THE FAUNAL ASSEMBLAGE FROM THE RIPARO MOCHI SITE (BALZI ROSSI): NEW INSIGHTS ON THE MOUSTERIAN-AURIGNACIAN HUMAN-ENVIRONMENT RELATIONSHIP.

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ABSTRACT: Due to its geography, the Liguria region represented an obligatory pathway for animals and human groups that moved along the northern Mediterranean route, connecting the central Italian peninsula to the South-eastern France. Among the several Ligurian sites yielding traces of palaeolithic human activities, Riparo Mochi is a key site to understand the human peopling dynamics occurred during the Middle to Upper Palaeolithic Transition (MUPT). Its archaeological deposit is in fact one of the most complete and well dated MUPT sequences in this region. This study will contribute to increase our knowledge about the behavioural differences between the last Neanderthals and the first Anatomically Modern Humans (AMHs) who inhabited the sites as well as the palaeoenvironmental changes that occurred from Marine Isotope Stage (MIS) 5 to 3. To do so, our study is focused on the zooarchaeological analysis of faunal remains coming from the Mousterian (Unit I), Protoaurignacian (Units H and G), and Aurignacian (Unit F) units of the site. Neanderthals inhabited the site during the early phases (MIS 5-4), hunting mainly *Cervus elaphus* and other middle-large size ungulates. A great variability in the faunal spectrum is shown during the coldest phases of the Mousterian. A decrease in variability is observed in the upper layers of Unit H, corresponding to the first AMHs occupation of the site. Despite the warmer climatic conditions, a decrease in diversity of faunas is observed, maybe due to a different hunting strategy operated by the Protoaurignacian occupants. Red deer is still the most common prey, but hunting seems also oriented on alpine *taxa*, such as *Capra ibex*. Deer hunting in the Proto- and Aurignacian economy might be highlighted by the production of antler tools founded only in the Upper Palaeolithic (UP) layers. Zooarchaeological and palaeoenvironmental data from Riparo Mochi shows a region characterized by an overall climatic and biological stability, reflected in the almost constant presence of certain species of large mammals during the MUPT. Nevertheless, the variations observed since the beginning of the UP appear to be related to an economic behavioural change attributable to the disappearance of Neanderthals and the arrival of AMHs at the site.

Keywords: Balzi Rossi; Protoaurignacian; Middle to Upper Palaeolithic transition; Thyrrenian region; Zooarchaeology.

1. INTRODUCTION

Marine Isotope Stage (MIS) 3 is recognized to be a chronological stage (ca. 60-30 ka) characterized by rapid climatic shift. This variability is associated with cyclical and sudden fluctuations in Greenland temperatures called Dansgaard-Oeschger (D/O) events, which have led to episodes of iceberg detachment in the North Atlantic, called Heinrich (HEs) events, resulting in a cooling of temperatures and drying climate conditions. This rapid alternation of warming and subsequent cooling of temperatures results in a strong climatic instability, alternating temperate-humid with cold-arid phases at mid-low latitudes (Heinrich, 1988; Bond et al., 1993; Dansgaard et al., 1993; Fleitmann et al., 2009; Naughton et al., 2009; Fletcher et al., 2010). It is in this context that the Middle to Upper Palaeolithic Transition (MUPT; ca. 50-40ka) occurred and the last Neanderthals, probably facing a demographic decrease while occupying smaller and smaller areas, were replaced by the first Anatomically Modern Humans (AMHs) (Higham et al., 2014; Benazzi et al., 2015; Hublin 2015; Been et al., 2017; Douka & Higham 2017; but see also Slimak et al., 2022)

How this transition occurred is widely debated (Mellars, 2006; Hoffecker, 2009; Higham et al., 2014; Villa & Roebroeks, 2014; Benazzi et al., 2015; Hublin, 2015; Rey-Rodríguez et al., 2016; Greenbaum et al., 2019; Timmermann, 2020). Mediterranean Europe, particularly the Italian peninsula, is a key region for understanding the dynamics of AMHs peopling and the disappearance of the Neanderthals (Marciani et al., 2020). Italy, while allowing the dispersion of AMHs along the so-called 'Mediterranean route' (Douka et al., 2012), has been characterised by an environmental asymmetry between the eastern Adriatic side and the western Tyrrhenian side; this is – and was – mainly due to the presence of two geographical barriers, the Alps and the Apennines mountains (Badino et al., 2020). This ecological dichotomy could have played a dramatic evolutionary role by providing 'refuge' zones (Columbu et al., 2020; Bicho & Carvalho, 2022; Jones, 2022) to the last Neanderthal groups. Among these refuge zones, the Liguria region, located on the north-western Tyrrhenian coast of Italy, appears to be a key area for understanding the MUPT and the subsequent AMHs peopling of the Mediterranean Europe. Liguria has a very narrow territorial surface, closed from the south by the Tyrrhenian Sea and from the North by the Alps. Thanks to its orography, Liguria could have largely played the role of a climatic
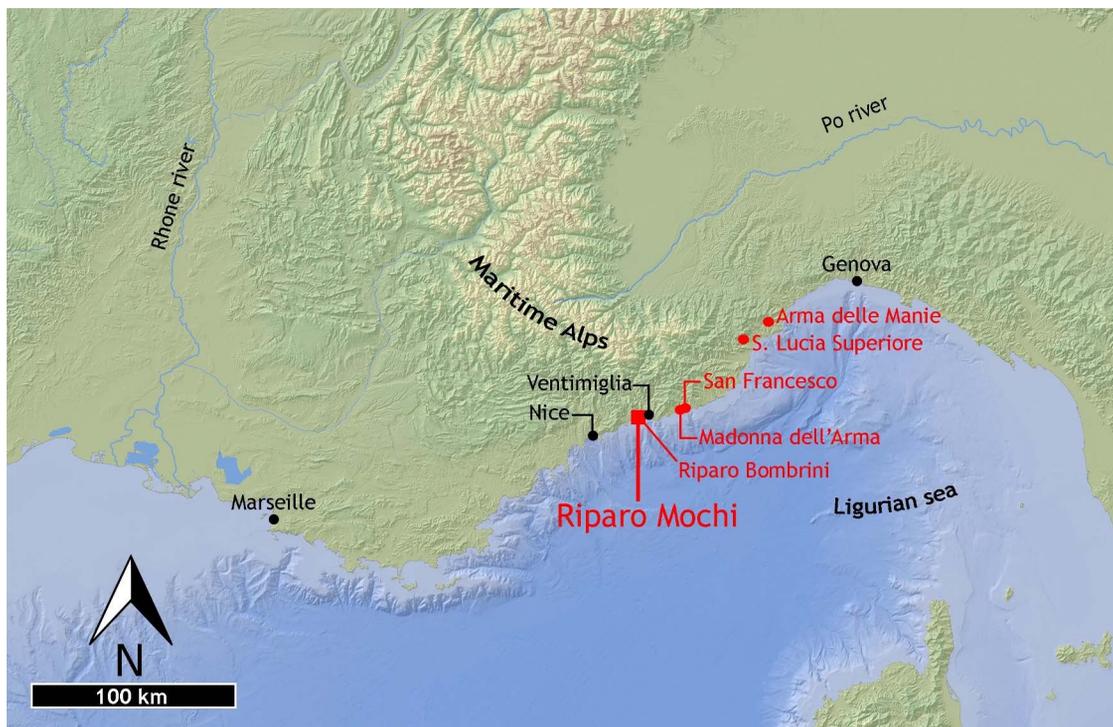
Fig. 1 - Geographical location of Riparo Mochi and other archaeological sites cited in the paper (in red).

