127; number of individuals = 18).

examination of epiphyseal fusion and bone development stages has been used to assess the age of red deer (Habermehl 1985). This led to the identification of four young individuals under 3 months old and five individuals over 36 months (Leduc 2010b, pp. 215–217).

Since antler fragments all come from shed antlers and skull fragments are rare, only few osteometric data could be used to attend to assess sex-ratio from red deer bones. The results show very high values, higher to actual males values (Boessneck *et al*. 1963) evidencing possibly three stags (Leduc 2010b, pp. 218–222). These data are also high in comparison with data from other Mesolithic sites, such as Star Carr, in England (Legge and Rowley-Conwy 1988, p. 54) or earlier Mesolithic sites from Kongemose or Ertebølle contexts (Noe-Nygaard 1995) and Neolithic contexts (cf. Seeberg Burgäschisee-Süd in Switzerland, Boessneck *et al*. 1963). But data from other Danish Early Maglemose sites also show high values (Bille Henriksen *et al.* 1980; Noe-Nygaard 1995) and could be related to higher sizes in red deer populations from this period in Scandinavia.

Regarding elk, only 21 dental elements allowed the identification of five individuals of different ages. Two individuals are 2.5 months old and one is approximately 1 year old (Habermehl 1985). Two individuals are adults, approximately 2–3 years old and approximately 4 years old (Quimby and Gaab 1957, pp. 441–443, Jensen 2001). But, like the red deer, examination of epiphyseal fusion and bone development stages (Habermehl 1985) increased the number of individuals: one more young individual and three more adults, over 36 months old, were identified (Leduc 2010b, p. 211). As stated above, the presence of two antlers of different morphology and size suggests the presence of two males. Rare osteometric data (atlas) confirm the presence of one male, in comparison with actual and archaeological data (Chaix and Desse 1981).

Concerning red deer, excluding the autumnal rut period during which stags are following hind groups, mature individuals form single-sex groups, hinds living with their offspring while stags are often solitary or forming small groups when they are young (Macdonald and Barrett 1995, Geist 1998). On the other hand, elk are more solitary, females staying with their offspring. But during and after the rut, elk form small family groups and occasionally gather in larger groups during winter (Macdonald and Barrett 1995, Geist 1998). Although, here, data are too weak to infer a real predominance of stags for the two species. Moreover, the presence of four young red deer and three young elks confirms that family groups were hunted. We can thus suggest that red deer and elk acquisition likely combined two different hunting strategies, in early summer before the rut period, when some of them were hunted: first, the hunting of herds of hinds with juveniles and, second, the hunting of solitary stags or herds of stags.

4.2.3. Roe deer

Nine individuals have been identified and aged from roe deer dental remains (*n* = 22 elements; 53 teeth). According to erupting and wear stages (Tomé 1999, Carter 2001, 2006, Tomé and Vigne 2003), one individual is 3–4 months old, five individuals are between 12 and 20 months old (among them two individuals approximately 15 months old), two are about 2 years old and one is over 3 years old. Young individuals are better represented by post-cranial elements, as four individuals are less than 9 months old according to analysis of epiphyseal fusion and bone development stages.

As presented above, six males are identified from complete or almost complete skulls wearing unshed antlers. The examination of the pelvis morphology (Boessneck *et al*. 1963, p. 112) allowed the identification of three males and two females.

Thus, for roe deer, considering the sex ratio from skull elements that are most numerous, and bearing in mind the small number of individuals, hunting strategies could have been mostly directed toward subadult and adult males, but did not exclude females and young individuals. As roe deer did not reach their maximal weight before reaching 2–3 years in age (Tomé 1999, p. 53), we can probably exclude the search of maximal meat weight as motivation for hunting of males. However, subadults and young males often form small herds during the rut period (Legge and Rowley-Conwy 1988, Tomé 1999), probably making them more vulnerable. On the other hand, the search for antlers could have been another motive, as they are all removed from skulls, despite the scarcity of clearly manufactured pieces from roe deer antlers on the site.

4.2.4. Aurochs

Excluding the two perforated teeth that could have been transported to the site as finished pieces, dental remains from aurochs are rare (*n* = 3). One complete maxillary bone with all the permanent teeth, without very deep wear is from an adult, and two isolated teeth (lower M2 and upper P4) are probably from another individual, an old adult showing advanced wear. The epiphyseal fusion stages from post-cranial elements (Habermehl 1975) allowed the identification of three young individuals (two less than 3 months old and one 3–10 months old), one individual less than 30 months old, and two adults more than 36 months old. Concerning the sex identification, according to the pelvis morphology and osteometric data (pelvis, horn core, scapula, femur, tibia), one female and four males have been identified.

Thus, although small herds of females with their offspring were hunted, adult males may have been a preferential target for hunters at Mullerup. Hunting large males can be considered more dangerous for hunters, but more profitable in terms of meat quantity and perhaps also of greater value from a symbolic point of view. If we

consider that these hunting episodes occurred during the warmer months, they could have occurred during the rut period, when males joined the females (Van Vuure 2005, p. 271), making them easier to find and hunt.

