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# Neanderthal ecology and the exploitation of cervids and bovids at the onset of MIS4: a study on De Nadale cave, Italy

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## Abstract

North-eastern Italy was a familiar region for Neanderthal groups, as attested by over 20 Middle Palaeolithic multi-layered sites in caves, rockshelters and at the open, investigated during the last decades. Of this large record, evidence pointing for human frequentation during to the Marine Isotopic Stage 4 is documented at a very ephemeral level. Here we contribute to shed light on a so sparse context through the presentation of De Nadale Cave, a single-layered Quina Mousterian site located in the Berici Hills and dated to 70.2  $\pm$  1/-0.9 ka BP. In the following article, zooarchaeological results are presented with important implications in hunting behaviour and subsistence strategies. The scarcity of comparative data from MIS 4 sites in continental and peninsular Italy does not provide hints for evaluating the significance of De Nadale in Neanderthal land-use, rather discussing differences on a diachronic scale with MIS 3 Middle Palaeolithic archaeofaunal assemblages in the same region.

**Keywords:** Zooarchaeology, Cervid, Bovid, Neanderthal, MIS 4, Italy



## 1. Introduction

Reconstructing Neanderthal subsistence strategies is one of the most challenging goals in prehistory and in paleoanthropological studies that researchers have been conducting for decades. This topic has been part of a long-standing argument into how similar or how different Neanderthals were to us (Grayson and Delpech, 2002, 2006; Discamps et al., 2011; Yravedra et al., 2016, among others). A large amount of papers has demonstrated that Neanderthals subsisted primarily on hunting herbivores, possibly complemented by scavenging (Grayson and Delpech, 1994; Stiner, 1994, 2005; Gaudzinski, 1995, 1996; Gaudzinski and Roebroeks, 2000; Speth and Tchernov 1983, 2001, 2007; Burke, 2004; Ready, 2010; Rendu, 2010, among others). Nevertheless, current studies hold that Neanderthals were skilled hunters of large mammals and that they had great behavioural flexibility, allowing them to exploit a wide spectrum of resources. Archaeological evidence attests, for example, the exploitation of marine food resources, including mammals, fishes and molluscs (Stiner, 1994, 2009/2010; Stringer et al, 2008; Colonese et al., 2011; Cortés-Sánchez et al., 2011; Hardy and Moncel, 2011; Nabais and Zilhão, 2019), of small game (Stiner et al., 2000; Hockett and Haws, 2002; Alhaique et al., 2004; Miracle, 2007; Blasco and Fernández Peris, 2012; Cochard et al., 2012; Carvalho et al., 2018; Romandini et al., 2018a; Morin et al., 2019), of birds, (Peresani et al., 2011; Finlayson et al., 2012; Romandini et al., 2014b, 2016; Blasco et al., 2016; Laroulandie et al., 2016) and of carnivores (Auguste, 2003; Petram et al., 2004; Camaròs et al., 2017; Romandini et al., 2018b). Several studies on isotopes, dental calculus and dental microwear pointed out the key role of vegetal component in Neanderthal's dietary spectrum, in addition to the meaty component. Some researchers, for instance, have revealed a large use of legumes in Kebara Cave (Lev et al., 2005), grass seed phytoliths in Amud Cave (Madella et al., 2002), starch grains in Shanidar (Henry et al., 2014), mushrooms, nuts and moss in El Sidron Cave (Weyrich et al., 2017) and various plant micro-remains in several specimens of the Mediterranean area (Power et al., 2018).

Despite this recently broadened dietary spectrum, however, the critical component of Neanderthal subsistence was the exploitation of large and medium-sized ungulates (Stiner, 1994; Conard and Prindiville, 2000; Patou-Mathis, 2000; Bocherens et al., 2005; Bocherens, 2009; Gaudzinski-Windheuser and Niven, 2009; Daujeard and Moncel, 2010; Ready, 2010; Discamps et al., 2011; Morin, 2012; Fiorenza et al., 2015; Morin et al., 2016; Marin et al., 2017 among others).

The topic is of crucial importance also in the North of Italy, where several studies have been carried out on a zooarchaeological base (Cassoli and Tagliacozzo, 1994a-b; Peresani 2001, 2015; Alhaique et al., 2004; Fiore et al., 2004; Thun Hohenstein, 2006; Thun Hohenstein and Peretto, 2005; Romandini et al., 2014a; Romandini et al., 2018a-b; Terlato et al., 2019). In order to contribute with further information to these investigations, the following study presents zooarchaeological evidence

from De Nadale Cave, a single-layered context in north-eastern Italy. This paper focuses on the taxonomical and taphonomical analysis of a faunal assemblage that dates back to the onset of the MIS 4 (at minimum) and is associated to a Quina lithic assemblage. The De Nadale Cave plays a crucial role in the knowledge of Neanderthal presence in north-eastern Italy since it sheds new light on a poorly known period in this part of Mediterranean Europe.

## **2. The regional context**

The De Nadale cave is located in the Berici Hills area, a karst plateau situated halfway between two similar formations, the Lessini Mounts and the Euganean Hills. The site looks onto the Calto valley, a narrow V-shaped basin where some active water springs are found in its inner zones.

This area in the North-East of Italy, which is part of the Veneto region, is characterized by the presence of three primary geomorphological units. Indeed, its landscape is dominated to the south by the alluvial plains of the two main rivers (the Po and the Adige rivers), to the north from the eastern sector of the pre-Alps (the Lessini mounts) and, to the south-east, by two small sub-alpine massifs (the Berici and the Euganean Hills). The Alpine foreland is a vast alluvial plain that mostly originated during the Middle and Late Pleistocene from the main rivers like the Po, the Adige and the rivers of the Friulan-Venetian plain. While the western region of the Alpine belt includes narrow and deep valleys alternating with summits that can reach 1,800 – 2,000 m and steep slopes, the eastern area presents wider and larger basins. This region also includes hills of different origins, such as the Berici Hills and the cone-shaped volcanic reliefs of the Euganean Hills, which are separated by the spreading outwash of the aggrading plain.

The Berici Hills are a karstic plateau at an average elevation of 250 m a.s.l., with a honeycomb of sink-holes and various depressions that delineate an extremely uneven topography with peaks and karstic blocks. The plateau is dissected by depressed systems (e.g., the Fimon, Liona, and Calto valleys) with pocket-valleys where ephemeral streams produced swampy environments and fed historic mills. The slopes are steep all around. To the east, a steep slope with rock cliffs connects the plateau to the alluvial lowlands that were occupied by marshes and swamps during the Pleistocene and earlier phases of the Holocene. To the west, the plateau gently connects to alluvial lowlands originated from the eastern Monti Lessini streams. In the southern eastern area, the Pozzolo depression is a wide trench cutting through the plateau in a NW-SE direction and with an elevation of 150 m. Its ancient karst surface is covered with palaeosols and thick red clayey residual deposits (Sauro, 2002).

This specific geomorphological context has been heavily investigated for the last years and turned out to be extremely rich in evidence dating back to the Middle Palaeolithic: over 20 Mousterian

open-air sites, caves or shelters have been discovered (Fig. 1) (Leonardi and Broglio, 1962; Bertola and Peresani, 2000; Peresani, 2001; Fiore et al., 2004; Duches and Peresani, 2009; Peresani, 2015), with additional sites and findings in the Euganean Hills (Peresani and Perrone, 1999; Duches et al., 2008; Peresani, 2013). Regarding open-air sites – such as, for example, Monticello di Barbarano (Duches and Peresani, 2009), Monte Versa (Peresani, 2000-2001), Gualivone and Monte del Cason (Bertola and Peresani, 2000) – they are attested by only lithic artefacts embedded in pedo-stratigraphic sequences or found dispersed on the surface and they vary in morphological position, distance from lithic sources and techno-typological features of the lithic industries. Caves and shelters, instead, are exclusively set along the eastern side of the Berici Hills, where Broion Cave and Broion rockshelter (150 m a.s.l.), Paina Cave (335 m a.s.l.), Col de la Stria Cave (365 m a.s.l.) and San Bernardino Caves (135 m a.s.l.) open (Fig. 1). While Paina, Col de la Stria and San Bernardino Minor Caves yielded few artefacts (Bartolomei et al. 1987-88), the San Bernardino Major Cave and the Broion Cave have produced complete evidence. Both of them preserved traces of human occupation across the whole stratigraphic sequence and the lithic industries show to be dominated by the Levallois knapping method (Peresani 1995-96; Picin et al., 2013), even if different provisioning strategies took place (Peresani and Porraz, 2004).

FIGURE 1 ABOUT HERE

### 3. The site

De Nadale Cave is a small cavity that opens in the Southern slope of the Berici Hills, at 80 m a.s.l., overlooking the narrow Calto valley, a lower area rich in springs and moist zones. The cave was first reported in 2006 by a collaborator of the University of Ferrara, who found several mammal bones and lithic implements on the surface of reworked sediments resulting from present-day burrowing animals and recent anthropic activities. After the removal of the reworked sediments in 2013, the entrance of a small cavity 8 m wide, almost filled by layered deposits, was discovered. Six excavation campaigns have been carried out, starting from 2014 until 2017, in order to investigate the deposit preserved at the cave entrance (Jéquier et al., 2015).

The excavations exposed a short stratigraphic sequence, including one single anthropic layer (Unit 7) embedded between sterile levels (Units 6 and 8), lying on a flat pavement coincident with the horizontal bedding of the local carbonate sandstone bedrock.

The original geometry of the Pleistocene deposits and the spatial extension of the stratigraphy are still not easy to determine: ongoing researches are in progress to evaluating the depth of the cavity

and the planimetry of the site. However, the field excavations have exposed its most complete section on the west, where a group of Units (3, 6, 7, 8) tilted to an angle of 15° to the north, is visible. Among them, only Unit 7 has been recognized as an anthropic layer: this is the Mousterian archaeological layer and consists of dark brown-grey silt loam with medium-small sized, sub-rounded rocks. This Unit was also disturbed by badger dens, partially emptied during the last two excavations (Units 12, 13, 14, 15 and 16). All these pits were characterized by a circular shape and the almost unique presence of rounded and loose pebbles; among them, a significant number of bone fragments and lithic remains has been recovered, mixed with recent bones and other organic matter. Apart from this, Unit 7 is well preserved and extends into the cave. It has yielded thousands of fragmented bones, flint implements, few tiny fragments of charcoal and a Neanderthal deciduous tooth (Arnaud et al., 2016). In the north-eastern part of the cavity, about 40/50 cm underneath the vault, two concentrations of charcoals and burnt bones (structures 7SI and 7SII, Fig. 2) have been interpreted as dumping areas or residual hearts. Below Unit 7, Unit 8 is archaeologically sterile, even though a few flaked stones and bones were recovered at the top, close to the boundary with Unit 7. This material has been attributed to Unit 7. Among all the bone fragments recovered, a second lower molar of a large-sized ungulate has been chosen to perform a U/Th dating: it provided a minimum age of 70.2 +1/-0.9 ka BP (Jéquier et al., 2015).

This result is consistent with the paleoenvironmental and paleoclimatic reconstruction based on small-mammals (insectivores, bats and rodents) assemblage from the anthropic layer. The presence of *M. arvalis*, which is the most abundant *taxon*, and which is currently reported to be more common in open areas and relatively drier regions, identifies a cold climate phase, with a landscape dominated by open woodland formations and open dry meadows. Taking into account the chronology of the site, this has been associated with the very beginning of MIS 4 (López-García, 2018).

Based on the ecological conditions inferred from the Fimon Lake pollen associations, the Berici area during the transition from MIS 5 to MIS 4 recorded no sharp decrease of Arboreal Pollen %. After a moderate decline of *Picea* sp., a mild oscillation enhanced strong expansion of *Betula* sp., *Alnus* sp. and *Tilia* sp. pollen and was followed by a further increase of steppe communities, giving origin to a mosaic of boreal forest and steppe (Pini et al. 2010).

The technological and typological features of the lithic techno-complex make this industry different from the Mousterian of the rest of the region, especially concerning the method adopted in core reduction, and the type of blanks and retouched tools. The reduction sequence recognized at De Nadale Cave, with the presence of 55 scrapers and invasive retouch (Jéquier et al., 2015), is comparable with Quina assemblages in Italy and south-western France (Palma di Cesnola, 2001;

Bourguignon, 1997). Given the absence of provisionable lithic raw material in the site nearby, chert were sourced in a district bounded from the eastern side of the Berici Hills and the western side of the Euganean Hills, and the central-western Lessini (20 to 80 km far from De Nadale).