refugium even during the coldest phases of MIS 3 (Negrino & Tozzi, 2008; Berto, 2019). Likewise, geography probably made Liguria an obligatory pathway for both MUPT animals and human groups resulting in a bidirectional route along the East-West axis that linked Italy and southern France (as also strongly suggested by the distribution of lithic raw materials; see Negrino & Starnini, 2003; Porraz et al., 2010; Negrino et al., 2016).

In this paper, we will focus on the study of faunal remains recovered from the Mousterian, Protoaurignacian, and Aurignacian layers of Riparo Mochi, a Ligurian site which has yielded one of the most complete and well dated MUPT sequences in this region (Douka et al., 2012; Frouin et al., 2022). This units had been investigated with a zooarchaeological approach while combining identified and unidentified bone remains together with data from previous studies (Alhaique, 2000; Arellano, 2004, 2009). The zooarchaeological analysis carried out on such a long sequence will contribute to the interpretation of the site by providing data about the surrounding palaeoenvironment and by defining both the behaviour and the economic choices of the hunter-gatherers groups during the MUPT: How did the fauna and the ecosystem around Riparo Mochi evolved? Which species were mostly hunted by Neanderthals and which by AMHs? Which hunting adaptations were implemented by humans between the Mousterian and throughout the Aurignacian? Answering these questions will provide a better understanding of how the continuous and rapid climate changes that occurred in Liguria during MIS 3 affected the region's palaeoenvironment and how human-environment interactions changed between the final MP and the beginning of the UP.

2. THE SITE

Riparo Mochi is a rockshelter located at the base of a dolomitic limestone cliff called Balzi Rossi (also known as Grimaldi Caves), an archaeological complex with over 15 sites located in Liguria (Ventimiglia, Italy), close to the Italian-French border (Fig. 1).

The site was discovered by A.C. Blanc and L. Cardini of the Istituto Italiano di Paleontologia Umana (IIPU) in 1938 and was initially excavated in the same year (Blanc, 1938; see a brief history of research at the site in Douka et al., 2012). The archaeological deposit is approximately 10m deep and the sequence consists of nine cultural macrounits named from I to A from bottom to top by G. Laplace (1977) (Fig. 2). Unit I, associated with Mousterian lithic industries, is the thickest unit (about 5 m) (Kuhn & Stiner, 1998; Grimaldi & Santaniello, 2014). Following Cardini's fieldnotes, Unit H (about 50-60 cm) is a semi-sterile layer where a mix of Mousterian and Protoaurignacian artifacts was found; recently, field work directed by one of us (S.G.) (Grimaldi et al., 2017) shows that the upper part of Unit H may represent the earliest UP occupation of the site above a thin sterile layer. Following these new data, it is reasonable to associate to the base of Unit G the faunal remains found during the 1959 L. Cardini excavations originally ascribed to Unit H; even if we will maintain the distinction in tables and graphs, this hypothesis is confirmed by the striking resemblance of the features evidenced in the lithic assemblages (see details in Grimaldi et al., 2014). Unit G (about 50 cm) provided Protoaurignacian (Laplace, 1977) or Early Aurignacian with Dufour bladelets (Bietti et al., 2004) lithic assemblages. The
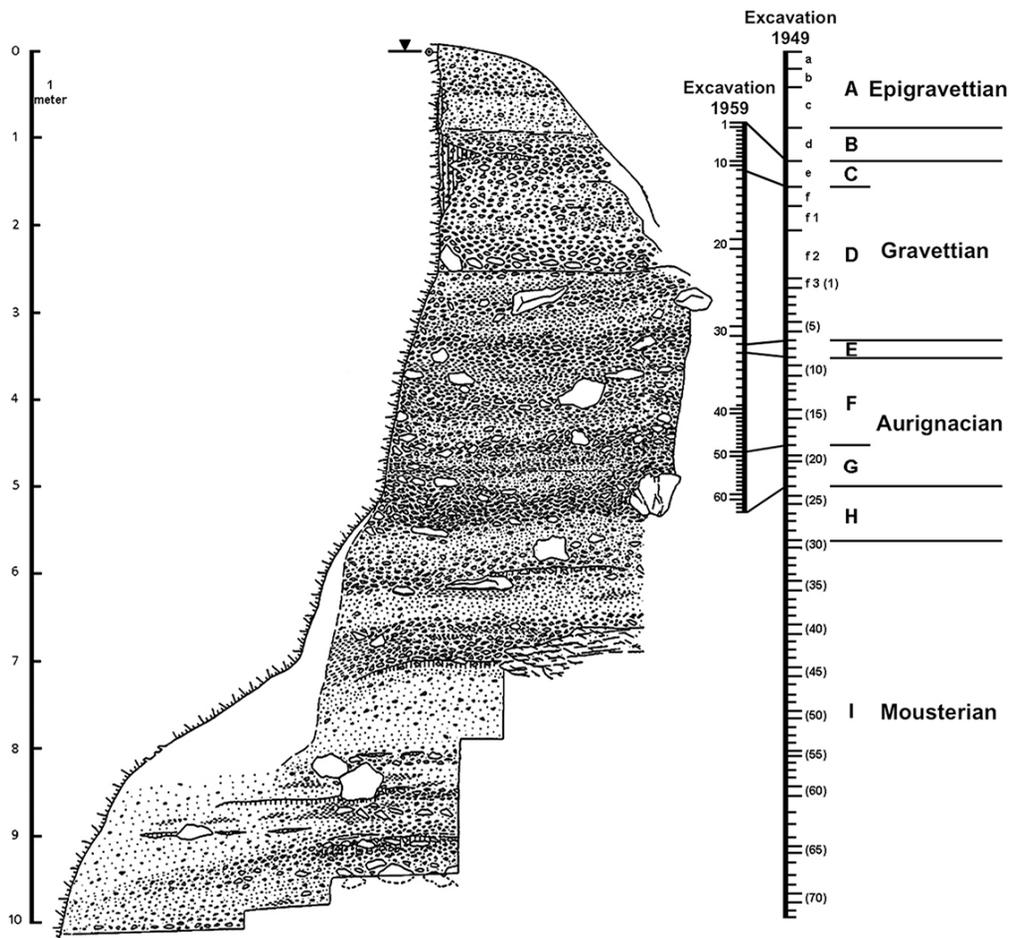
Fig. 2 - Stratigraphic profile of the Riparo Mochi (original unpublished drawing by A. Segre 1949, modified from Douka et al., 2012).