Since the duration and the number of occupations at Mullerup are not known, it is difficult to interpret hunting strategies at the scale of occupation. At the site scale, hunting strategies for the five ungulates seem to be quite similar, i.e., without real selection aimed toward specific individuals. However, complementary strategies depending on species could have occurred, showing a kind of gradient concerning the presence of adult males as target. Boars were occasionally hunted, males are present among the large cervids, and finally, males are the main target for roe deer and aurochs. Bearing in mind the small number of individuals for each taxa and the relative weakness of age and sex data, preventing clear conclusions, this gradient, if reflecting real hunting strategies, could be due to specific needs: meat and specific raw materials such as boar tusks, big and strong long bones, antlers. Though, at Mullerup, evidence supports rather several successive hunting episodes that were more or less selective depending on species and immediate needs.

4.3. Exploitation patterns

4.3.1. Wild boar

At Mullerup, under-representation of wild boar axial skeletons (Figure 9) can partly be explained by taphonomic

reasons: vertebrae and ribs are often less preserved and less identifiable to species level in archaeological contexts than are long bones (Lyman 1985, 1994). This could also be due to selective collecting and the lack of sieving, which would also account the under-representation of lower extremities such as phalanges and sesamoid bones. However, such bones could also be absent due to specific treatment of hides, for instance. They could have been still attached to the skin when removed. Despite these losses, which could be explained by taphonomic reasons or excavation methods, and perhaps by selective behaviour linked to hide treatment, wild boar skeletal parts are well represented, particularly by heads and limb bones. All parts of wild boar carcasses must have been transported to the site, as a whole or as large portions of carcasses, after disarticulation of some elements (limbs, head).

More than a third of wild boar anatomical elements (36.3% of MNE) have cut-marks from different activities. Hide and sinew removal is suggested by specific cut-marks on skulls and lower extremities. Disarticulation is widely represented, at each articulation (to a lesser extent at the knee), and all the fleshy parts show cut-marks from meat removal. Finally, all long bones, but also mandibles, and first and second phalanges were broken for marrow extraction. Only 2% of the bones from wild boars were used in the bone tool industry. These are mainly complete male tusks ($n = 8$), which often show some scraping marks on the occlusal surface. Two other pieces are interpreted as used as 'Knives' and one more, which is shaped on a longitudinal enamel
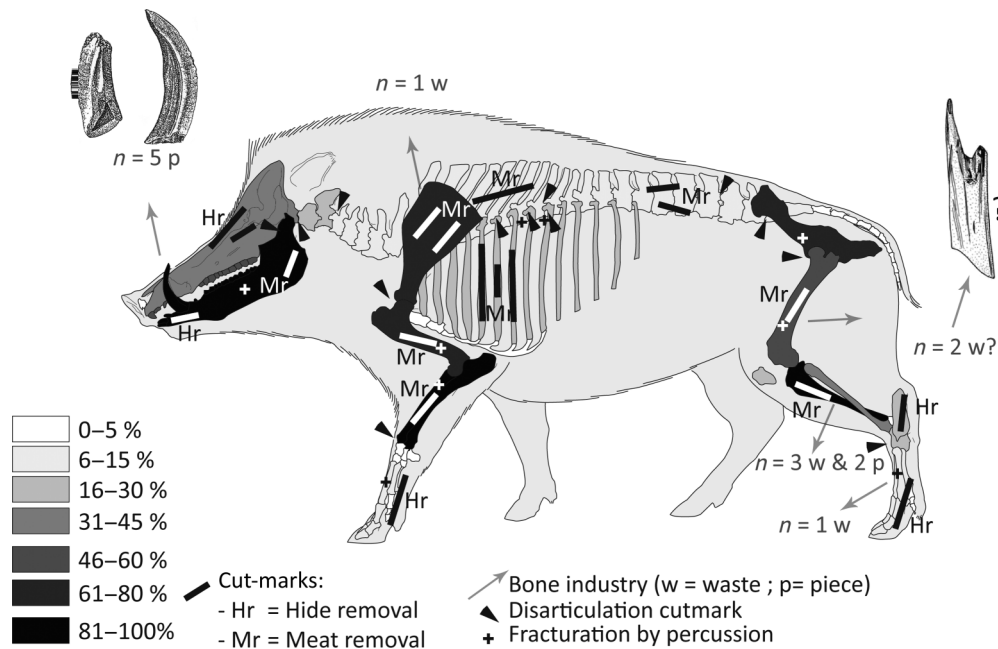

Figure 9. Skeletal part, cutmark and bone tool industry distribution for adult wild boar at Mullerup (NISP = 837; MNE = 465; MNI = 16). Drawing of the wild boar: M. Coutureau, after Pales & Garcia (1981); bone tool industry drawings from E. David (1999; 2004) and G. F. L. Sarauw (Sarauw *et al.* 1903).

fragment, as an 'adze blade' (Sarauw *et al.* 1903). Some of these tusks could have been transported from another site as finished pieces, given that males are not very well represented in the assemblage. A few bone fragments are tool-making waste (*n* = 6) from tibia, femur, scapula and metapodial. The use of wild boar bones as raw material for the bone tool industry seems, however, to be occasional.