FIGURE 2 ABOUT HERE

#### 4. Materials and Methods

At De Nadale Cave, 30.654 osteological fragments have been unearthed during the seven excavation campaigns, which interested a 19 m<sup>2</sup> area. All the specimens that were at least 5 cm long or identifiable were spatially recorded during the excavations using an electronic theodolite. Sediment was water-screened using a superimposed mesh from 5 to 0.5 mm and all the bone fragments were recovered after sieving and considered for this study.

In the current state of research, zooarchaeological analyses have been carried out on the whole osteological sample, including bones and teeth recovered in the abovementioned badgers' dens. All of them have been studied and classified from the taxonomical and taphonomical point of view. This paper focuses especially on 28088 fragments of animals' bones and teeth that represent the totality of the remains yielded by the ensemble of Units 6base, 7, 8tetto and their interfaces (hereafter Unit 7). They are considered to be archaeologically and stratigraphically affordable, while the rest came from reworked layers and dens filled up with materials mixed to nowadays deposits. These fragments, yielded by reworked layers and dens, are not completely meaningless to the zooarchaeological analysis, considering that their preservation is consistent with the osteological material of the Unit 7 and that the site is characterized by the presence of a single anthropic layer. Evaluating these bone remains is particularly suitable to have a complete estimation of bone retouchers, whose number increases considerably if we include the fragments from reworked layers. Despite not being stratigraphically reliable, there is no doubt about their Mousterian origin.

Taxonomical and anatomical identifications made in this study are based on the complete Alpine fauna reference collection of the Department of Humanities at the University of Ferrara with the help of the well-established literature (Davis, 1987; Lyman 1994; Reitz and Wing, 2008; France, 2009).

Remains, both identified and those considered unidentifiable on the basis of morphological or size characteristics, have been grouped into five mammal body-size classes, following Bunn et al. (1988): I - small (i.e. *Lepus* sp. and other lagomorphs, Mustelidae, *Vulpes vulpes*); II - small-medium (i.e. *Capreolus capreolus*, *Rupicapra rupicapra*, *Canis lupus*); III - medium (i.e. *Capra*

*ibex*, *Sus scrofa*); IV- medium-large (i.e. *Cervus elaphus*, *Megaloceros giganteus*, Ursidae); V- large (i.e. Bovinae). This partition has been considered more useful to evaluate the faunal assemblage of De Nadale Cave since it underlines the difference in body-size between red deer and giant deer/bovids.

Following the criteria of birth of modern animals, teeth eruption, replacement sequences and dental wear have been used to establish the age at death of the animals, as well as the state of fusion of the epiphysis. Among the ungulates, we considered mainly *Capreolus capreolus* (Aitken, 1974), *Cervus elaphus* (Mariezkurrena, 1983; Hillson, 1986; D'Errico and Vanhaeren, 2002), and bovids (Habermehl, 1975; Bunn and Pickering, 2010; Silver, 1969). In order to avoid distortion in the proportions of age groups in the various units, estimations were also calculated for those remains generally identified as Bovines by considering only the age or the size of the animal not represented in the two categories of the determined taxa (*Bison priscus* and *Bos primigenius*). The collection coming from the paleontological site of Settepolesini di Bondeno (Italy) has been used to give indications about the age of *Megaloceros giganteus* specimens. In this regard, five categories have been identified, following those proposed by Bunn and Pickering (2010) and by Marín et al. (2017): 1) young juvenile (I – 0-5 months; deciduous teeth); 2) subadult juvenile (J – 5-30 months; M3 in eruption); 3) early prime adult (AD I – 30-78 months; complete permanent dentition without wear traces); 4) late prime adult (AD II – 78-144 months; complete dentition with light wear traces); 5) old adult or senile (S – > 144 months; permanent dentition with heavy wear traces). Regarding seasonality, data are too scarce to provide a high-quality interpretation. However, ongoing researches on this topic, carried out by means of the cementochronology and microwear analyses on ungulates' teeth, will provide more specific results that can also be useful to interpret the meaning of the narrow prey spectrum noted at De Nadale Cave.

Concerning the skeletal part profiles, all taxonomically identified specimens, including shaft fragments, were taken into account. NISP (Number of Identified Specimens, Grayson, 1984) and MNI (Minimum Number of Individuals, Bökönyi, 1970) indexes were used in order to evaluate species abundance. Estimation of MNI was based on all of the skeletal elements (bones and teeth), even if the most reliable specimens turned out to be the tibia, especially for ungulates, and teeth for carnivores. Minimum Number of Elements (MNE) (Binford, 1981; Klein and Cruz-Urbe, 1984; Stiner, 1994) and fragmentation indexes (Binford, 1981; Brain, 1981; Lyman, 1994) were calculated to evaluate the skeletal representation of different animals and the skeletal survival rate. The following formula was used to calculate the % of survival of anatomical element =  $(MNE \times 100) / (NEE - \text{number of expected elements})$ .



Concerning the taphonomic analyses, samples of bones and of sediments (Fig. 2) has been selected from Unit 7 to investigate on diagenetic processes with the intent to further contribute to the reconstruction of the history of bone taphonomy, the sedimentary context and the modifications occurred (Quattropiani et al., 1999; Weiner et al., 1993; Berna et al., 2004; Cohen – Ofri et al., 2006; Karkanas and Goldberg, 2010). The main goal of this analysis is to detect the differences in the preservation of bone remains, yielded by two opposite areas of the site. All bone surfaces were evaluated both at macroscopic and at microscopic level: the first examination was effectuated using a hand lens (magnification 10x) under a low-angle light, while the second with a Leica S6D Greenough stereomicroscope with 0.75-70X. Remains coming from the western area appear to be more brownish and with a solid texture, while fragments found in the eastern zone are light-coloured and more fragile. While the reasons for the changing in the preservation status between osteological material found in caves or shelters and remains yielded by open air contexts are well documented, situations in which changes in preservation develop inside the cave, according to the area of the cavity itself (Quattropiani et al., 1999, Weiner et al., 1993), are still considerably unknown. The study of this diversity has been carried out observing thin sections from bones and applying Fourier Transform Infrared spectroscopy (hereafter FT-IR) executed at the Department of Chemical and Farmaceutic Sciences of the University of Ferrara.

Thin sections have been realized on 21 remains which shared common features. Shafts of long bones of large sized animals, without anthropic traces, yielded by distinct areas of the archaeological layer and showing a microscopically different state of preservation were selected. The material has been recognized to be homogeneous (as far as possible) in terms of size: the 21 remains shared a set of dimensional features that make the bones suitable for comparisons (i.e. average length between 4 and 5 cm, average width between 2 and 3 cm and average thickness between 1 and 2 cm. Observations were conducted with Olympus BX 51 microscope. The films of sesquioxides of Fe and Mn were classified according to a scale ranging from 0 to 2: -0 = absent; -1 = present in superficial fissuring; -2 = present inside the assemblage.

FT-IR analyses were carried out on 9 samples, given the substantial homogeneity of the preservation detected on the thin sections (see section 5.1). Two soil samples have been added to these remains, from squares Q12 b-e, N11c in order to have a comparison framework of the osteological specimens. The powders extracted from the samples were analysed with a Bruker Vertex 70 in diffuse reflectance, set at 16 scans with the spectra range from 4000 to 400cm<sup>-1</sup>. The data were interpreted using existing bibliography and the reference collection of FT-IR spectra of standard materials provided by the Kimmel Center for Archaeological Science, Weizmann Institute (<http://www.weizmann.ac.il/kimmel-arch/infrared-spectra-library>).

In order to identify the nature of bone surface alterations and to distinguish human from animal traces (pits, punctures, scores, furrowing, scooping-out, etc.), trampling abrasion, and modern mechanical modifications produced by excavation tools, reference was made to taphonomic literature (Binford, 1981; Brain, 1981; Shipman, 1981; Blumenschine and Selvaggio, 1988; Capaldo and Blumenschine, 1994; Blumenschine, 1995; Blumenschine et al., 1996; Fisher, 1995; Domínguez-Rodrigo and Piqueras, 2003; Fernández-Jalvo and Andrews, 2016). Evidence of anthropic modification has been achieved by considering the type, the position and the orientation of the cutmarks. Cutmarks have been classified as incisions and scraping marks (Binford, 1981; Potts and Shipman, 1981; Shipman, 1981; Shipman and Rose, 1983, 1984; Lyman, 2008). An incision is defined as a striation with a linear outline, a V-shaped section and common internal microstriations, while a scraping mark is a shallow sub-parallel cutmark caused by a stone tool dragged transversally along the length of the bone (Shipman and Rose, 1983, 1984; Bromage and Boyde, 1984; Noe-Nygaard, 1989). In order to hypothesize the performed action (skinning, defleshing, periosteum removal, etc.), a brief description of the cutmarks was made, taking into account the number of striations, their location and distribution on the bone and their orientation. Chopmarks have also been observed. A chopmark is defined as a broad, relatively short, linear depression that generally has a V-shaped cross section (Fisher, 1995; Lyman, 2008 among others). Anthropic traces caused during done breakage for marrow extraction were analysed and divided into two categories: percussion marks and impact flakes. Percussion marks are semi-circular shaped sockets located on the fracture edges with corresponding negative flake scars. Impact flakes refer to positive flakes of the percussion notches derived from the action of breaking the diaphysis (Blumenschine and Selvaggio, 1988, 1991; Capaldo and Blumenschine, 1994; Blasco et al, 2013; Vettese et al., 2017). Intentional bone breakage to access marrow has been recognized by analysing the shape of the fragmented ends of the shafts themselves (Villa and Mahieu, 1991; Blumenschine, 1995; Fisher, 1995; Outram, 2001; Grunwald, 2016; Coil et al., 2017). According to excavation protocol, non-anthropic traces such as natural post-depositional degradation and animal chewing were identified only on 5 cm long objects - or longer ones - or on those taxonomically relevant. The degree of combustion was evaluated by employing the methodology developed by the well-established literature; burnt bones have been divided into two different categories: calcined (>700° C, grey/white) and subject to moderate combustion (200-500° C, black/brown) (Shipman et al., 1984; Stiner et al., 1995; Théry-Parisot, 2002; Théry-Parisot et al., 2005; Costamagno et al., 2005; Mentzer, 2009).

## 5. Results



In Unit 7 of De Nadale Cave, 28088 bone fragments have been unearthed. Within the analyzed sample, it has been possible to identify 2103 remains of mammal species, 1 remain of fish and 9 remains of avifauna, which correspond to 46 individuals, from 13 taxonomic groups (Table 1).

### *5.1 General taphonomic observations*

In general, an excellent preservation of the osteological material has been observed. The most common post-depositional modification is the presence of manganese stains that affect the bones surface in a high proportion: 43.5% of the fragments present this kind of oxide. Degradation due to root-etching is attested in a lower, but still significant, rate (33.1%). The percentage of carbonate concretions is quite relevant (18.6%) and the osteological shafts showing that alteration are plentiful; they have been found mainly along the boundary of the inner part of the cave, close to the walls, where dripping and water percolation are abundant. Trampling traces (16.4%) are common and can be associated with the rocky composition of the sediment. Some shafts show micro fissures from weathering and/or weathering cracks (13.6%), rare exfoliations (1.5%), chemical corrosion (2.6%) or roundings (0.8%).

Observations of the thin sections (Fig. 3) reveal that the bone tissue is well preserved. The Haversian systems are clearly recognizable and not shattered in most of the cases. This result is consistent with the scarcity and doubtful presence of fluoride carbonate detected by FT-IR analyses confirming the low degree of diagenesis and structural modifications in which these faunal specimens have been incurred and the great abundance of carbonate hydroxyapatite. Bone trabeculae, where present, are filled by infiltrations of Fe-Mn sesquioxides. These characteristics are equally distributed among the sample (Fig.4). Fe 0 appears in almost all the specimens. Fe 1 appears well distributed like Fe 2. Mn 0 is present and well distributed among the various parts, while Mn 1 and 2 appear more present in the N-M squares. It is important to note that the Mn 0 is always in association with the Fe 0, the Mn 1 always with the Fe 1, and the Mn 2 always with the Fe 2. Fe 1 and 2 are not always associated with Mn of type 1 and 2. This could explain the different coloration of the faunistic finds in the two zones: in fact, in the area N-W the bones appear more yellow/ochre coloured. The presence of iron not linked to the presence of manganese indicates that the deposit underwent substantial fluctuations in terms of humidity. This is, probably, linked to the repeated cycles of humidity that may have affected the deposition of manganese.