sequence continues with Unit F (about 1 m) defined as Middle Aurignacian (Laplace, 1977) or Classic Aurignacian (Bietti & Negrino, 2007). Unit E is a semi-sterile and very thin unit, with rare artefacts and faunal remains. Unit D (about 1,65 m) is defined as Gravettian with Noailles burins (Laplace, 1977) while Unit C (about 55 cm) provides a Final Gravettian assemblage without Noailles burins (Palma di Cesnola, 1993; Santaniello & Grimaldi, 2019). Unit B (about 60 cm) is semi-sterile with few poor characterizable artefacts, and few bone remains. Finally, the upper Unit A (about 60 cm), previously defined as Proto-Mesolithic (Laplace, 1977), is now defined as Epigravettian (Palma di Cesnola, 1993; Tomasso, 2014).

2.1. Chronology

Previous radiocarbon dates were obtained using the Acid-Base-Oxidation/Stepped Combustion (ABOx-SC) (Higham et al., 2009, 2011; Douka et al., 2012). Using a Bayesian statistical model built with OxCal 4.1 (Bronk Ramsey, 2009), it has been possible to calculate that the Mousterian Unit I ended between 44 and 41.8 ka cal BP (68.2%), the earliest Aurignacian from the

bottom of Unit G was dated at 42.7 - 41.6 ka cal BP (68.2%), while the transition from G to F occurs between 37.3 and 36.4 ka cal BP (68.2%). Gravettian Unit D started at 30.5 – 30.2 ka cal BP (68.2%) (Douka et al., 2012). Recently, a new chronological assessment of Riparo Mochi's sequence has been published on the base of both radiocarbon ABOx-SC and luminescence technique (Frouin et al., 2022). These dates provide new information about the timing of the MUPT at this site: while the bottom of the Mousterian sequence starts at the beginning of MIS 4 - probably earlier (MIS 5) - the end of the Mousterian is dated between 45.8-41.9 ka.

2.2. Palaeoenvironmental studies

Palaeoenvironmental data concerning small mammals (Berto et al., 2019), large mammals (Alhaique, 2000; 2004; Arellano, 2004; 2009; Zeppieri, 2009; Tagliacozzo et al., 2012), and palynological studies (Renault-Miskovsky, 1972), allow a first reconstruction of the sequence from the bottom to the top:

Unit I: small mammal data coming from the uppermost spits of this Unit suggest the presence of cold wet conditions with a landscape characterized by forest

patches with shrubs surrounded by open and rocky areas. Large fauna remains from this Unit were studied only from a palaeontological perspective (Arellano, 2004; 2009) depicting a wide and diversified animal spectrum, mainly composed of ungulates. According to Berto et al. (2019), by grouping the artificial spits into macro groups, it is possible to obtain useful data from the variations of the fauna for palaeoenvironmental observations. At the bottom part of Unit I (spits 52 to 64, A. C. Blanc excavations) the abundance of cervids, wild boar, and roe deer shows a relatively humid climate. In the middle sequence (spits 37 to 46, A. C. Blanc excavations), the higher presence of horse, chamois and ibex, as well as the decrease of wild boar suggests a shift towards a colder and arid climate. Finally, in the upper part of the unit (spits 32 to 36, A. C. Blanc excavations), the presence of *Dama dama* suggests a milder climate.

Unit H-G: Above Unit I, a change through warmer conditions is observed in Units H and G (Berto et al., 2019), leading to a reduction of the forest environment and an increase of the open areas. Faunal remains from the semisterile Unit H are missing in the A. C. Blanc excavations, while data regarding the UP layers comes from Alhaique (2000). To sum up, *Cervus elaphus* is the most common *taxon* in Unit G, followed by *Capra ibex*. *Marmota marmota* is also attested but, due to its different degree of fragmentation and fossilisation, which differs from other remains of the same layer, its presence is defined as intrusive (Alhaique, 2000). Due to the low frequency of remains recovered in the Protoaurignacian level, it is difficult to integrate large faunal data into the palaeoenvironmental reconstruction.