4.3.2. Red deer and elk

The red deer and elk skeletal part distribution shows that the axial skeleton is under-represented, likely for taphonomic reasons (Figures 10 and 11). Yet the attested use of ribs in the bone tool industry, for making the numerous barbed points, could also partly explain such under-representation. At Mullerup, waste and tools from large ruminant ribs are numerous, but difficult to attribute to one particular species given that they are fragmented and deeply worked (e.g., scraped).

Red deer heads are nearly absent and the reason of such absence is not very clear. If we consider a predominance of stags but the absence of unshed antlers, one can suppose that red deer heads could have been left at the kill-site or discarded elsewhere. Elk heads are better-represented, possibly for the use of unshed antlers, and thus selected to be transported to the site. Like wild boar, cervid lower extremities may be missing due to collecting techniques during excavation or a specific hide treatment. In contrast, fleshy parts and metapodials in particular are well represented. All elk skeletal parts are generally less well represented than red deer: all bones are present but often under-represented relative to the scapula and pelvis bones. It can be inferred that elk may have been sometimes transported to the site as large carcass portions, favouring specific pieces such as the fleshy upper legs. This could also be the case, to a lesser extent, for red deer carcasses of which the heads were removed and probably left at the kill-site.

Considering the red deer skeletal part distribution, the over-representation of metapodials is striking and must be clarified (Figure 12). Quantification of metapodial fragments indicates the presence of 10 individuals (10 left
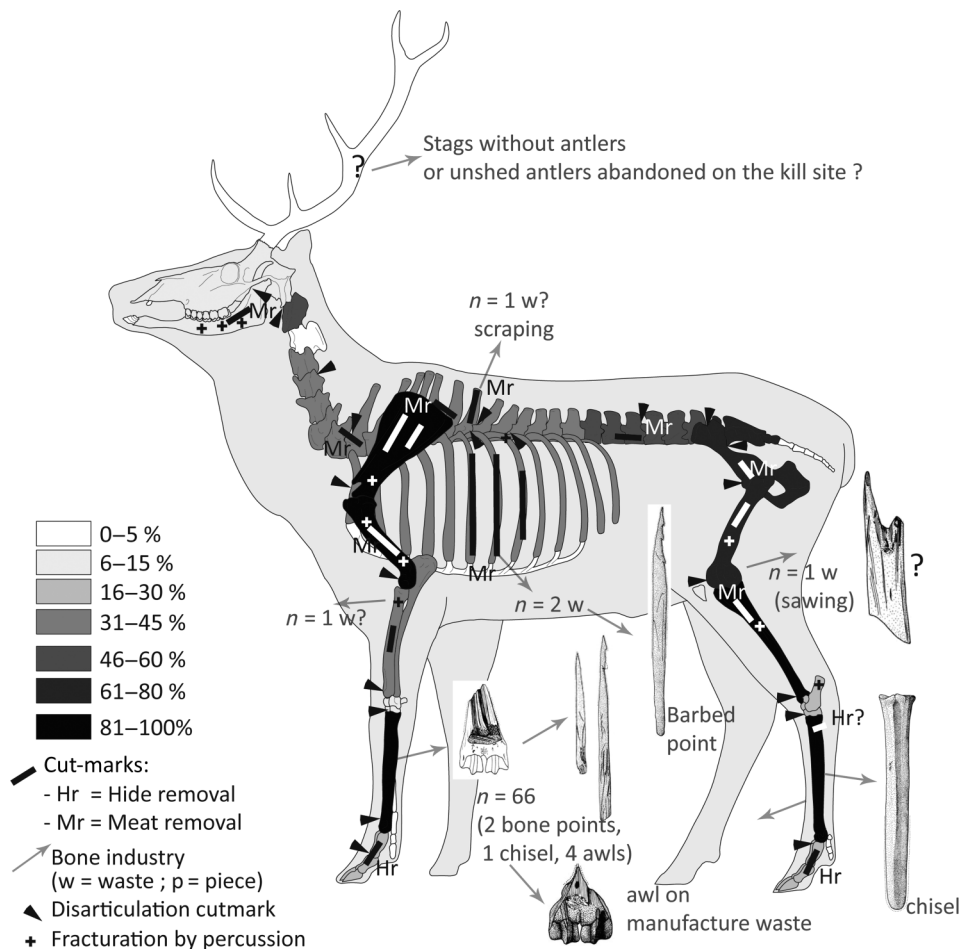