Finally, a fissuration trace is present only in N11e, perhaps attributable to frost-thaw. Tunnelling traces due to fungi are present on three samples located in squares Q and O. This is associated with the presence of oxides: microorganisms such as bacteria and fungi can cause the precipitation of oxides that accumulate on the findings if affected by oxidants conditions. However, microbiotic

activity could be stimulated even in the presence of large quantities of organic matter (Courty et al., 1989).

FT – IR spectroscopic analysis of bones reveals that peaks around 2900cm<sup>-1</sup> indicate the presence of CH<sub>2</sub> and-CH<sub>3</sub> groups (Fig. 5, A – B). The range of vibrations from 1350cm<sup>-1</sup> to 1500cm<sup>-1</sup> due to the functional-CO group, relates to the presence of carbonates, and those between 900cm<sup>-1</sup> and 1200cm<sup>-1</sup> that can be attributed to PO-groups, confirms the presence of phosphates. More specifically, it would be carbonate hydroxyapatite (Dahillite), confirmed by the key peaks for its recognition at 1414cm<sup>-1</sup> and 872cm<sup>-1</sup> and from the peak to 565cm<sup>-1</sup> higher than that at 603cm<sup>-1</sup> (Weiner, 2010).

In soil samples (Fig. 5, C - D), in 1350cm<sup>-1</sup> - 1500cm<sup>-1</sup> range, there is the presence of -CO groups, calcium carbonate. In 900cm<sup>-1</sup> - 1200cm<sup>-1</sup> range phosphates, -PO groups. It is also possible to identify the clay's typology. Peaks at 3622cm<sup>-1</sup>, 914cm<sup>-1</sup>, 778cm<sup>-1</sup>, 472cm<sup>-1</sup> suggests presence of Montmorillonite's minerals and peaks at 3695cm<sup>-1</sup>, 540cm<sup>-1</sup> presence of Kaolinite. Organic matter is identified with the peaks at 1737cm<sup>-1</sup>, -COOH groups, that indicates humus' presence and 1615cm<sup>-1</sup> peaks, referred to Amide I, collagen. Organic fraction, possibly related to roots in the soil, seems to be confirmed by the -CH<sub>3</sub> e -CH<sub>2</sub> groups, identified at 2930cm<sup>-1</sup> e 2850cm<sup>-1</sup> peaks. This context presents clays that tend to form a typically acid situation with, however, the presence of calcium carbonates and phosphates in significant quantities that, conversely, certify alkaline/sub-alkaline contexts. In fact, phosphates can react with clays. This tends to happen in acidic conditions: clays lose a sheet of tetrahedrons, becoming structurally more similar to Kaolinite, and more stable forms of phosphates tend to form (Weiner, 2010). This would explain the quantitatively minor presence of Kaolinite in the soil and the abundance of carbonate hydroxylapatite.

FIGURE 3, 4 and 5 ABOUT HERE

### 5.2 Composition of the assemblage

Among the 2103 mammals remains, the 21.8% (NISP: 458) has been identified both at an anatomical and at a specific level, while the 78.2% has been recognized as generic Ungulata (NR: 1644) or Carnivora (NR: 3). 25975 fragments have been categorised as generic mammals and sorted into the abovementioned body-size classes (Table 1) since no other more specific identification was possible. Considering the totality of the osteological fragments (NR: 28088), only the 1.6% (NISP: 456) of the whole sample has been recognized at a precise taxonomical and anatomical level. This is due to the high rates of breakage (the 87.5% of the remains are smaller than 2 cm) and combustion (49.6%).

## TABLE 1 ABOUT HERE

At De Nadale Cave, red deer (*Cervus elaphus*) and giant deer (*Megaloceros giganteus*) are the most represented species, according to NISP and MNI (Fig. 6). Large bovids (*Bison priscus*; *Bos primigenius* and Bovines) are also abundant according to the MNI, although the NISP for them is considerably lower than for other taxa. Other ungulates, such as roe deer (*Capreolus capreolus*), chamois (*Rupicapra rupicapra*), wild boar (*Sus scrofa*) and ibex (*Capra ibex*) have also been recovered although in lower quantity. Carnivore remains yielded by Unit 7 are also rare and they have been identified as belonging to cave bear (*Ursus spelaeus*) and other non-identifiable bear species, wolf (*Canis lupus*), fox (*Vulpes vulpes*) and badger (*Meles meles*).

Bones grouped into body-size categories display the same tendency as the one observed in the taxonomic representation: elements of the large-sized carcasses (NR: 1285) are the most frequent even if the possibility or underrepresentation of the other categories is to be taken into account. This is due to the high fragmentation of the assemblage that makes the recognition of the body-size class not always possible, as proved by the unidentified size fragments (NR: 24646, 89.2%). Cervids' remains follow the same tendency: all the 59 fragments have been recognized as belonging to the medium- large and large-sized animals' category (IV/V, following Bunn et al., 1988).

## FIGURE 6 ABOUT HERE

### 5.3 Age estimation and Minimum Number of Individuals

Concerning age distribution (Table 1), the predominance of late prime adults is evident, although the proportion of juvenile individuals is also substantial.

For red deer, the combination of dental wear data and the state of epiphyseal fusion in the post-cranial skeleton shows that nearly all age classes are represented. Among the 9 individuals, at least, recognized in the faunal assemblage, two are subadult juveniles (5-30 months), four are early prime adults (30-78 months), two are late prime adults (78-144 months), and one is an old adult (more than 144 months) (Table 1). Regarding giant deer age distribution, the pattern is similar but slightly shifted to the late prime adult category: among the 8 individuals, two are subadult juveniles, one is an early prime adult, four are late prime adults and one is an old adult.

On the other hand, the age distribution trend is different considering *Ursus spelaeus* that shows a slight predominance of younger on adult individuals. Nevertheless, the presence of infants and very young animals is remarkable and can lead to interesting future hypotheses about the seasonality and

the timing of the occupation of both humans and carnivores. In this regard, important hypotheses can be inferred by the presence of a fragmented radius belonged to a foetal individual of a large-sized herbivore.

#### *5.4 Carnivore, rodent and human modifications*

Bone modifications caused by carnivores or rodents are scarce: the first is attested on the 0.3% of the total number of remains and the latter on the 0.1%. Pits, scores and gnawing toothmarks on the diaphysis of large-sized animals are the main identified alterations. Regarding the shape and the dimension of these carnivore toothmarks, they seem to indicate that the main non-human predator that acted on the assemblage might be a medium-large/large-sized carnivore, with a dimension spanning from the one of a wolf to the one of a bear.

The incidence of burnt fragments, which represents almost the half of the total remains (39.4% are burnt and 10.2% are calcined), is elevated: within this group, 79.5% were subject to moderate combustion while 20.5% were calcined.

Among the whole assemblage, anthropic modifications caused by butchering have affected only ungulates (Table 2, fig. 7). The butchering sequence is complete: 5% of all the recovered shafts bear anthropogenic modifications due to defleshing, skinning, marrow extraction activities, etc. This percentage grows if we consider only the determined fragments (63.7%). Cutmarked bones are frequent in the assemblage: most of these human traces are incisions (63.1%), although scraping marks related to periosteum removal activity and chop marks were identified (16.7%). The incisions are usually located on the bone shafts and they are either longitudinal or oblique. This kind of cutmarks are mainly caused by defleshing, even if some of them, located on cranial fragments and ribs suggest skinning and removal of viscera. Removal of fat and periosteum is documented from scraping marks. On the other hand, chop marks, which are few, are associated with disarticulation and dismembering processes or tendons removal.

Diagnostic elements of anthropogenic breakage have been noted and documented on several faunal remains (Table 2, fig. 7). Percussion marks, which are often associated with cutmarks, and impact flakes are the most represented. The faunal assemblage from De Nadale Cave is characterized by oblique, curved and smooth fractures, which indicate that the bones were mainly broken green. The result of this activity, carried on in order to extract marrow for an alimentary purpose, is a quite highly fragmented assemblage.

TABLES 2 AND 3 ABOUT HERE

FIGURE 7 ABOUT HERE

In the whole Unit 7, the amount (NR: 156) of shaft fragments that were used as retouchers to produce flint tools, is significant. Punctiform traces, linear impressions, retouch-induced incisions and notches related to this purpose were found mainly on bone fragments characterized by substantial weight and thickness, such as shafts identified as belonged to large sized herbivore (red deer, giant deer and bovids) (Jéquier et al., 2018; Terlato et al., 2109). The same situation has been noted regarding unidentified remains: 87 retouchers was determined as large-sized Ungulata (Table 2). Additionally, it is important to underline that the quantity of retouchers increases significantly if we add the remains yielded by the reworked units (interpreted as dens): in total 224 bone shafts have been recognized as implements used in the retouching phase of the lithic *chaîne opératoire*.

### 5.5 Skeletal part representation

Considered as a whole, the assemblage is dominated by fragmented shafts and teeth, while epiphyses and spongy tissue are underrepresented (Table 3). Ungulates skeleton, altogether, show the predominance of the limbs over the bones of the axial skeleton. The general trend is characterized by a significative presence of the long bones of the hindlimbs (tibia, femur and metatarsal in particular) and of the forelimbs (humerus, radius and metacarpals), followed by the paw bones (tarsals and carpals, phalanges and sesamoids), which are very scarce. In general, cranium fragments are present but rare and predominantly represented by isolated teeth and parts of the maxilla. The trunk and the spinal column are nearly absent.

A more detailed analysis can be carried out on the most frequent species, red deer, giant deer and bovids (Table 4, fig. 8). Both red deer and giant deer have been exploited in a similar way: the MNE shows a clear predominance of the limbs over the bones of the axial skeleton (Table 6). As shown by the survival rate values, in fact, the percentage of ribs, vertebrae and sternum elements that has been found in the assemblage, is meagre, both for *C. elaphus* (1.1%) and for *M. giganteus* (0.5%). The absence of the atlas and the axis is also remarkable, because these bones may have been still connected either with the cranium or with the rest of the spine when the head was disarticulated from the body. This trend is evident not only for red deer and giant deer, which are represented mainly by fragments of long bones shafts, but it becomes even more pronounced in the case of bison, aurochs, and remains identified as Bovines (Table 3). A similarly differential representation was also noted for medium-sized ungulates such as roe deer and chamois, which are missing ribs, vertebrae, and fragments of spongy tissue.

Much higher are the values for limb bones, among which tibia and metatarsal are always the most represented elements. Some differences can also be detected between forelimbs and hindlimbs

representation. This issue is noticeable as regards the skeletal part representation of red deer (hindlimbs survival rate stands at 46.3%, while the same value for forelimbs stands at 15.1%) and the discrepancy is still present if we compare these values for giant deer (26% for hindlimbs and 21.9% for forelimbs), even if the trend is not so pronounced. Moreover, no carpals and just one tarsal of *M. giganteus* have been detected, while phalanxes are underrepresented (skeletal survival rates stand at 3.2% for red deer and 3.9% for giant deer). Cranial elements are more frequent for *M. giganteus* (%surv. rate: 16.7%) than for *C. elaphus* (%surv. rate: 7.4%), but they are not even close to the values of limbs.

The skeletal part representation of bovines' carcasses is to take into account to complete this scenario. Although the site did not yielded a number of remains sufficiently representative to calculate the skeletal survival rate, the frequency pattern of skeletal elements is close to the one of red deer and giant deer: hindlimbs turned out to be more present than forelimbs and, in general, limbs are more common than axial skeleton specimens (Terlato et al., 2019).

TABLE 4 ABOUT HERE

FIGURE 8 ABOUT HERE

### 5.6 Carcass processing

Traces of human exploitation have been recognized on bones belonged to all the species recovered at De Nadale Cave. In particular, from the few cranial elements to the more abundant limbs, the large-sized ungulates (red deer, giant deer and large bovids) show different phases of carcass processing, which were carried out more consistently compared to smaller animals (ibex, chamois, roe deer and wild boar). No traces have been observed on carnivores' remains.

Despite the non-homogeneous presence of skeletal portions, the exploitation of the prey is attested on the whole carcass (fig. 9): as shown in tables 5, 6 and 7, all anatomical districts bear traces of human activities, both for dietary and non-nutritional purposes.