Unit F: A shift to colder temperatures and a general reduction of precipitations are observed during the transition between Unit G and F; small faunal and palynological data suggest the presence of sparse wooded areas without shrubs and a decrease of open meadows (Renault-Miskovsky, 1972; Berto et al., 2019). Subsequently, milder climatic conditions were observed during the evolution of Unit F. Large faunal remains are few but more abundant in this unit than in Unit G (Alhaique, 2000) *Cervus elaphus* is still the common species in the faunal assemblage and an increase of *Capreolus capreolus* is observed.

Unit E: Here, while decreasing temperatures and humidity followed by an improvement of the climatic conditions has been suggested (Renault-Miskovsky, 1972), small mammals remains and large faunal assemblage (mainly composed of red deer remains, Alhaique, 2000) are very scarce.

Unit D: following (Berto et al, 2019), cold and dry conditions are still present in the lower stage of Unit D, followed by a decrease of open environments at the final phases. Large faunal remains were extensively studied by Zeppieri (2009): forest fauna like deer, roe deer, and wild boar coexist together with mountain fauna like ibex, chamois, and marmot.

Unit C: Small mammal species are comparable to the previous Unit D, but a decrease of the open environments has been suggested (Berto et al, 2019). The unit C is poor in large mammals remains, but cold species such *Capra ibex* and *Marmota marmota* are attested

(Alhaique, 2000).

Unit B-A: while no changes in the small fauna composition from unit C to unit B are reported, while an increase of temperature and a decrease of the open environment is observed in unit A, leading to a more forested environment (Berto et al., 2019). Here, the only available information about large faunal remains comes from the original 1938 excavation notes; the presence in unit A of remains identified as *Marmota marmota*, *Capreolus capreolus*, *Cervus elaphus* and *Capra ibex* is reported.

3. MATERIALS AND METHODS

Previous zooarchaeological data from the Riparo Mochi allow a general assessment of the sequence but the lack of data about anthropic activities and their impact on the bone assemblages prevents more accurate interpretations. In fact, while large mammals from Unit D were extensively studied by a zooarchaeological approach (Zeppieri, 2009, summarized in Tagliacozzo et al., 2012), the same cannot be said for the Units below. Nowadays, Unit I was sampled and studied only from a paleontological perspective (Arellano, 2004, 2009) while data from Units G, F, and E (Alhaique, 2000) come only from limited archaeological samples. Finally, data from unit H (L. Cardini 1959 excavations) are still unpublished. The aim of this paper is to fill these gaps by analyzing the whole faunal assemblages coming from the site.

3.1. The analysed faunal assemblage

The analysed faunal assemblage counts a total of 41.162 remains from Units E, F, G, H, and I. The remains were found during the A. C. Blanc excavation campaigns (1938, 1941-2, and 1948-9), L. Cardini excavation (1959), A. Bietti excavations (1995-2006), and current excavations led by one of us (SG) since the 2007. A re-examination of previously studied materials (Alhaique, 2000; Arellano, 2004, 2009) was followed by the analysis of all other unstudied remains. As already said above, recent field work, allows to consider faunal remains from Unit H likely to be in association with the Protoaurignacian level found at the base of Unit G; faunal remains from Unit E may be seen as a homogenous sample without any internal subdivision. On the contrary,

Sample lab code	Unit	Depth (m)	Spit	Age ± (Feldspar)	Phase
X6746	H	5.5	28-29	42.86 ± 3.99	
X6750	I	5.9	31-32	51.83 ± 4.20	Top
X6745	I	5.7	34-35	49.80 ± 5.92	
X6744	I	6	37-38	54.25 ± 4.25	Corpus
X6742	I	7.1	47-48	54.10 ± 4.57	
X6741	I	7.3	49-50	49.37 ± 3.95	
X6740	I	7.6	51-52	58.73 ± 7.93	Base
X6743	I	8.7	62-63	68.23 ± 6.89	

Tab. 1 - Dating estimate made by luminescent determinations on feldspar from Mousterian (Unit I) and semi sterile (Unit H) of Riparo Mochi (see detailed discussion about bayesian models in Frouin et al., 2022). The subdivision in phases takes in account the variation of sedimentology and the techno-typological features of the lithic assemblages.

the remains from the Mousterian Unit I have been divided into three groups named: Unit I – base (Ib), Unit I – corpus (Ic), and Unit I – top (It) (Tab. 1). The reason for that is to be found in a clear sedimentological variability found during the earliest excavation activities as well as in techno-typological differences found in recent studies of the lithic assemblages (see details in Grimaldi et al., 2017). In sum, the middle part of the Mousterian sequence in Unit I (that is to say, I-corpus) suggests an environmental change, possibly corresponding to a colder/dryer landscape (Blanc, 1938; Laplace, 1977), presumably associated with a behavioural adaptation evidenced by the lithic production (Grimaldi & Santaniello, 2014).