Figure 10. Skeletal part, cutmark and bone tool industry distribution for adult red deer at Mullerup (NISP= 405; MNE= 203; MNI= 4 [metapodials are excluded for the calculation of MNI, see in the text]). Drawing of the red deer: J.G. Ferrié (2004), modified after "Reindeer" (C. Beauval). Bone tool industry drawings from E. David (1999; 2004).
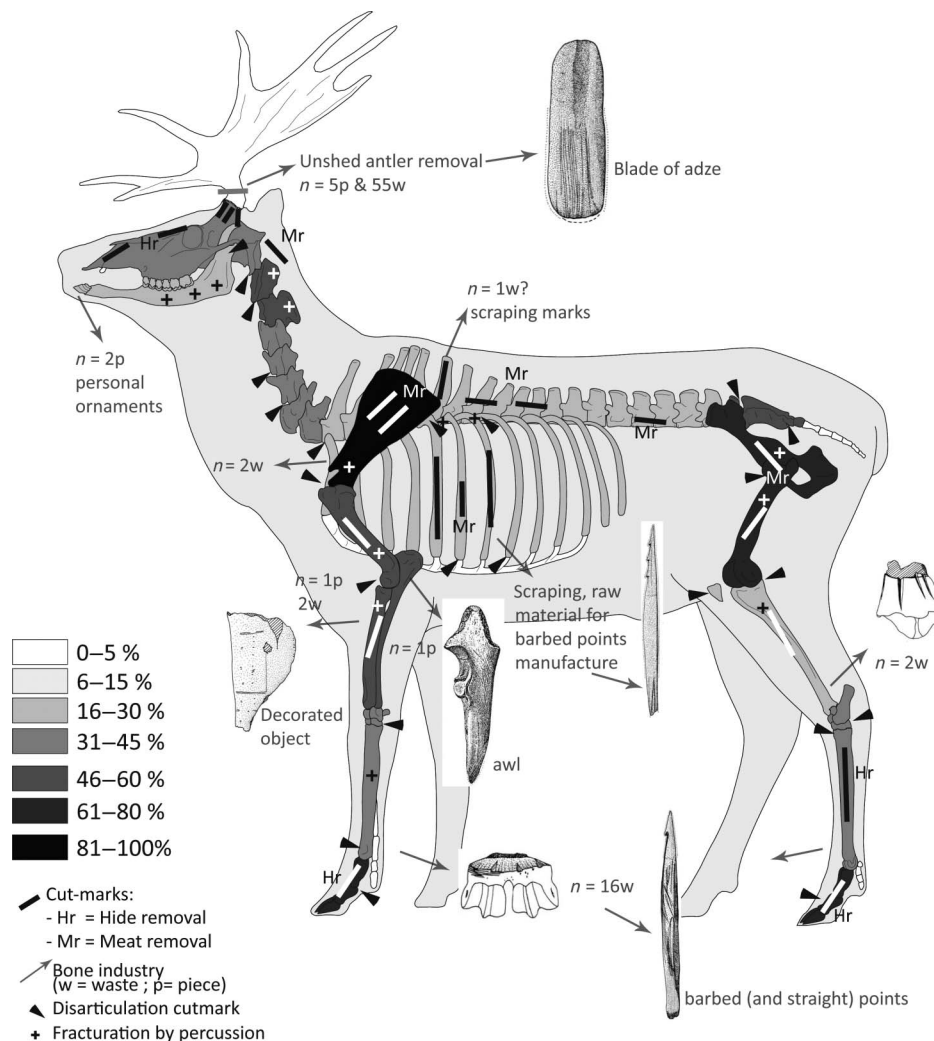
Figure 11. Skeletal part, cutmark and bone tool industry distribution for adult elk at Mullerup (NISP= 559; MNE= 260; MNI= 5). Drawing of the elk: "red deer" J.G. Ferrié (2004), modified after "Reindeer" (C. Beauval); antlers: C. Leduc. Bone tool industry drawings from E. David (1999; 2004).

metatarsal bones) whereas all of the other anatomical parts point to only four individuals. This can be considered as a real over-representation since it is as for all long bones based on the number of epiphyses.

Furthermore, all the metapodial fragments are waste or fragments of finished pieces from bone weapon production (NISP = 66), nearly exclusively for bone points, using a very standardized method of manufacture, the 'method D' as defined by David (1999, 2003a, 2003b, 2004). This method includes specific calibration techniques of the bone (e.g. removal of axial flakes from the upper articular surface, using wedge-splinter technique and dotted perforation of the upper articular surface; and drilling technique for taking off distal ends) before grooving for getting long products.

Therefore, such over-representation of metapodials may reflect systematic selection of these parts for the bone industry. This issue led to the hypothesis that some

of these metapodials could have been imported from another site as raw material in order to make some of the very abundant bone points. Thus, some of these metapodials would have been not extracted from the red deer carcasses exploited at Mullerup, but from other red deer carcasses exploited elsewhere. Following this hypothesis of additional imported metapodials, and taking into account the discrepancy between the MNI relying on the metapodials (10) and the one considering other long bones (4), the skeletal part distribution was thus calculated considering the smallest MNI data, probably more close to the relative importance of the species, in terms of individuals exploited onsite at Mullerup (Leduc 2010a, 2010b, p. 271).