Cut-marks (NR: 1028; 3.7% of the total NR) due to the use of lithic implements are the most common human traces: they are usually repeated and insisting on a particular area and they are generally the result of attached soft tissue (muscles, tendons, ligaments and so on) removal activity. The same marks on cranial or appendicular elements suggest skinning. Longitudinal and parallel scrapings (NR: 149; 0.5% of the total NR) on shafts point out that the periosteum has been removed to clean the bone from residual meat and to achieve greater control over breakage. At De Nadale cave, this kind of marks is more commonly found on metapodial, tibia and femur.

Bone breakage activity that enables marrow recovery is also linked to the presence of a series of percussion that includes chopmarks, percussion pits, spiral fractures and impact flakes. They have been found primarily on bones that are long, thick, and resistant to trauma, such as distal tibias and humeri, metapodials and, in some cases, femurs. Among all the remains, 339 impact flakes (1.2%) and 191 conchoidal flake scars have been found, some still carrying visible chopmarks on the cortical surface. Of the huge amount of fragmented bone shafts, over 200 have been used like retouchers, giving peculiarity to De Nadale Cave in the Middle Palaeolithic of the north of Italy (Jéquier et al., 2012; 2013; 2018).

TABLES 5, 6 AND 7 ABOUT HERE

FIGURE 9 ABOUT HERE

## 6. Discussion

The faunal assemblage of De Nadale Quina context expresses some zooarchaeological features that allow researchers to state its anthropogenic nature: there are dominant taxa, most of the fragments can be referred to adult individuals, there is a great abundance of limb and cranial bones compared to the axial elements, etc. In addition to that, the high number of cutmarks and intentional bone breakages for marrow recovering and the use of shafts as retouchers are related to a primary and immediate access to the ungulates and an intensive exploitation of the carcasses (Binford, 1981; Bunn 1986, 1989; Blumenshine, 1988; Domínguez-Rodrigo, 1999; Gaudzinski and Roebroeks, 2000). On the other hand, features produced by carnivores (pits, scores, digested bones, etc. but also deciduous teeth of other juvenile specimens) have been detected among the fragments, although the percentage of these traces is not enough substantial to indicate the presence of a den or other evidence that can support hypothesize the action of natural agents for the deposition of the osteological material. In addition to this, the relevant quantity of burnt and calcined fragments can further underline the human origin of this deposit.

The amount of data recovered during the excavations and inferred from the zooarchaeological analysis provides hints to shed light on the ecology and the subsistence strategies of the Quina Neanderthals in the North-east of Italy. Moreover, they can propose a framework for models of mobility from comparisons with few but significant indicators from Western Europe.

### 6.1 *Paleoecological implications*

The De Nadale Cave is located at the centre of the Berici Hills, a physical landscape positioned at between the wide Po plain to the south and the Alpine mountain range to the north. Therefore, it



opens on a tributary of a long valley cut (Val Liona) at a position dominating valley bottoms and in proximity of the wide plateau above. This favourable location could have been suitable to control the movements of grazing large herbivores, such as aurochs and bison, giant deers and red deers, also attracted from water springs and bodies located at the valley bottoms.

The faunal spectrum resulting from the zooarchaeological analysis is consistent with an environment characterized by open woodland formation and open dry meadows. The presence of *Megaloceros giganteus* and *Cervus elaphus* and large bovids enhances this hypothesis. Following Vislobokova (2012) and van der Made (2006, 2010) the ecogenesis of the genus *Megaloceros* shows that the giant deer may have been a mixed feeder living in an open woodland or shrub environment since morphometric features typical of grazers are poorly pronounced (Chritz et al., 2009; Immel et al., 2015). *M. giganteus* seems to have preferred grass-shrub vegetation and open woodland with larch, spruce, pine and birch trees (Stuart et al. 2004). Moreover, red deer is actually a ubiquitous species and its ecological niche can be considered overlapping with the giant deer's one. These animals are highly adaptable and thrive in a variety of habitats. They prefer, nowadays, an interspersed environment including meadows, grasslands with fragmented forested areas and brushy zones (Geist, 1998; Clutton-Brock, 1982). The presence of large bovids completes the scenario: paleoenvironmental evidence suggests that, like the extant American bison, *Bison priscus* favoured extensive dry meadows and steppe grasslands (Brugal et al., 1999; Julien et al., 2012; Massilani et al., 2016). On the contrary, *Bos primigenius* inhabited a forested, fluvio-lacustrine, and marshy areas, even if the fossil record suggests that the aurochs could probably adapt to colder and drier climate conditions, at least to a certain extreme (Brugal, 1985; van Vuure, 2002, 2005; Vercoûtère and Guérin, 2010).

These data fit well with a recent study on small mammals (López-García et al., 2018) which highlights the presence of *Microtus arvalis* that is currently reported to be common in open areas and relatively drier regions of northern Italy (Amori et al., 2008). In addition to that, *Chionomys nivalis* and *Microtus agrestis*, which can be found nowadays at over 1000 m of elevation in the Veneto region (Bon et al., 1996), are indicators of harsh climatic conditions prevailing at the time when the formation of Unit 7 took place. This analysis agrees with the Italian terrestrial pollen sequences from Fimon Lake (Pini et al., 2010) and Azzano Decimo core in Friuli (Pini et al., 2009), revealing for MIS 4 a mosaic of open forest and steppe with a predominance of *Pinus-Picea* and an abundance of *Betula* and herbaceous plants.

## 6.2 Skeletal representation: human choice or matter of conservancy?



As the results of this study show, at De Nadale cave the frequency of axial elements is low. The almost total lack of these elements cannot be ascribed to a differential preservation process caused by post-depositional events, even considering that differences in bone diagenesis have been observed as a function of local physical chemical sedimentary conditions and that parts of the vertebrae and ribs could not have been identified at a taxonomic level and they were consequently sorted into body-size categories.

Based on the skeletal part representation of all ungulates, it is reasonable to assume that the treatment of the carcasses did not take place in the cave but presumably at the kill site. Only selected parts of the animal were transported to the cave, increasing the difference between the amount of useful anatomical elements recovered in the cave and those of “low caloric utility” (Binford, 1978a, 1978b, 1982; Metcalfe and Jones, 1988). From the data recovered, it is inferable that at least one complete carcass has been brought into the site, but the general trend was to introduce preferably the quarters.

According to several naturalistic studies (Blumenschine, 1988) and experimental works (Marean and Spencer, 1991; Marean et al., 1992) hominids and carnivores are the primary agents that lead to this situation, in which vertebrae, ribs and epiphyses of long bones are scarcely present. Considering the scarcity of the features attributable to carnivores (pits, scores and so on), the bias in the skeletal profiles observed in Unit 7 could be interpreted as a consequence of the anthropic differential transport of skeletal parts, comparably to other Middle Palaeolithic assemblages – Kobeh Cave (Marean and Kim, 1988), Kujin (Marean and Cleghorn, 2003), Level J at Abric Romaní (Rosell et al., 2011), Les Pradelles (Costamagno et al., 2006), Salzgitter-Lebenstedt (Gaudzinski and Roebroeks, 2000) among others. If the entire animals were carried to the site, numerous ribs, vertebrae and spongy tissue remains should be found. This transport choice could have had several advantages from the cost-effectiveness point of view: only skeletal parts with high nutritive values (meat and marrow), easy to transport and advantageous in terms of nutritional gain, were introduced in the site, with a consequential optimisation of energy costs (Rosell et al., 2011). Once the animal has been dismembered, in fact, limbs are easy to transport while the axial trunk is heavier and prevents the hunter from moving freely. Moreover, once the back muscles and the viscera have been removed, the thoracic skeleton results completely useless (at least for alimentary purpose) and could be left on place (Oliver, 1993).

However, this hypothesis alone cannot explain the absence of epiphyses of long bones and spongy element, such as vertebrae, ribs and articular short bones. The well-established presence of longitudinal and oblique scraping marks and cut marks on diaphysis suggests that limb bones were entire when they were introduced into the cave and they lose their epiphyses after defleshing

(Domínguez-Rodrigo, 1999). In addition to that, another possibility could be found in the anthropic processing and consumption patterns: epiphyses contain fat and grease that have a great nutritional utility and that can be extracted by heating the bones. For this purpose, the epiphysis must be separated from the diaphysis and crushed. The result of this activity is a systematic breakage that fits well with the high percentage of fragments less than 2 cm long and that has been recognized in other Middle Palaeolithic sites such as Abric Romaní (Rosell et al., 2011), Les Pradelles (Costamagno et al., 2006, 2017) and Grotte du Noisetier (Costamagno, 2013). A similar hypothesis can be made about spongy elements, although difficult to prove archeologically (Daujeard, 2008; Costamagno, 2013; Speth, 2015; Morin and Soulier, 2017), as it has been observed in other Palaeolithic sites such as Roc de Marsal (Castel et al., 2017) and Abri du Maras (Daujeard et al., 2017) among the others. These data fit well also with the high rate of burnt and calcined bone fragments recovered at the site which can be linked to an intense use of bone material as a fuel, such as attested by Costamagno et al. (2005).

### 6.3 *A deliberate economic strategy or a purely “ecological” specialization?*

As the taxonomic data demonstrate, the majority of animal remains brought onto the site was from species inhabiting lowlands, valley bottoms and the plateaux. At De Nadale cave the meat income was based mainly on cervids and bovids and this subsistence strategy seems not to reflect the probable natural association of species around the cave. This evidence of targeted exploitation of large-sized/medium-large-sized prey types, which may have had lower encounter rates than medium/small-medium-sized ones (ibex, wild boar, roe deer and chamois) or perhaps they might have been disregarded on occasion if the hunters' success rates were too low (Bird et al., 2009), is remarkable. At the current state of research, it is still unclear to what extent this difference in the faunal spectrum can be linked to significantly diverse environmental conditions, or to differences in the season of occupation or to a deliberate subsistence choice, possibly related to techno-cultural features of the human groups. Further analyses, concerning, for example, seasonality, paleoenvironment and faunal niche, on De Nadale cave itself and on other possibly MIS 4 Middle Palaeolithic sites, would be fundamental to frame the situation. Nowadays, there are no sites in the North of Italy that yielded deposits dated or clearly referable to the MIS 4. A dominance of middle-sized ungulates (red deer and ibex) has been preliminarily recorded at Fumane Cave unit BR11 (Fiore et al., 2004), chronologically positioned at the end of MIS 4 unless this chronometric set will be confirmed from a new dating programme. Additional MIS 4 archaeofaunal assemblages from Tagliente Rockhelter, Ghiacciaia Cave and San Bernardino Cave require further chronological refinements and in-depth analyses to assess consistency in the range of medium-large or medium-

sized ungulates represented (Cassoli and Tagliacozzo, 1994b; Bertola et al., 1999; Fiore et al., 2004; Thun Hohenstein, 2004). Moreover, extensive studies have been carried out on the faunal assemblage of unit A9 of Fumane Cave (Romandini et al., 2014a), which, however, dates to MIS 3 and cannot be directly compared with the case of De Nadale Cave. Anyway, the unit A9 points out a different situation: medium-sized cervids, *Cervus elaphus* and *Capreolus capreolus*, were the primary meat income resources, in association with *Capra ibex* and *Rupicapra rupicapra*, exploited to a lesser extent. Bovids, *Megaloceros giganteus*, *Alces alces* and *Sus scrofa* are also present but in a less significant quantity.

Without specific comparisons, speculating about the faunal spectrum noted at De Nadale, is difficult and reckless. Moreover, the discrimination between “faunal specialization as a deliberate economic strategy” and “purely ‘ecological’ specialization” (Mellars, 2004) is uncertain using only archaeological information and the debate about a monospecific hunting strategy adopted by Neanderthals is still lively (David and Enloe, 1993; Mellars, 2004; Costamagno et al., 2006; Delagnes and Rendu, 2011).