3.2. The analytical approach

Taxonomic and anatomical identifications were carried out using the reference collections of the Laboratory of Zooarchaeology of MUSE (Trento, Italy) and of the Laboratory of Large Vertebrate of the University of Ferrara (Ferrara, Italy); skeletal and anatomical atlases were also used (Pales & Lambert, 1971, 1981; Schmid, 1972; Barone, 1976). Undetermined remains were sorted into four weight size classes, following the criteria proposed by Bunn (1986) with some adaptations related to the studied materials: (1) small-size mammals weighing >20 kg (small carnivores, Lagomorpha, Rodentia); (2) medium-size mammals weighing between 20 and 100 kg (Capridae, small cervids, *Sus scrofa*); (3) medium-large size mammals weighing between 100 and 300 kg (*Cervus elaphus*, Ursidae); (4) large size mammals weighing >300 kg (Equidae, Rhinocerontidae, *Alces alces*, *Megaloceros giganteus*). The remains were also arranged according to their maximum length: (1) 0 to 2,9 cm; (2) 3 to 3,9 cm; (3) 4 to 4,9 cm; (4) 5 to 5,9 cm; (5) 6 to 7,9 cm; (6) 8 to 9,9 cm; (7) 10≤cm. Quantification of the identified remains were operated using: Number of remains (NR) and Number of identified specimens (NISP) Grayson (1984). Minimal number of individuals (MNI) was estimated from the observation of skeletal elements and teeth of the same laterality and osteological development (Grayson, 1984; Klein & Cruz-Uribe, 1984; Lyman, 1994), Minimal number of elements (MNE) was counted considering the side, size and ontogeny of the elements (Binford, 1984; Klein & Cruz-Uribe, 1984), Minimal anatomical units (MAU) (Binford, 1984). %MAU was calculated dividing the MAU value of each element by the highest MAU value of the assemblage. A percentage equal to 100% for all the body parts would imply the entire presence of a complete animal skeleton. Age at death estimation was made based on the degree of dental wear and the presence of deciduous teeth, also the fusion stage of the epiphysis was considered (Habermehl, 1961, 1992; Silver, 1969; Noddle, 1974; Mariezkurrena & Altuna, 1983; Stiner, 1998; Gipson et al., 2000; Azorit et al., 2002; Tomé & Vigne, 2003; Weinstock, 2009; Geiger et al., 2016). Five age groups were defined according to the degree of dental wearing: Infant (animals with unworn deciduous teeth), Juvenile (animals with slight to moderate worn deciduous teeth), Subadult (animals with highly worn deciduous teeth or unworn permanent teeth according to the timing of dental eruption for each species), Adult (animals with permanent teeth with low or moderate wear) and Senile (animals with highly worn teeth). Understanding variations of evenness and diversity of the faunal assemblage throughout different archaeological units, correlated with the presence of anthropic modifications and other natural events (e.g. carnivores activity, post-depositional processes, etc.), allows us to better comprehend possible human-environment interactions that occurred between the MP and UP (e.g. the data might show if there was hunting activity was focused on specific animals). To evaluate the diversity of the faunal assemblage Inverse Simpson's index of diversity (1/D) was calculated; this index allows to measure the diversity of the animal population (Simpson, 1949) found in an archaeological site. We decided to use this index because is the most reliable when applied to a faunal assemblage as diverse as the one observed at Riparo Mochi (Faith & Du, 2018). It is also a very reliable index even for relatively small assemblages. The resulting values permit to understand the taxonomical evenness of the faunal assemblage: the lower the value, the more the faunal assemblage is dominated by a single species; on the contrary, the higher the value, the more the diversity of species in the faunal assemblage. To investigate pre- and post-depositional processes that occurred at the site, all specimens were examined with a 10x hand lens and with a binocular microscope. Modifications of major interest were captured with a Leica SD6 microscope. Non-human biotic modifications made by rodents, carnivores and roots were recorded as well as a-biotic modifications such as concretions, weathering, manganese oxide and trampling (Behrensmeyer, 1978; Lyman, 1994; Fisher, 1995; Blumenschine et al., 1996; Domínguez-Rodrigo & Barba, 2006; Fernández-Jalvo & Andrews, 2018). Carnivores' marks were classified as pits, punctures, gnawing, furrowing and digestion (Fisher, 1995; Domínguez-Rodrigo & Piqueras, 2003; Domínguez-Rodrigo & Barba, 2006; Coil et al., 2020). Anthropogenic modifications observed in the assemblage includes cut-marks, percussion marks and burned remains. These traces have been documented and analysed, however their morphological characterisation, location on the skeleton and their correlation to specific carcass exploitation activities will not be treated in this study (Binford, 1981; Potts & Shipman, 1981; Shipman, 1981; Shipman & Rose, 1984; Blumenschine & Selvaggio, 1988; Pickering & Egeland, 2006; Galán et al., 2009; Vettese, 2014; Vettese et al., 2017, 2020; Fernández-Jalvo & Andrews, 2018;Coil et al., 2020). Finally, burnt specimens were sorted according to the colour: brown (burnt), black (carbonized) and grey-white (calcinated) (Stiner et al., 1995). We also carried out a preliminary investigation to distinguish between remains truly affected by thermal alterations and remains darkened by post-depositional processes (Perez et al., 2020).

4. RESULTS

4.1. The faunal assemblage

The taxonomically identified specimens are 792 (NISP), belonging to 111 (MNI) individuals (Tab. 2). There were identified 22 *taxa*, mainly large mammals,