Elk metapodials were also quite often used in the bone tool industry, as 71.4% of the metapodial fragments are finished pieces or waste, again mostly for bone points. This use is thus very important, but not as systematic as
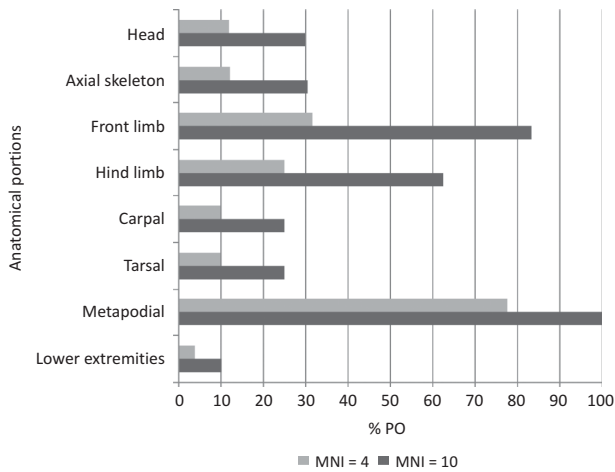
Figure 12. Red deer anatomical portions distribution, according to MNI = 10 (number of metapodials) and MNI = 4 (number of other bones), given in %PO = the ratio of 'found/expected' skeletal elements (Bridault 1993, after Grigson and Mellars 1987).

for red deer. Moreover, unlike red deer, these bones do not appear to be over-represented and we cannot infer the importation of some of these bones as isolated raw materials.

Around 40% of the red deer and 38% of the elk anatomical elements show cut-marks. Hide and probably sinew removal can be inferred from a few cut-marks on phalanges. Disarticulation cut-marks are visible on red deer first vertebrae and mandibles. This supports the hypothesis of a specific treatment of red deer heads that were removed and left at the kill-site. Elk heads were also removed, but for some of these, likely at Mullerup where they were then discarded. Disarticulation can also be seen at each joint for both species and suggests that the majority of carcass treatment took place at Mullerup. Evidence of meat removal is broadly present on every fleshy bone. Like wild boar, all of the long bones, mandibles, and first and second phalanges were broken for marrow extraction.

More than 17% of red deer bone fragments are waste or finished pieces from the bone industry. These are rib fragments (*n* = 2), probably for barbed points (David 1999, pp. 210–212, figs. 67 and 68, 2003a, p. 81, fig. 7), long bones represented by radius (*n* = 2), femur (*n* = 1), and metapodials (*n* = 66), almost exclusively for the manufacture of bone points (David 1999, 2003a, 2003b, 2004, Leduc 2010b). Elk bones (excluding antlers) were less often used for the bone industry (only 5.3%). These include two perforated incisors, a few long bones (one decorated piece and two waste pieces from a radius, two waste pieces from a tibia and one awl from an ulna), a few pieces from ribs and thoracic vertebrae (*n* = 3) and bone points and waste from metapodial *debitage*.

4.3.3. Roe deer

Taphonomic processes and the lack of sieving would have more significantly affected roe deer bone than the other ungulates since this is the smallest species among them. This could explain the under-representation of some fragile bones (Figure 13) such as ribs and vertebrae, and small bones such as phalanges, sesamoids, carpals, and tarsals. We can thus infer that roe deer must have been transported as whole carcasses since the heads and long bones are well represented. Along with the scapula, heads are the best-represented skeletal parts and the need for antlers could explain this. Skulls are often complete or almost complete and antlers are fractured at their basis or under the fork, and thus easy to identify within the whole bone assemblage, while long bones were highly fragmented for marrow extraction.

Only 29.3% of roe deer anatomical elements have cut-marks, primarily for disarticulation and meat removal. This lower percentage could be related to the size of the animal. It is possible that roe deer were more easily disarticulated than other ungulates, using 'flexion' techniques, i.e., without cutting as far as reaching the bone. The well-represented heads and the atlas rarely show decapitation cut-marks. We also suggest that roe deer were not treated in the same way because of their smaller size, i.e., not completely disarticulated or boned before consumption.

A large part of the roe deer bones were used as raw material (11%, antlers excluded). Some finished pieces were made from anatomically unidentified long bones, including barbed and straight points, awls and one personal ornament; waste from long bones is also present. Like red deer and elk, the bones most commonly used as raw material are the metapodials, 60.4% of which are related to the manufacture of points.

4.3.4. Aurochs

Unlike the roe deer, aurochs bones undergo less taphonomic degradation and are easier to collect and identify as they are bigger and thicker than those of the other ungulates. Thus, the skeletal part distribution likely reflects a real picture of which aurochs parts were discarded at Mullerup (Figure 14). All skeletal parts are present, but are often under-represented, relative to the MNI of five, calculated from the number of scapula and pelvis which are the best represented bones. This may be due to selection of the fleshiest parts of most of the carcasses, such as the upper legs, to be transported and consumed at the site. But the absence of some long bones such as humerus or femur may suggest intense disarticulation offsite, in order to take only the pelvic or pectoral girdles. We note that two scapula fragments are waste from point manufacture and could thus partly explain why these bones were

Figure 13. Skeletal part, cutmark and bone tool industry distribution for adult roe deer at Mullerup (NISP= 433; MNE= 239; MNI= 13). Drawing of the roe deer: J.G. Ferrié (2005), modified after "Red deer". Bone tool industry drawings from E. David (1999; 2004).