Even if the De Nadale Cave has been occupied probably at the onset of a cold period, it is likely that the prey catchment zone around the site, which probably included the nearby Val Liona and Pozzolo plateau, would have provided species other than giant deer, red deer and bovids. Thus, the narrow species focus that characterizes the assemblage may reflect a particular hunting pattern, which is still not well known in Italy. However, evidences of this specialized diet have been found, in the south-east of Italy, at the Oscurusciuto Rockshelter with its dominance in *Bos Primigenius* in unit 4 (Boscato et al., 2011), at the Santa Croce Cave with the exclusive representation of *Bos primigenius* and *Equus ferus* (Boscato et al., 2010) and at the Cavallo Cave unit F with the association of *Bos primigenius*, *Cervus elaphus* and *Equus ferus* (Boscato and Crezzini, 2006). Regarding the North-eastern part of Italy, a particular pattern is the one recognized at Rio Secco Cave where anthropically modified bear bones abound in the levels 5top+7 and 5+8 (Romandini et al. 2018b). Although the directionality in hunting behavior in Neanderthal context has always stimulated controversy, a large number of deposits, however, have been interpreted as probable accumulation resulting from specialized hunting. Narrow animal spectrum or even monospecific-based diet have been revealed at numerous Middle Paleolithic sites in different regions, for example, in the Zagros Mountains at Kobeh (Marean and Kim, 1998), in the Caucasus at Il'skaya I (Hoffecker et al., 1991), in Western Europe at Mauran (Girard and David, 1982; Farizy et al., 1994), La Borde (Jaubert et al., 1990), Coudoulous I (Mellars, 1996; Jaubert et al., 2005), Le Roc (Mellars, 1996), Jonzac (Niven et al., 2012) and Les Pradelles (Costamagno et al., 2006; Rendu et al., 2012) and in Central Europe at Wallertheim (Gaudzinski, 1995) and, Salzgitter Lebenstedt

(Gaudzinski and Roebroeks, 2000; Gaudzinski, 2006) and Neumark-Nord (Gaudzinski-Windheuser et al., 2018).

## 7. Conclusions

The targeting of a limited spectra of games is not a novelty in Neanderthal dietary habits as some of the above-mentioned studies demonstrate, although it requires additional evidence to overcome the patchiness of this record in western Eurasia. De Nadale assumes here specific relevance in that it contributes to shed light on hunting behavior at the onset of MIS4 in a regional context where the data available are still embryonal for reconstructing human ecology and land-use. The estimation of the territory covered by the Neanderthals settled at De Nadale remains to be implemented with major detail after the chert provisioning strategies adopted for stone tools equipment will be inferred from the on-going petroarchaeological investigation of the lithic assemblage. Comparably to the other sites distributed on the southern slope of the prealpine mountain range, the position of the cave remains unfavourable for catching knappable stones at the short distance range and stimulates inquiries on the comparison of a set of scales in human land-use with their different encounter rates.

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**Table captions**

**Table 1:** The faunal assemblage at De Nadale Cave: NISP, NISP% and MNI by age classes. The value written in brackets refers to two adult individuals recognized as generic bovids not distinguishable from the other *B. priscus* or *B. primigenius* adult individuals on the basis of age. Those, therefore, have not been added to the bovids MNI.

**Table 2:** Ungulates with a list of butchering marks, thermal alterations and carnivore marks. CM: cut-marks; PM: percussion marks; CM+PM: cut-marks + percussion marks; IF: impact flakes; CM+IF: cut-marks + impact flakes; Tot. BM: Total butchering marks; % BM: % butchering marks; R: retoucher; B: burned-black/brown bones; C: calcined-grey/white bones; GM: carnivore gnawing marks. Percentages of butchering marks are calculated on the total NR for each taxon and on the total NR analyzed in this paper.

**Table 3:** NR and % of diaphysis, epiphysis + spongy bone and unidentified elements, both burnt or calcined and unburnt.

**Table 4:** MNE (Minimum Number Elements), NEE (Number Expected Elements), skeletal survival rate and fragmentation index of *Cervus elaphus*, *Megaloceros giganteus* and large bovids (*Bos primigenius*, *Bison priscus* and Bovines).

**Table 5:** Number of anatomical elements of *Cervus elaphus* with anthropic modifications and carnivore marks. CM: cut-marks; PM: percussion marks; CM+PM: cut-marks + percussion marks; IF: impact flakes; CM+IF: cut-marks + impact flakes; Tot. BM: Total butchering marks; % BM: % butchering marks; R: retoucher; B: burned-black/brown bones; C: calcined-grey/white bones; GM: carnivore gnawing marks.

**Table 6:** Number of anatomical elements of *Megaloceros giganteus* with anthropic modifications and carnivore marks. CM: cut-marks; PM: percussion marks; CM+PM: cut-marks + percussion marks; IF: impact flakes; CM+IF: cut-marks + impact flakes; Tot. BM: Total butchering marks; % BM: % butchering marks; R: retoucher; B: burned-black/brown bones; C: calcined-grey/white bones; GM: carnivore gnawing marks.

**Table 7:** Number of anatomical elements of Bovinae with anthropic modifications and carnivore marks. CM: cut-marks; PM: percussion marks; CM+PM: cut-marks + percussion marks; IF: impact flakes; CM+IF: cut-marks + impact flakes; Tot. BM: Total butchering marks; % BM: % butchering marks; R: retoucher; B: burned-black/brown bones; C: calcined-grey/white bones; GM: carnivore gnawing marks.

### Figure captions

**Figure 1.** A sector of the northern Adriatic area with position of De Nadale Cave and Paleolithic sites cited in the text (A – caves and rockshelters in red, open air sites in blue); the location of the De Nadale Cave, at mid-elevation on the southern slope of Monte Spiadi, indicated by the arrow (B); sketch of N section (C - dotted lines show the roof and the bedrock of the cave); the N section showing the archaeological Unit 7 (D).

**Figure 2.** Plan of the cave with the location of the two possible anthropic structures (modified from Govoni, 2018) and the location of the bones sampled for FT-IR analysis.

**Figure 3.** Micrographs from bone thin sections: presence of Fe and Mn (XPL - 200X) (A); (B) tunnelling due to fungi attack (PPL - 12.5X) (B); trace of fissuration (XPL - 12.5X) (C); presence of Mn and Fe 0 (D) (XPL - 12.5X); the presence of Mn and Fe 1 (PPL – 12.5X) (E); the presence of Mn e Fe 2 (XPL – 12.5X) (F).

**Figure 4.** Most relevant features observed on the bone thin sections from layer 7 listed in accordance with the grid system.

**Figure 5.** FT-IR spectra of bone samples (A - B) and soil samples (C - D) from layer 7. Bones: sq. 11g and 12e showing peaks of Carbonate - idroxiapatite (Dahillite, yellow), -CO group ( $1350\text{cm}^{-1}$  –  $1500\text{cm}^{-1}$  range), -PO group (red), -CH<sub>2</sub>/-CH<sub>3</sub> groups (black, around  $2900\text{cm}^{-1}$ ). Soil: sq. Q12b-e and N11c showing additonal peaks of Montmorillonite (M), Caolinite (C), organic matters (-COOH/ Amide I).

**Figure 6.** Bone shafts from Unit 7. *Megaloceros giganteus*: right maxilla and teeth (A), left humeri (B, C) and right radius (D); *Cervus elaphus*: right maxilla and teeth (E), left tibia with a post-depositional fracture (F), left tibia (G) and metatarsals (H, I).

**Figure 7.** Cutmarks and impact marks impressed on some of the recovered specimens, with closeups. *Cervus elaphus*: left femur (A, 1) and false metacarpal (B, 2); Bovinae: metacarpal (C, 3) and left tibia (D, 4); *Megaloceros giganteus*: left humerus (E), metacarpal (F, 5) and metatarsal (G, 6). Arrows indicate the impact marks.

**Figure 8.** Frequency of skeletal elements of the three main taxa, *Cervus elaphus*, *Megaloceros giganteus* and large bovids (*Bos primigenius*, *Bison priscus* and Bovinae).

**Figure 9:** Skeletal survival rate and distribution of the anthropic modifications on the skeletal elements of *Cervus elaphus* and *Megaloceros giganteus*. Distribution of the anthropic traces on the skeletal elements of large bovids (*Bos primigenius*, *Bison priscus* and Bovinae).



**Table 1**

<i>Taxa</i>	NISP	% NISP	MNI by age classes					MNI
			I	J	AD I	AD II	S	
<i>Canis lupus</i>	3	0.7				1		1
<i>Vulpes vulpes</i>	3	0.7				1		1
<i>Ursus spelaeus</i>	8	1.7		2		1		3
<i>Ursus sp.</i>	18	3.9						
<i>Meles meles</i>	1	0.2				1		1
Mustelidae	1	0.2						
Carnivora undet.	3	0.7						
<b>TOTAL Carnivora</b>	<b>37</b>	<b>8.1</b>						
<i>Sus scrofa</i>	1	0.2				1		1
<i>Megaloceros giganteus</i>	126	27.5		2	1	4	1	8
<i>Cervus elaphus</i>	127	27.7		2	4	2	1	9
<i>Capreolus capreolus</i>	20	4.4		2		2		4
Cervidae	59	12.9						
<i>Bison priscus</i>	10	2.2				3		3
<i>Bos cf. primigenius</i>	1	0.2				1		1
Bovinae	69	15.1		1		(2)		1
<i>Capra ibex</i>	1	0.2				1		1
<i>Rupicapra rupicapra</i>	3	0.7		1		1		2
Caprinae	4	0.9						
Ungulata	1645							
<b>TOTAL Ungulata</b>	<b>2066</b>	<b>100.0</b>						
<b>TOTAL NISP</b>	<b>458</b>	<b>100.0</b>						
Small-medium sized mammals	5							
Medium sized mammals	17							
Medium-large sized mammals	22							
Large sized mammals	1285							
Undet. sized mammals	24646							
Total mammals undet.	25975							
Pisces	1							
Aves	9							
<b>TOTAL NR</b>	<b>28088</b>							

Table 2

<i>Taxa</i>	NR	CM	PM	CM+PM	IF	CM+IF	Tot. BM	% BM	R	B	C	GM
<i>Sus scrofa</i>	1	1					1	100.0				
<i>Megaloceros giganteus</i>	126	40	14	23	1		78	61.9	17	3	1	8
<i>Cervus elaphus</i>	127	55	9	13	2	1	80	63.0	27	6		4
<i>Capreolus capreolus</i>	20	2					2	10.0		1	1	
<i>Cervidae</i>	59	19	3	4	2	1	29	49.2	4			
<i>Bison priscus</i>	10	1	2	3			6	60.0				1
<i>Bos cf. primigenius</i>	1	1					1	100.0	1			
<i>Bovinae</i>	69	20	8	9			37	53.6	14			7
<i>Capra ibex</i>	1											1
<i>Rupicapra rupicapra</i>	3									1		
Caprinae	4	1					1	25.0				
Ungulata	1645	643	50	51	247	40	1031	62.7	86	448	58	61
Mammals undet.	25975	98	1	1	44	1	145	0.6	7	10622	2084	6
<b>TOTAL</b>	<b>28088</b>	<b>881</b>	<b>87</b>	<b>104</b>	<b>296</b>	<b>43</b>	<b>1411</b>	<b>5.0</b>	<b>156</b>	<b>11081</b>	<b>2144</b>	<b>88</b>

**Table 3**

	<b>Unburnt</b>		<b>Burnt + Calcined</b>	
	<b>NR</b>	<b>%</b>	<b>NR</b>	<b>%</b>
diaphysis	13660	96.6	13819	99.1
epiphysis + spongy bones	179	1.3	88	0.6
other elements + unidentified	306	2.2	36	0.3
<b>TOTAL</b>	<b>14145</b>	<b>100.0</b>	<b>13943</b>	<b>100.0</b>