Taxon	Unit I Mousterian - Base NISP	%NISP	MNI	Unit I Mousterian - Corpus NISP	%NISP	MNI	Unit I Mousterian - Top NISP	%NISP	MNI	Unit H Semisterile NISP	%NISP	MNI	Unit G Protoaurignatian NISP	%NISP	MNI	Unit F Aurignatian NISP	%NISP	MNI	Unit E Semisterile NISP	%NISP	MNI
Rhinocerontidae	1	1	1																		
Bison priscus	2	2	1	2	2.8	1	4	3.1	2												
Bos primigenius	2	2	1	2	2.8	1	14	11	3												
Bos/Bison	20	20	1	4	5.6	1	9	7.1	3	3	4.8	1	21	10.6	1	11	6.2	1			
Equus sp.	6	6	2	28	39.4	3	1	0.8	1	1	1.6	1	2	1	1	2	1.1	1			
Alces/Megaloceros				1	1.4	1															
Cervus elaphus	30	30	3	11	15.5	1	26	20.5	3	23	36.5	1	100	50.3	4	95	53.4	4	34	58.6	3
Dama dama							1	0.8	1												
Capreolus capreolus	2	2	1				1	0.8	1	5	7.9	2	22	11.1	1	11	6.2	2	14	24.1	1
Capra ibex	6	6	1	8	11.3	1	5	3.9	2	12	19	1	27	13.6	3	40	22.5	3	7	12.1	1
Rupicapra rupicapra													1	0.5	1	1	0.6	1	1	1.7	1
Sus scrofa	27	27	5	12	16.9	3	48	37.8	4	7	11.1	1	21	10.6	2	17	9.6	2			
Total Ungulate	**96**	**96**	**16**	**68**	**95.8**	**12**	**109**	**85.8**	**20**	**51**	**81**	**7**	**194**	**97.5**	**13**	**177**	**99.4**	**14**	**56**	**96.6**	**6**
Ursus spelaeus	3	3	1				1	0.8	1	3	4.8	1									
Ursus arctos				1	1.4	1															
Ursus sp.										2	3.2	1	1	0.5	1				1	1.7	1
Panthera sp.				1	1.4	1															
Crocuta sp.													1	0.5	1						
Canis lupus	1	1	1	1	1.4	1	2	1.6	1				1	0.5	1				1	1.7	1
Mustela sp.													1	0.5	1						
Total Carnivore	**4**	**4**	**2**	**3**	**4.2**	**3**	**3**	**2.4**	**2**	**5**	**7.9**	**2**	**4**	**2.0**	**4**	**0**	**0**	**0**	**2**	**3.4**	**2**
Lepus sp.							15	11.8	3	6	9.5	2	1	0.5	1						
Marmota marmota																					
Erinaceus sp.										1	1.6	1				1	0.6	1			
Total small mammals	**0**	**0**	**0**	**0**	**0**	**0**	**15**	**11.8**	**3**	**7**	**11.1**	**3**	**1**	**0.5**	**1**	**1**	**0.6**	**1**	**0**	**0**	**0**
Total NISP	**100**	**100**	**18**	**71**	**100**	**15**	**127**	**100**	**25**	**63**	**100**	**12**	**199**	**100**	**18**	**178**	**100**	**15**	**58**	**100**	**8**
Large size	19			14			32			2			13			9			1		
Medium-large size	24			10			32			30			82			56			4		
Medium size	4			1			6			15			35			18			33		
Small size	2			2			18			7			19			10			17		
Cervidae	18			5			23			12			78			23			11		
Carnivore Medium size													1								
Small bird							5			1						1			1		
Total id. size class	**67**			**32**			**116**			**67**			**228**			**117**			**67**		
Indeterminate	45			46			13924			5362			9461			10802			32		
Total NR	**212**			**149**			**14167**			**5492**			**9888**			**11097**			**157**		

Tab. 2 - NISP (Number of Identified Specimens), %NISP and MNI (Minimum Number of Individuals) of the faunal assemblage of Riparo Mochi.

and few unidentified bird bones. Ungulates dominate the faunal assemblage of each unit, while carnivores are rare. Lagomorpha, Insectivora, and Rodentia were also observed.

The three phases of Unit I are dominated by different species: Unit Ib (100 NISP, 18 MNI, 11 *taxa*) by *Cervus elaphus* (30% NISP, 3 MNI), Unit Ic (71 NISP, 15 MNI, 11 *taxa*) by *Equus* sp. (39% NISP, 3 MNI), Unit It (127 NISP, 25 MNI, 12 *taxa*) by *Sus scrofa* (20% NISP, 3 MNI) (Tab. 2). A single fragmented tooth of Rhinocerontidae (1% NISP, 1 MNI) is only observed in Ib levels, while large mammals are common in the entire Unit I. *Bos/Bison* is more common in Ib (20%NISP, 1 MNI) and It (11%NISP, 3 MNI) than in Ic (6%NISP, 1 MNI). On the contrary, *Equus* sp. NISP has a peak in Ic layers (39%NISP, 3 MNI). Medium-large size ungulates like *Cervus elaphus* are much more abundant in Ib and Ic layers (Tab. 2). As red deer belongs to the medium-large size class, its presence in the archaeological record may be underestimated. It is interesting to note that, within the Unit I, antler (Ib: 4 NR; Ic: 1 NR; It: 8 NR) and metapodial fragments (Ib: 14 NR; Ic: 4 NR; It: 12 NR) of undetermined cervidae show a similar distribution to that of *Cervus elaphus* (minor NISP in Ic than Ib and It). *Capreolus capreolus* (Ib: 2% NISP, 1 MNI; It: 1% NISP, 1 MNI) and *Capra ibex* (Ib: 6% NISP, 1 MNI; Ic: 11% NISP, 1 MNI; It: 4%, 2 MNI) are scarce, while *Dama dama* is observed only in It (1% NISP, 1 MNI). As far as weight size classes are concerned, small and medium size mammal remains are scarce; medium-large size remains are more common in Ib and It and this coincides with the high presence of red deer and wild boar in the same layers; large size mammal remains are common in each phase of the unit. Carnivores are rare: few remains of *Ursus spelaeus* (Ib: 3% NISP, 1 MNI; It: 1% NISP, 1 MNI), *Ursus arctos* (1% NISP, 1 MNI),, *Canis lupus* (Ib: 1% NISP, 1 MNI; Ic: 1% NISP, 1 MNI; It: 2% NISP, 1 MNI), and *Panthera* sp. (Ic: 1% NISP, 1 MNI) are observed. *Lepus* sp. (12%NISP, 3 MNI) is present only in It, but a different preservation as well as the presence of three individuals coming from the same spits and from the same sector of the excavation, could suggest their appearance in the stratigraphy after the deposition of Unit I. The fossorial nature of this animal might support this hypothesis.