Figure 14. Skeletal part, cutmark and bone tool industry distribution for adult aurochs at Mullerup (NISP= 292; MNE= 178; MNI= 5). Drawing of the aurochs: M. Coutureau, after skeleton from the Angoulême Museum (2009). Bone tool industry drawings from E. David (1999; 2004).

selected to be transported to the settlement site. Under-representation of aurochs bones may also be due to the transport of boned meat to the settlement site or to the discarding of butchering waste elsewhere, specifically concerning this species. The metapodials are also under-represented but are all (*n* = 6) waste or pieces associated with heavy bone tools. It is not possible to determine with certainty whether these objects (adzes, hammers) were made from the aurochs carcasses processed at Mullerup. Indeed, such pieces could have had a 'long' use life, longer than weapons, and could thus have been transported to the site as finished pieces and discarded after being broken. Like the large cervids, the under-representation of ribs may be due partly to their use in the manufacture of barbed points, since waste and finished pieces (*n* = 3) resulting from such use is present. Finally, the lack of lower extremities and coccygeal vertebrae may be interpreted as resulting from hide removal or discard at a primary butchering site. The importation of selected carcass portions for aurochs can be easily understood in terms of transportation constraints, as the species is the largest ungulate known during the Mesolithic (approximately 800 to 1000 kg for a male; Guintard 1999, p. 10).

Around 40% of the aurochs anatomical elements have cut-marks. Like the other ungulates, the most represented cut-marks result from disarticulation (legs, trunk, head) and meat removal (head and upper legs), but many cut-marks indicating hide removal are visible on one skull and some phalanges. Only 4.5% of the aurochs bone fragments were used in the bone industry, mostly metapodials and the flat bones scapula and ribs.

5. Discussion

The five ungulates – wild boar, red deer, elk, roe deer, and aurochs – together form the basis of subsistence and furnished raw materials for a very large part of material culture production at Mullerup. The hunting of these animals does not appear to have been very selective but rather occurred in successive hunting episodes, during the warm season, in addition to the acquisition of small mammals, birds, and fish.

Regarding the five ungulate species, the exploitation for dietary products, such as meat and marrow, has been very intensive. This is shown by the high number of cut-marks related to disarticulation and meat removal, involving every skeletal part of each species, in quite uniform proportions. Only roe deer showed fewer cut-marks but as suggested, this could be due to specific butchering patterns. The removal of hides is suggested for each species, but often by very little evidence, such as specific cut-marks on skulls, metapodials, and phalanges. However, the general under-representation of the lower extremities and the absence of coccygeal vertebrae may indicate the removal of hides, processed onsite or elsewhere. One

common feature is the systematic breakage of all marrow-yielding bones, including mandibles, and bones that yield very little marrow, including the first and second phalanges and some tarsal bones (calcaneus). Such intensive marrow extraction is well known in Maglemose contexts and has been described at several Maglemose sites (Friis Johansen *et al*. 1919, Broholm *et al*. 1924, Bille Henriksen *et al*. 1976, Bille Henriksen *et al*. 1980, Andersen *et al*. 1982). The bone breakage patterns for marrow extraction observed at Mullerup are very similar to those known from Maglemose sites and to those described in detail by Noe-Nygaard (1977, 1987, 1995), for early Danish Mesolithic sites. The very specific breakage of the mandibles, along the tooth row, possibly to extract the fat which surrounds the nerves into the *canalis mandibulae*, has been described by Møhl (1978) at Skottemarke and Favrbo, and is also known at Lundby Mose (Møller Hansen 2003, Møller Hansen *et al*. 2004, 2006, Leduc 2010b), and could thus be a particular characteristic of the Maglemose bone breakage pattern, since the earliest phases of this culture.

While there are clearly common patterns in the exploitation of ungulates, when examined in more detail, carcass exploitation patterns vary for each species (Figure 15), depending mainly on transport practices, but also on raw material needs.

Wild boar and roe deer would have been transported as whole carcasses to the site (Figure 15). Carcass processing took place at Mullerup. For wild boar, such exploitation mainly focused on dietary resources. However, some skeletal parts were used for the bone industry, mainly male tusks, among which some were possibly imported. Roe deer supplied additional raw materials, including antlers and long bones, mostly metapodials, which were quite often selected to make tools and weapons.