Table 4

	<i>Cervus elaphus</i>					<i>Megaloceros giganteus</i>					Bovidae			
	NISP	MNE	NEE	Skeletal surv. Rate (%)	Fragm. Index MNE/NISP	NISP	MNE	NEE	Skeletal surv. Rate (%)	Fragm. Index MNE/NISP	NISP	MNE	NEE	Fragm. Index MNE/NISP
Cranium	1	1	9	11.1	1.0	4	1	8	12.5	0.3	2	1	5	0.5
Hemimandible	1	1	18	5.6	1.0	4	3	16	18.8	0.8	4	3	10	0.8
Tooth	10					8								
<b>Total cranium</b>	<b>12</b>	<b>2</b>	<b>27</b>	<b>7.4</b>	<b>0.2</b>	<b>16</b>	<b>4</b>	<b>24</b>	<b>16.7</b>	<b>0.3</b>	<b>6</b>	<b>4</b>	<b>15</b>	<b>0.7</b>
Vertebra	2	2	225	0.9	1.0									
Rib	5	3	234	1.3	0.6	1	1	208	0.5	1.0				
Sternum											2	1	5	0.5
<b>Total axial skeleton</b>	<b>7</b>	<b>5</b>	<b>459</b>	<b>1.1</b>	<b>0.7</b>	<b>1</b>	<b>1</b>	<b>208</b>	<b>0.5</b>	<b>1.0</b>	<b>2</b>	<b>1</b>	<b>5</b>	<b>0.5</b>
Scapula	3	3	18	16.7	1.0	3	2	16	12.5	0.7	2	2	10	1.0
Humerus	12	6	18	33.3	0.5	8	6	16	37.5	0.8	6	5	10	0.8
Radius/Ulna	1	1	18	5.6	1.0	1	1	16	6.3	1.0	1	1	10	1.0
Radius	5	2	18	11.1	0.4	15	6	16	37.5	0.4	8	6	10	0.8
Ulna						1	1	16	6.3	1.0	2	2	10	1.0
Metacarpal	13	6	18	33.3	0.5	11	5	16	31.3	0.5	2	1	10	0.5
Metacarpal rudim.	1	1	36	2.8	1.0									
<b>Total forelimb</b>	<b>35</b>	<b>19</b>	<b>126</b>	<b>15.1</b>	<b>0.5</b>	<b>39</b>	<b>21</b>	<b>96</b>	<b>21.9</b>	<b>0.5</b>	<b>21</b>	<b>17</b>	<b>60</b>	<b>0.8</b>
Coxal											1	1	5	1.0
Femur	11	5	18	27.8	0.5	12	6	16	37.5	0.5	4	4	10	1.0
Tibia	39	12	18	66.7	0.3	23	9	16	56.3	0.4	27	7	10	0.3
Tarsals						1	1	48	2.1	1.0				
Metatarsal	14	8	18	44.4	0.6	23	9	16	56.3	0.4	9	5	10	0.6
<b>Total hindlimb</b>	<b>64</b>	<b>25</b>	<b>54</b>	<b>46.3</b>	<b>0.4</b>	<b>59</b>	<b>25</b>	<b>96</b>	<b>26.0</b>	<b>0.4</b>	<b>41</b>	<b>23</b>	<b>35</b>	<b>0.4</b>
Metapodials	5	3			0.6	3	2		0.7	0.7	5	4		0.8
First phal.	2	2	72	2.8	1.0	1	1	64	1.6	1.0				
Second phal.	1	1	72	1.4	1.0	3	3	64	4.7	1.0	3	2	40	0.7
Third phal.											2	2	40	1.0
First phal. rudim.	1	1	72	1.4	1.0	2	2	64	3.1	1.0				
Second phal. rudim.						1	1	64	1.6	1.0				
Third phal. rudim.														
Sesamoid						1	1			1.0				
<b>Total undet. limb</b>	<b>9</b>	<b>7</b>	<b>216</b>	<b>3.2</b>	<b>0.8</b>	<b>11</b>	<b>10</b>	<b>256</b>	<b>3.9</b>	<b>0.9</b>	<b>10</b>	<b>8</b>	<b>80</b>	<b>0.8</b>
<b>TOTAL</b>	<b>127</b>	<b>58</b>	<b>882</b>	<b>6.6</b>	<b>0.5</b>	<b>126</b>	<b>61</b>	<b>680</b>	<b>9.0</b>	<b>0.5</b>	<b>80</b>	<b>47</b>	<b>195</b>	<b>0.6</b>



Tibia	39	15	4	3	1		23	59.0	8	2	2
Metatarsal	14	9	1	1		1	12	85.7	3	2	
<b>Total hindlimb</b>	<b>64</b>	<b>30</b>	<b>5</b>	<b>8</b>	<b>1</b>	<b>1</b>	<b>45</b>	<b>70.3</b>	<b>16</b>	<b>5</b>	<b>2</b>
Metapodials	5	4					4	80.0	1		
First phal.	2										1
Second phal.	1	1					1	100.0			
First phal. rudim.	1										
<b>Total undet. limb</b>	<b>9</b>	<b>5</b>					<b>5</b>	<b>55.6</b>	<b>1</b>		<b>1</b>
<b>TOTAL</b>	<b>127</b>	<b>55</b>	<b>9</b>	<b>13</b>	<b>2</b>	<b>1</b>	<b>80</b>	<b>63.0</b>	<b>27</b>	<b>6</b>	<b>4</b>

Journal Pre-proof

Journal Pre-proof

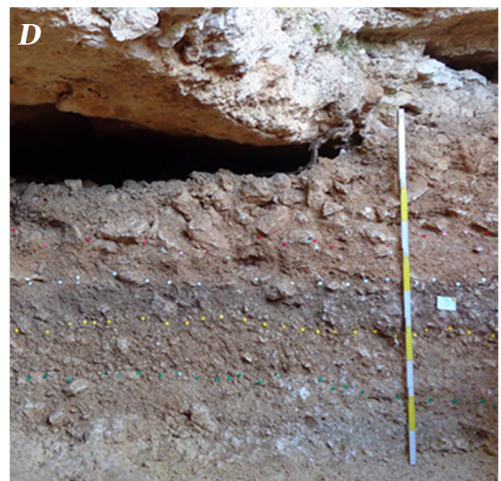
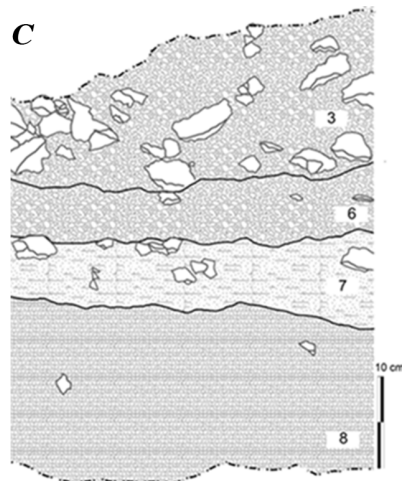
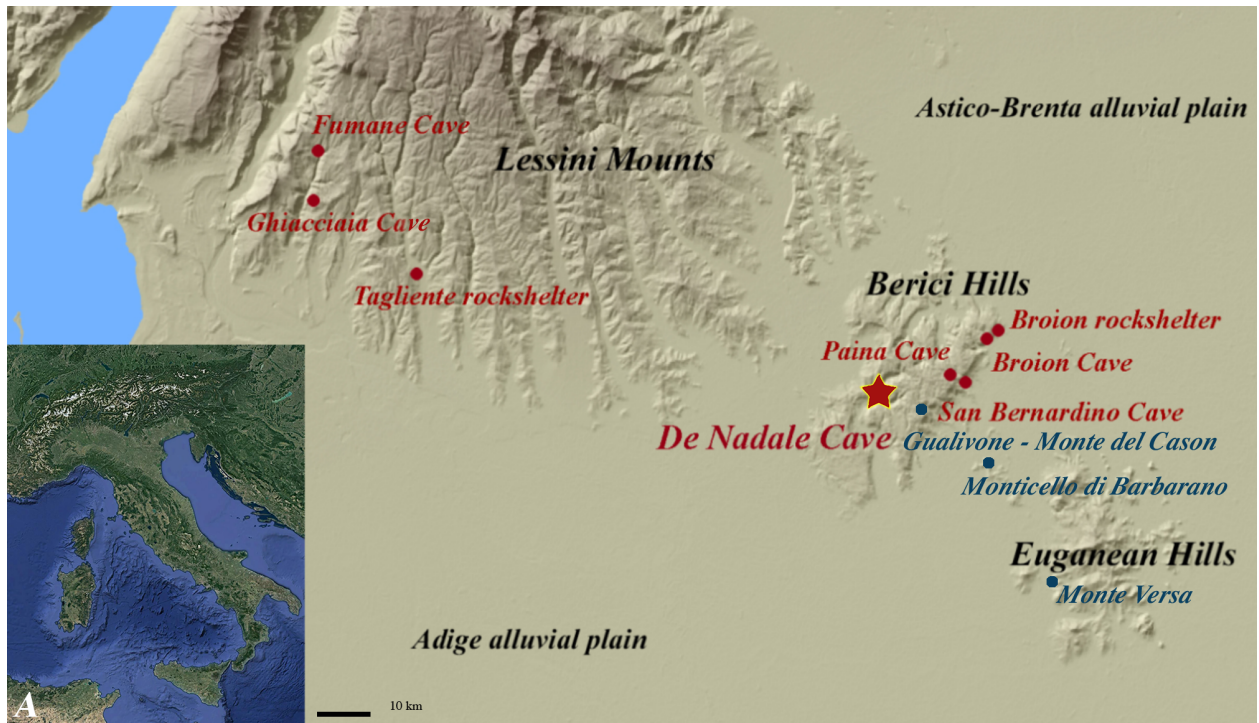


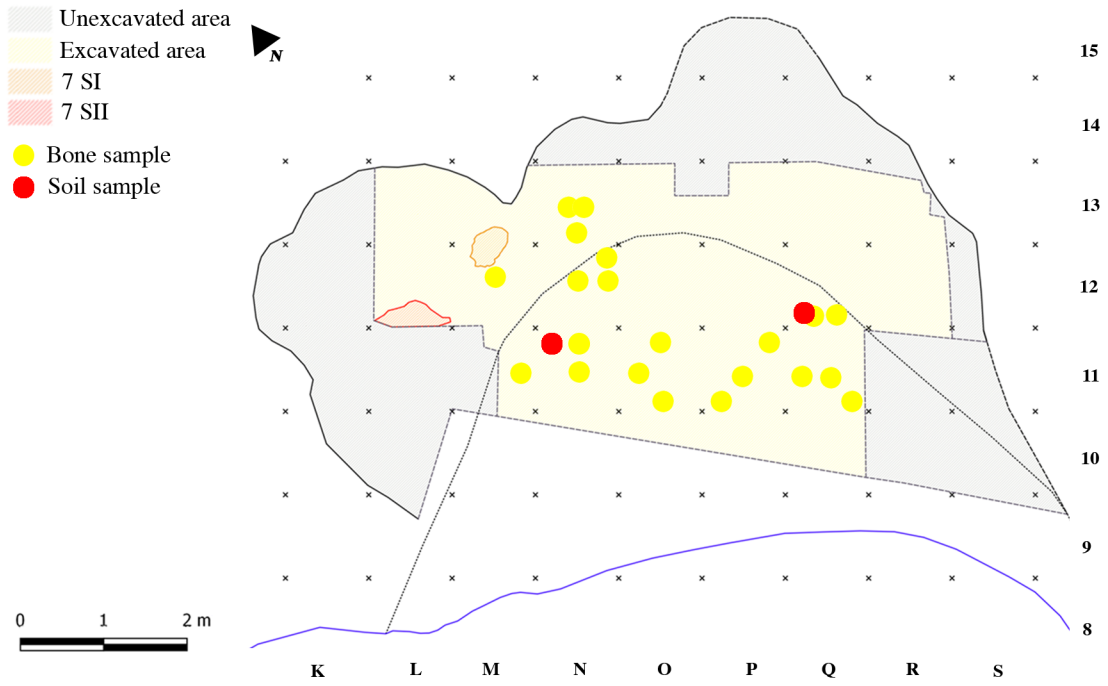
Table 6

	NISP	CM	PM	CM+PM	IF	Tot. BM	% BM	R	B	GM
Cranium	4			1		1	25.0			1
Hemimandible	4	2				2	50.0			
Tooth	8									
<b>Total cranium</b>	<b>16</b>	<b>2</b>		<b>1</b>		<b>3</b>	<b>18.8</b>			
Rib	1	1				1	100.0			
<b>Total axial skeleton</b>	<b>1</b>	<b>1</b>				<b>1</b>	<b>100.0</b>			
Scapula	3	3				3	100.0			1
Humerus	8	2	1	4		7	87.5	1		
Radius/Ulna	1	1				1	100.0	1		
Radius	15	6		5		11	73.3	1	1	1
Ulna	1		1			1	100.0			
Carpals										
Metacarpal	11	4	2	3		9	81.8	5		3
Metacarpal rudim.										
<b>Total forelimb</b>	<b>39</b>	<b>16</b>	<b>4</b>	<b>12</b>		<b>32</b>	<b>82.1</b>	<b>8</b>	<b>1</b>	<b>5</b>
Coxal										
Femur	12	4	2	2		8	66.7	2		1
Patella										
Tibia	23	7	4	5		16	69.6	4	1	
Tarsals	1									
Metatarsal	23	6	4	3		13	56.5	2		1
<b>Total hindlimb</b>	<b>59</b>	<b>17</b>	<b>10</b>	<b>10</b>		<b>37</b>	<b>62.7</b>	<b>8</b>	<b>1</b>	<b>2</b>
Metapodials	3	2			1	3	100.0	1		
First phal.	1									
Second phal.	3	1				1	33.3			
Third phal.										
First phal. rudim.	2	1				1	50.0			
Second phal. rudim.	1									
Sesamoid	1									
<b>Total undet. limb</b>	<b>11</b>	<b>4</b>			<b>1</b>	<b>5</b>	<b>45.5</b>	<b>1</b>		
<b>TOTAL</b>	<b>126</b>	<b>40</b>	<b>14</b>	<b>23</b>	<b>1</b>	<b>78</b>	<b>61.9</b>	<b>17</b>	<b>2</b>	<b>7</b>