From the semisterile Unit H (63 NISP, 12 MNI, 10 *taxa*) it is possible to observe a variation in the faunal assemblage which will persists into the subsequently Unit G (199 NISP, 18 MNI, 12 *taxa*) and Unit F (178 NISP, 15 MNI, 8 *taxa*). In these Units, large ungulates show a decrease in NISP and, in the case of *Equus* sp. (H: 1.6% NISP, 1 MNI; G: 1% NISP, 1 MNI; F: 1.1% NISP, 1 MNI), the reduction is remarkable (Tab. 2). Medium size ungulates are highly represented as in the previous Unit I: *Cervus elaphus* is the most common species in each unit (H: 36.5% NISP, 1 MNI; G: 50.3% NISP, 4 MNI; F: 53.4% NISP, 4 MNI). Also, cervids remains result noticeably well represented in Unit G (78 NR) coinciding with the highest NISP observed for red deer in the entire deposit (100 NISP). It is also observed an increase of NISP of *Capra ibex*, which is the second most abundant *taxon* (H: 19% NISP, 1 MNI; G: 13.6% NISP, 3 MNI; F: 22.5% NISP, 3 MNI), while NISP of *Sus*

scrofa decreases (H: 11.1% NISP, 1 MNI; G: 10.6% NISP, 2 MNI; F: 9.6% NISP, 2 MNI). Medium size ungulates are more abundant than those observed in the lower unit: *Capreolus capreolus* is well represented in Units G and F (G: 11.1% NISP, 1 MNI; F: 6.2% NISP, 2 MNI) while few remains of *Rupicapra rupicapra* (G: 0.5% NISP, 1 MNI; F: 0.6% NISP, 1 MNI) have been found. The abundance of red deer and roe deer in Protoaurignacian /Aurignacian layers could be related to the high
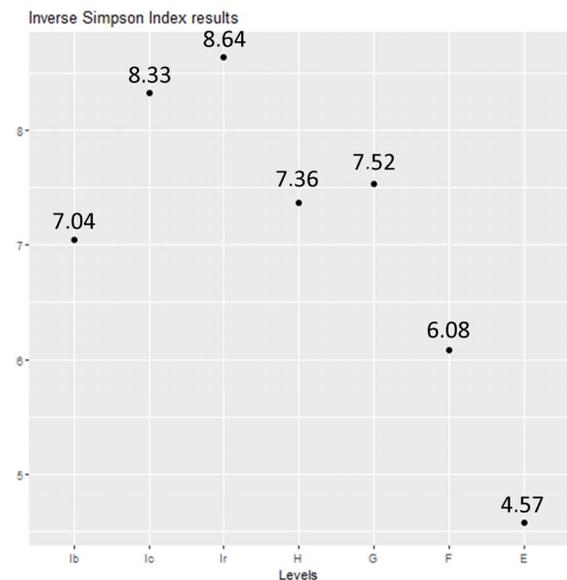
Fig. 3 - Inverse Simpson's index (1/D) calculated on MNI for each archaeological unit of Riparo Mochi.

Site	Cultural context	NISP 1/D	MNI 1/D
Mochi Ib	MP	4.71	7.04
Mochi Ic	MP	4.42	8.33
Mochi It	MP	3.79	8.64
Mochi H	Semisterile	4.07	7.36
Mochi G	UP	3.24	7.52
Mochi F	UP	2.84	6.08
Mochi E	Semisterile	2.4	4.57
Bombrini M[a]	MP	4.45	*
Bombrini MS[a]	Semisterile	3	*
Bombrini A[a]	UP	5.94	*
Madonna[b]	MP	2.12	6.39
Manie[b]	MP	1.95	6.72
S. Lucia sup.[b]	MP	3.37	6.89
S. Francesco[b]	MP	1.2	2.8

Tab. 3 - Comparison between the inverse Simpson's index (1/D) calculated in Riparo Mochi and other contemporary sites of the Ligurian region. Both NISP and MNI were used to calculate the 1/D. (a) data from Holt et al. (2019). (b) data from Valensi & Psathi, (2004). (*) data not available.

	Mousterian-Base					Unit I Mousterian-Corpus					Mousterian-Top					Unit H Semisterile					Unit G Proto-aurignation					Unit F Aurignatian					Unit E Semisterile				
	I	J	Sad	Ad	S	I	J	Sad	Ad	S	I	J	Sad	Ad	S	I	J	Sad	Ad	S	I	J	Sad	Ad	S	I	J	Sad	Ad	S	I	J	Sad	Ad	S
Rhinocerontidae				1																															
Bison priscus				1					1																										
Bos primigenius				1					1					2																					
Bos/Bison				1					1					3					1					1					1						
Equus sp.				2		1			2					3					1					1					1						
Alces/Megaloceros									1					1																					
Cervus elaphus				3					1					3					1					3	1				4					3	
Dama dama														1																					
Capreolus capreolus				1										1					1	1				1					2					1	
Capra ibex				1					1					2					1					3					3					1	
Rupicapra rupicapra																								1					1					1	
Sus scrofa	2			3			1		2		1			3					1					2					2						
Total Ungulate	**2**			**14**		**1**	**1**		**10**		**1**			**19**					**6**	**1**				**12**	**1**				**14**					**6**	
Ursus spelaeus				1										1					1																
Ursus arctos									1																										
Ursus sp.																			1					1										1	
Panthera sp.									1																										
Crocuta sp.																								1											
Canis lupus				1					1					1										1										1	
Mustela sp.																								1											
Total Carnivore				**2**					**3**					**2**					**2**					**4**										**2**	
Lepus sp.														3					2																
Marmota marmota																			1					1											
Erinaceus sp.																													1						
Total small mammals														**3**					**3**					**1**					**1**						

Tab. 4 - Age classes for each taxon of Riparo Mochi. Infant (I), Juvenile (J), Sub-adult (Sad), Adult (Ad), Senile (S).