After removal of the head, red deer may have been transported as whole or sometimes large carcass pieces, selected for both meat and raw material. A similar pattern, but more significant, can be seen for elk, for which transportation as pieces of carcasses seems to have been more frequent, probably due to its bigger size. Metapodials must have been a priority in red deer exploitation and to a lesser extent also for elk as they are over-represented and systematically used as raw materials for weapons. Some transport or storage strategies must have been developed for this purpose. This may be due to very important needs for projectile bone points, as these skeletal parts were quite exclusively used to manufacture such pieces, amounting to 54.7% of the pieces made of osseous material. The question of a preference for weapons using bone points during the Maglemose culture has been debated (David 1999, p. 269, 2004, p. 256) and remains open. The use of bone points as hunting weapons for large mammals and not only as fishing weapons is probable (Vang Petersen 2009, Leduc in press). But the presence
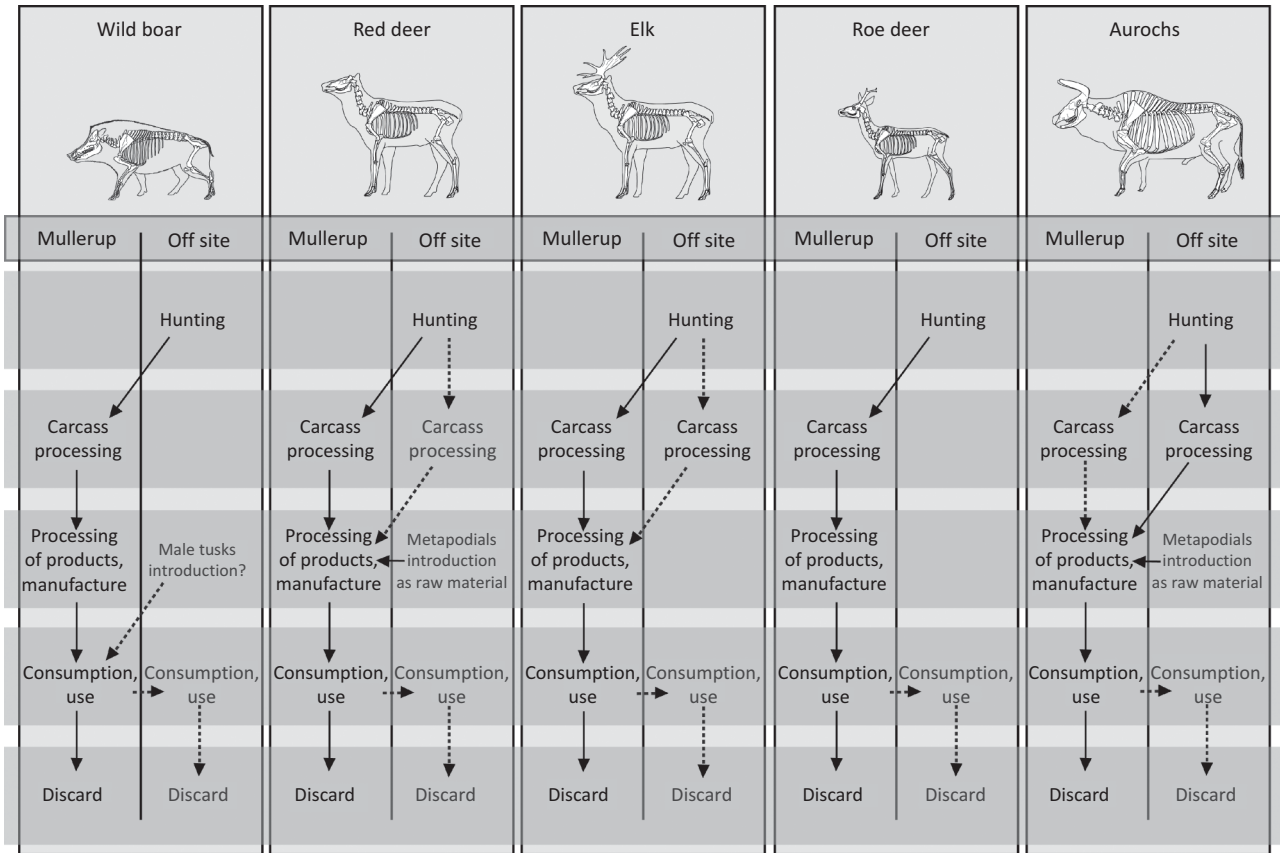
Figure 15.   Schematic animal exploitation patterns at Mullerup, for each ungulate.

at Mullerup of embedded lithic fragments in some bones (an aurochs rib, thoracic vertebrae from a young deer and wild boar), demonstrates the use of lithic arrowheads for hunting (Leduc in press). Other examples such as the discovery of Maglemose lithic arrowheads associated (and sometimes embedded), with aurochs complete carcasses at Vig and Prejlerup, in Zealand (Noe-Nygaard 1973, Aaris-Sørensen and Brinch Petersen 1986a; 1986b) also confirm this assertion.

Finally, the selective transportation of carcasses is more significant regarding aurochs for which the very large size required selection of the meat-yielding parts. Here again, the use of metapodials as raw material is systematic, but these bones are not very well represented and used only for heavy tools, thus exploiting the specific properties of these bones: big size, strength, and weight.