Table 7

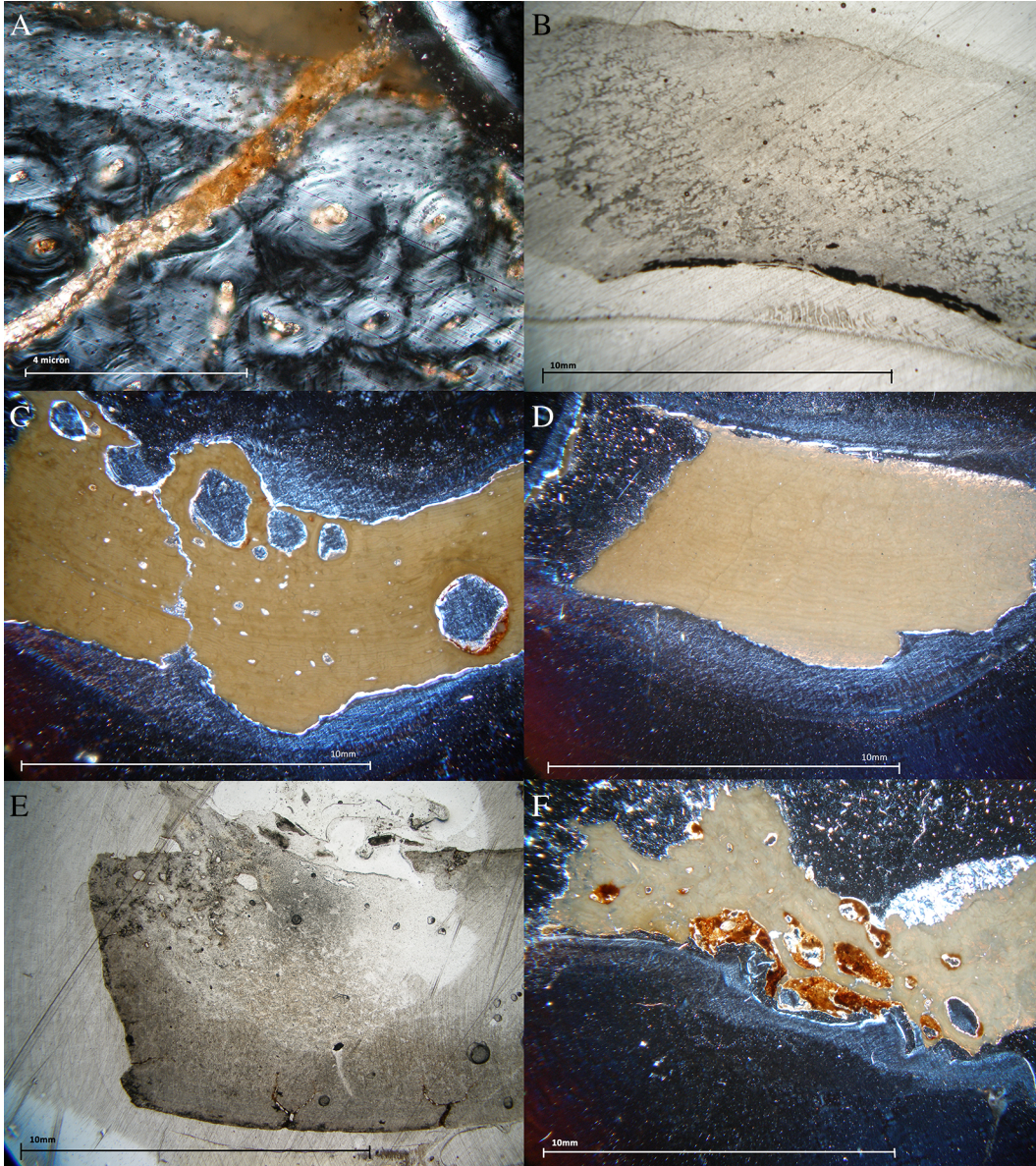
	NISP	CM	PM	CM+PM	Tot. BM	% BM	R	GM
Cranium	2							
Hemimandible	4	2			2	50.0	1	1
<b>Total cranium</b>	<b>6</b>	<b>2</b>			<b>2</b>	<b>33.3</b>	<b>1</b>	<b>1</b>
Rib (stern)	2							
<b>Total axial skeleton</b>	<b>2</b>							
Scapula	2						1	
Humerus	6	1	1	2	4	66.7	2	
Radius/Ulna	1							
Radius	8	4		2	6	75.0	5	1
Ulna	2	1			1	50.0		
Metacarpal	2							
<b>Total forelimb</b>	<b>21</b>	<b>6</b>	<b>1</b>	<b>4</b>	<b>11</b>	<b>52.4</b>	<b>8</b>	<b>1</b>
Coxal	1			1	1	100.0		
Femur	4	1	1		2	50.0		1
Tibia	27	9	5	4	18	66.7	3	3
Metatarsal	9	1	2	2	5	55.6	2	1
<b>Total hindlimb</b>	<b>41</b>	<b>11</b>	<b>8</b>	<b>7</b>	<b>26</b>	<b>63.4</b>	<b>5</b>	<b>5</b>
Metapodials	5	2		1	3	60.0	1	
Second phal.	3	1	1		2	66.7		1
Third phal.	2							
<b>Total undet. limb</b>	<b>10</b>	<b>3</b>	<b>1</b>	<b>1</b>	<b>5</b>	<b>50.0</b>	<b>1</b>	<b>1</b>
<b>TOTAL</b>	<b>80</b>	<b>22</b>	<b>10</b>	<b>12</b>	<b>44</b>	<b>55.0</b>	<b>15</b>	<b>8</b>

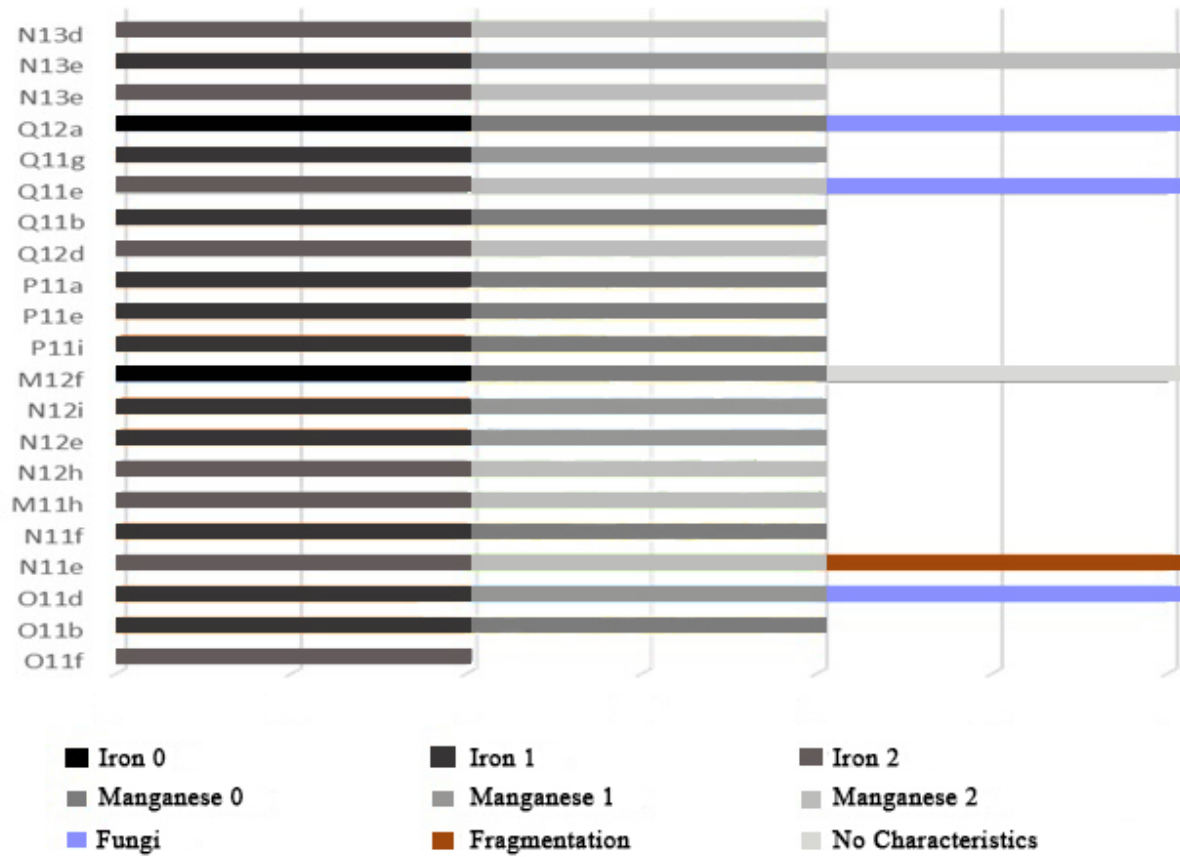




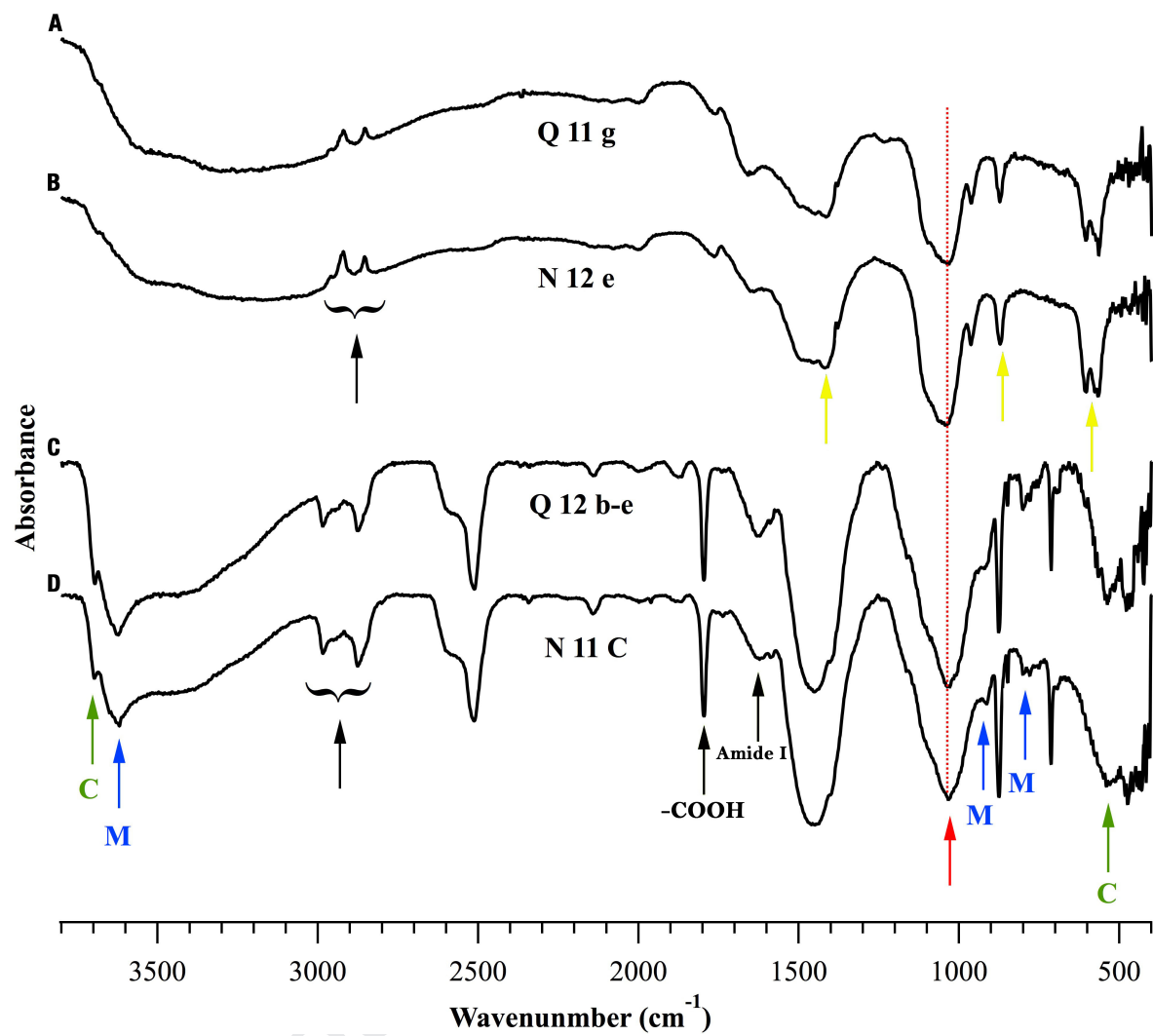
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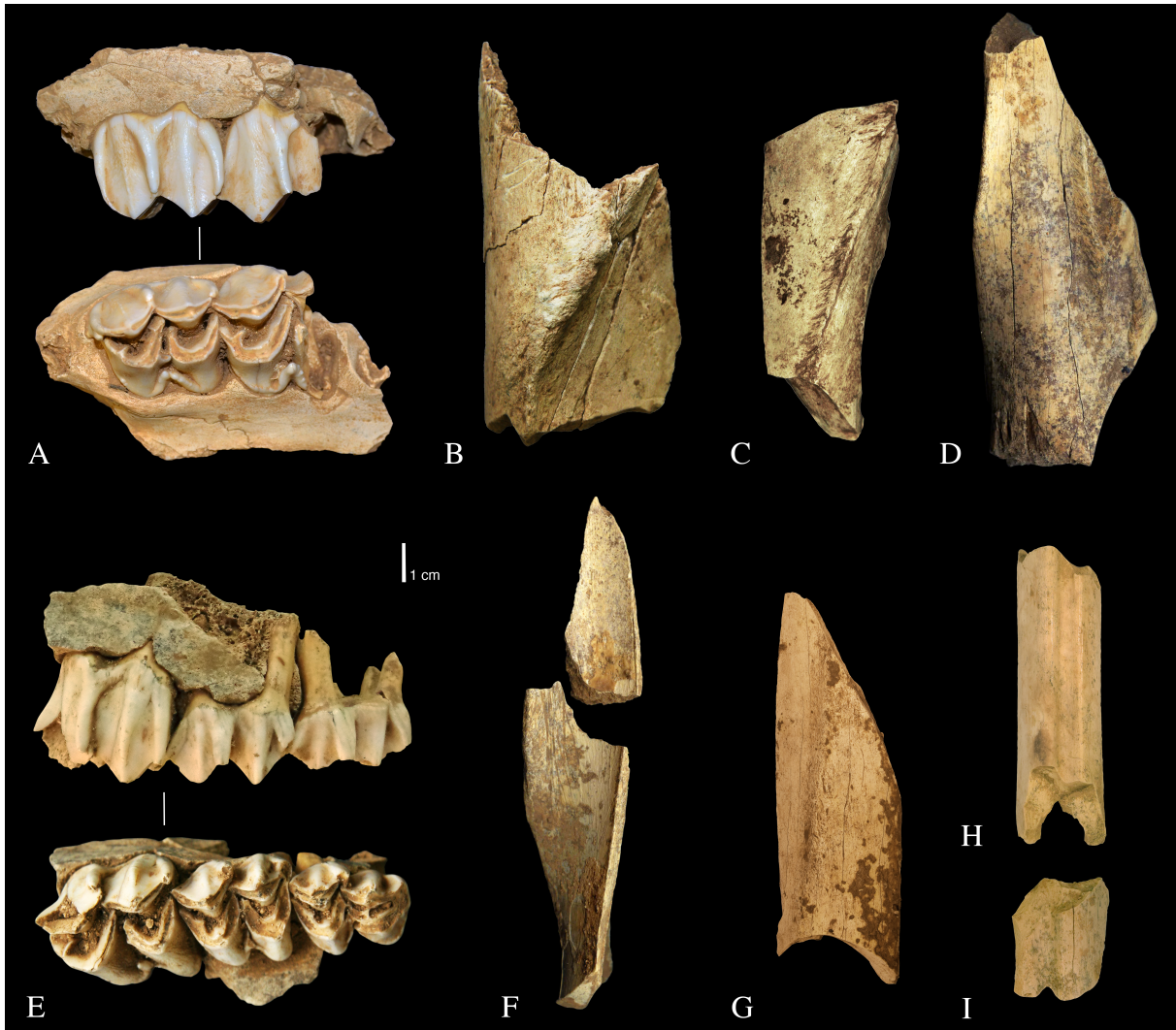


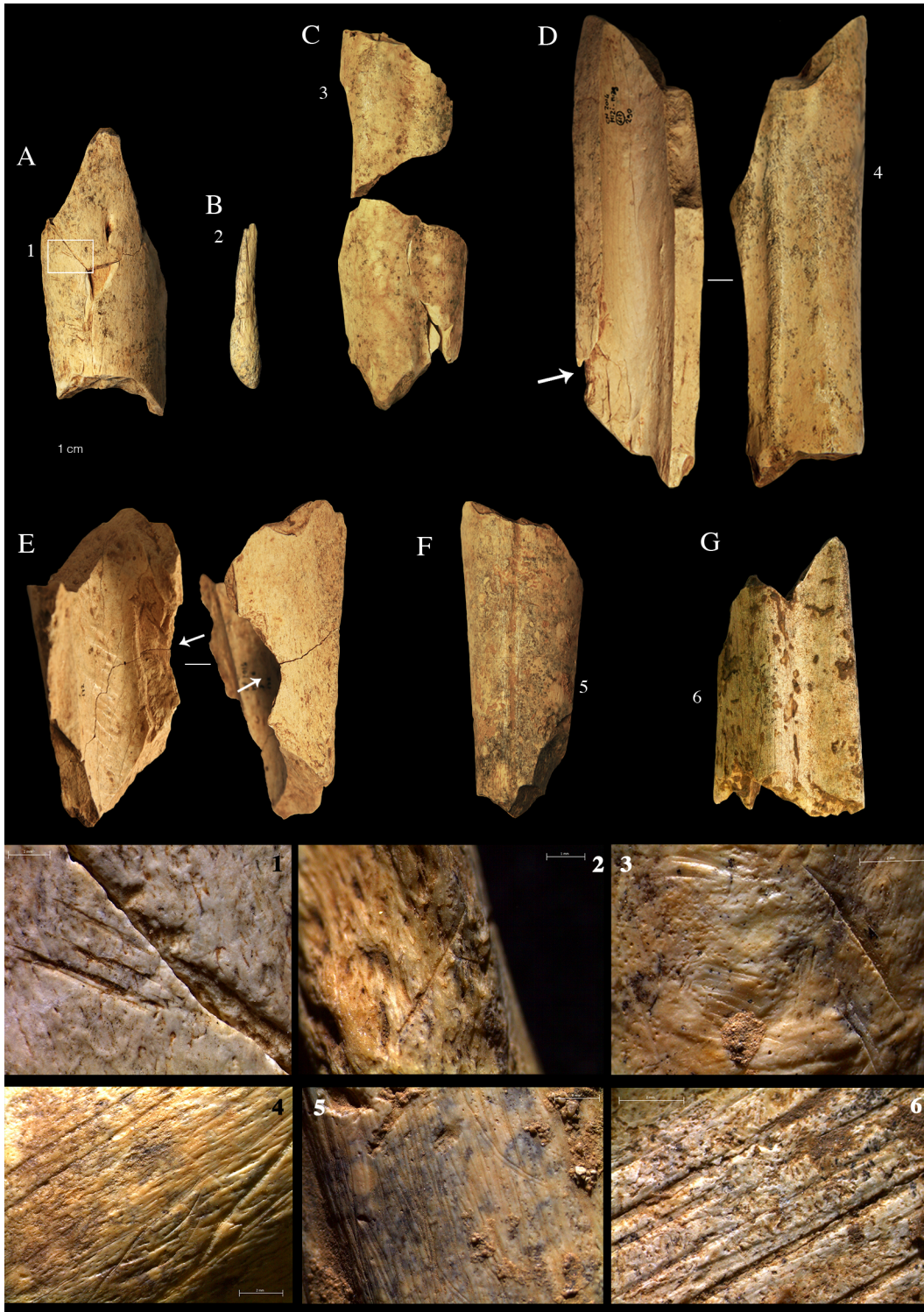


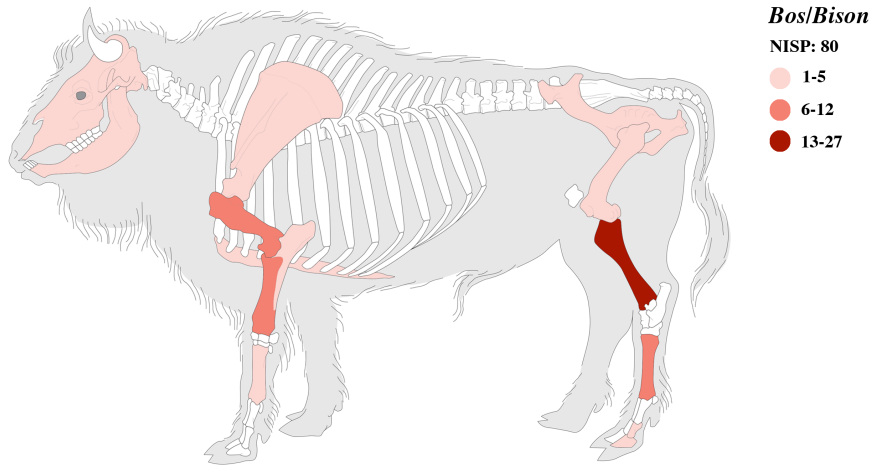
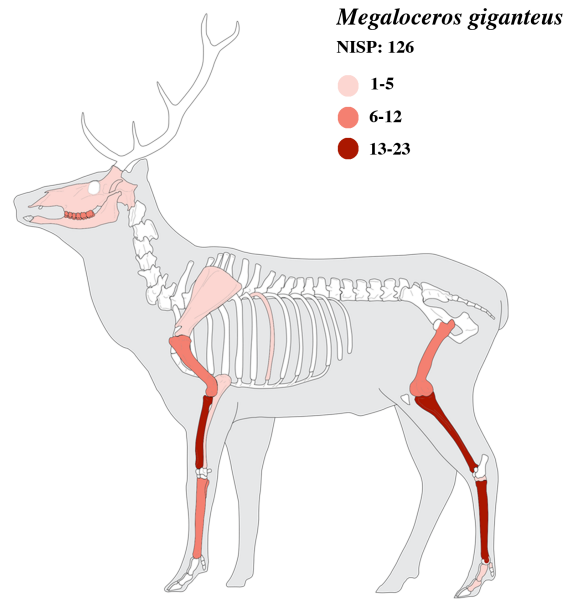
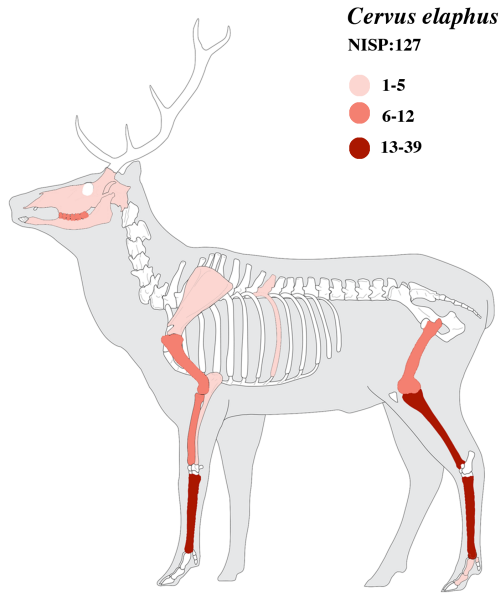
















## Quaternary International

We the authors declare that this manuscript has no conflicts of interest at any level.

On behalf of all authors

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