The importance of cervid metapodials for the Maglemose bone industry has already been discussed. Their abundance was noted early in Maglemose settlement bone assemblages (Friis Johanssen *et al*. 1919, p. 262, Bille Henriksen *et al*. 1976, p. 137). The detailed quantification of fragments and skeletal elements emphasize not only the abundance, but the over-representation of these bones at Mullerup. This might also be the case at other classical Maglemose settlements whereas metapodials are missing

from kill-sites or butchering sites, such as Skottemarke and Favrbo (Møhl 1978) and Lundby Mose (Møller Hansen 2003, Møller Hansen *et al*. 2004, 2006, Leduc 2010b). These latter sites, assigned to the very Early Maglemose culture, are older than the Maglemose settlement sites, for which such contemporaneous specialized sites, yielding preserved faunal remains, are unknown. It is thus not possible to establish clear contemporaneous links between sites where metapodials are missing and sites where they are over-represented. But, looking at the Maglemose culture as a whole, in Denmark, it can be concluded that cervid metapodials must have received particular treatment by means of selection, transport (import and export), storage, '*débitage*', and manufacturing (mainly bone points). This may also be the case, but to a lesser extent, for aurochs metapodials and wild boar tusks, which could also have been transported as finished pieces.

The circulation of such resources, between sites with different functions implies fragmented '*chaînes opératoires*' of exploitation, in different places, at kill-site/butchering sites and settlement sites, i.e., a disconnection in time and space of processing sequences, integrated in Maglemosian mobility, at local and regional scales. Unfortunately, data concerning the mobility of these early Mesolithic hunting societies are rare, and only

small summer settlement sites, with faunal remains, are known in Zealand. The chronological gap between the earliest kill/butchering sites during the Late Preboreal/ Early Boreal period and the classical settlement sites during Boreal and Early Atlantic period and the absence of winter sites prevent detailed reconstruction of the annual cycle of occupation and the Maglemose mobility pattern. But considering these few elements, probable mobility of small (family) groups (Grøn 1995), in a relative restricted area or with repeated seasonal occupations of the same areas, can be proposed. This was, for instance, discussed after the discovery and analysis of healed hunting injuries on some mammal bones (Noe Nygaard 1974, 1975, Leduc in press), suggesting a certain territoriality of animals and humans, probably at a seasonal level, during this period, and leading occasionally to the hunting of the same ungulate populations. While a kind of residential mobility or 'foraging system' (Binford, 1980) can be proposed from these few elements, the study of the Mullerup faunal assemblage suggests a more complex system, including some 'logistical mobility' for the acquisition of animal resources, as evidenced by the broken '*chaînes opératoires*' of animal exploitation and the circulation of raw materials. Expeditions for ungulate acquisition do not necessarily imply long distances since the immediate surroundings of the site offered particularly optimal conditions (lake, forest, marsh) for hunting not only ungulates but also waterfowl and for fishing.

6. Conclusion

The detailed analysis of the complete bone assemblage from Mullerup, the bone industry and faunal remains combined, provides relevant data to reconstruct the respective contributions of subsistence and 'technical' activities relative to animal exploitation, undertaken on the site. Such analysis, relying on rigorous methodology (quantification criteria, cut-mark analysis, etc.) and exhaustive study of all of the faunal remains enables a global view of animal resource management by the human groups occupying the site. The subsistence economy relies mainly on the exploitation of the five main ungulates, which supplied the most important parts of the diet. The exploitation of specific raw materials such as antlers, tusks, metapodials, ribs, or long bones to produce an abundant and standardized bone tool industry led to variations in exploitation patterns. Some specific results, in the first line those concerning the circulation of certain resources (e.g., metapodials) and their extrapolation to other Maglemose sites from published data, emphasize the role of animal resources in Maglemose socioeconomic organization and suggest that animal exploitation should be highly linked to the mobility of Maglemose hunter-gatherers. In addition, animal exploitation seems to be very standardized at the scale of Maglemose culture, in

Denmark, since the pattern described here seems to exist at other Maglemose settlements, with a very high predominance of ungulate exploitation, following standardized patterns for subsistence and the production of material culture.

Notes

1. Here, 'Mullerup' only refers to the site excavated by G.F.L. Sarauw in 1900 (Sarauw *et al.* 1903), also known as 'Mullerup Syd' (=Mullerup South) or 'Mullerup Sarauw's Island'.
2. According to the recent excavation of the Lundby Mose site, dated from 9650 to 9270 cal BC, averaged from three dates published by K. Møller Hansen *et al.* (2004).
3. Male tusks (lower canines) have been excluded for the calculation of wild boar sex-ratio (which relies mostly on female upper and lower canines, male upper canines and tooth alveolus morphology from maxilla or mandible) since these pieces are often manufactured or used as tools and thus, could have been transported to the site as finished pieces unrelated to the wild boar hunted at Mullerup.

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