presence in unit G and F, of numerous antlers (G: 45 NR; F: 6 NR) and metapodials fragments (G: 30 NR; F: 17 NR) identified as Cervidae Specimen sorted by weight size classes might reflect the distribution of NISP from Units H, G, and F. Medium-large size ungulate remains are the most numerous (H: 30 NR; G: 82 NR; F: 56 NR), followed by medium (H: 15 NR; G: 35 NR; F: 18 NR) and small size (H: 7 NR; G: 19 NR; F: 10 NR), while large size ungulates (H: 2 NR; G: 13 NR; F: 9 NR) decrease in number. Carnivores are rare and absent Unit F. *Ursus spelaeus* is present only in Unit H (4.8% NISP, 1 MNI), while *Ursus sp.* is present in Unit H (3.2% NISP, 1 MNI) and Unit G (0.5% NISP, 1 MNI). *Crocuta* sp. (0.5% NISP, 1 MNI), *Canis lupus* (0.5% NISP, 1 MNI), and *Mustela* sp. (0.5% NISP, 1 MNI) are only present in Unit G. *Lepus* sp. from Unit H (9.5% NISP, 2 MNI) could be linked to the analogous remains recovered in the top of Unit I as both seem to share different taphonomic characteristics from those of the fossil record; moreover, they come from the same excavation sector. Two remains of *Marmota marmota* (H: 1.6% NISP, 1 MNI; G: 0.5% NISP, 1 MNI) and a mandible of *Erinaceus* sp (1% NISP, 1 MNI). from Unit G and F are observed. At last, few specimens (157 NR) come from the semisterile Unit E. Among the ungulates, only *Cervus elaphus* (58.6% NISP, 3 MNI), *Capra ibex* (12.1% NISP, 1 MNI), *Rupicapra rupicapra* (1.7% NISP, 1 MNI), and *Capreolus capreolus* (24.1% NISP, 1 MNI) are present (Tab. 2). Cervids remain the most common ungulate *taxa*, while carnivores are scarce with the presence of *Ursus* sp. (1.7% NISP, 1 MNI) and *Canis lupus* (1.7% NISP, 1 MNI). Weight size classes remains are differently distributed: medium size mammals (33 NR) are the most abundant followed by small size (17 NR), medium-large (4 NR) and large size (1 NR) are scarce.

MNI value was used to calculate 1/D, *Lepus* sp. and *Marmota marmota* are not included as they both appear to be intrusive. The graph in Figure 3 shows how Mousterian faunal spectrum is characterized by a high diversity of *taxa*. Unit H and G, have a similar lower 1/D value (Fig. 3, Tab. 3). In the Aurignacian layers (Unit F) a decrease in diversity is observed, while in Unit E the diversity drops drastically. On the light of this, a decrease of faunal variety seems to happen during the UP units, especially in Unit F.

4.2. Mortality profile

A total of 111 individuals were identified in the site (Tab. 4). Young individuals are observed only in Unit I. Four juvenile individuals of *Sus scrofa* were identified: in Ib, two juveniles by two left dp4 (age estimation 5-7 weeks according to Silver 1969; Habermehl, 1961); in Ic, one individual by an unfused metatarsal distal epiphysis, and in It, one individual from a left DP3. A new-born individual of *Equus* sp. were identified from a left DP3 in Ic. Senile individuals are observed in Unit H and Unit G, respectively an old *Capreolus capreolus*, identified from a high worn molar, and a *Cervus elaphus* old individual identified from a marked worn M1. The other *taxa* show only adult individuals. *Cervus elaphus* appears to be the species with the most number of individuals (19) across the entire stratigraphy (Tab. 4). In units G and F the MNI of the red deer increases slightly (Tab. 4) and antler fragments are present. The only observable variation is the presence of a senile individual in Unit G (Tab. 4). Despite the presence of undetermined cervids antler fragments in unit I, G and F, it was not possible to define whether they were antlers obtained by hunting the animal or simply collected. For this reason, it is currently not possible to hypothesise a hunting seasonality for *Cervus elaphus*. However, it must be taken into account that the undetermined antler fragments may have be-

longed to *Capreolus capreolus* (from unit I to E), *Dama dama* and *Alces/Megaloceros* (only in unit I). *Sus scrofa* is the second ungulate with the highest number of total individuals (17 MNI). It is noted that throughout the Mousterian sequence there is a large presence of individuals (12 MNI), four of which are juvenile. We observed that, starting from unit H, its MNI value decreases (Tab. 4). Considering that the wild boar can give birth twice a year when conditions are optimal (Mauget, 1981), we could theorise that during the deposition of Unit I the regional environmental conditions have been milder compared to the upper levels. To strenghten this hypothesis, we observed similar variations in MNIs of *Equus* sp., *Bos primigenius*, *Bison priscus* and the genus *Bos/Bison* sp.: these appear to have higher values in the Mousterian levels than in the Aurignacian levels (Tab. 4). In particular *Equus* sp., which in Unit I has a total MNI equal to 8, one of which is an infant, reduces its MNI to a single individual in units H, G and F. This decrease is also observable in the NISP (Tab. 2). Conversely, an increase in the MNI of *Capra ibex* is observed in units G and F. This decrease in the MNI of species wich inhabitate forests and/or open environments, such as *Equus* sp. and *Bos/Bison* and the increase in the MNI of mountain species such as the ibex, might suggests a change in the environmental conditions and/or in human hunting strategies that occurred between the MP (Unit I) and the UP (Unit G and F), reflected in the composition of the faunal spectrum.

4.3. General taphonomy

Except for Unit E, Ib, and Ic which have few remains, the whole assemblage is highly fragmented (Fig. 4). Bone fragments smaller than 2.9 cm represent the 87% of the total remains. Whole specimens are the

0.3% (140 NR) of the total, which are primarily represented by small fat bearing bones, such as sesamoids, carpals, tarsals, phalanges, and metapodial of small fauna, in association with isolated teeth (Fig. 5); low density bones as ribs, scapulae, and vertebras are rare. We have divided them according to the weight size of the species to which they belong. The remains belonging to small animal (small carnivores, rodents, birds) are primarily represented by short limb bones like tarsals and phalanges. Those concentrated in It and H (Fig. 5) are almost exclusively determined as Lepus sp. The scarcity
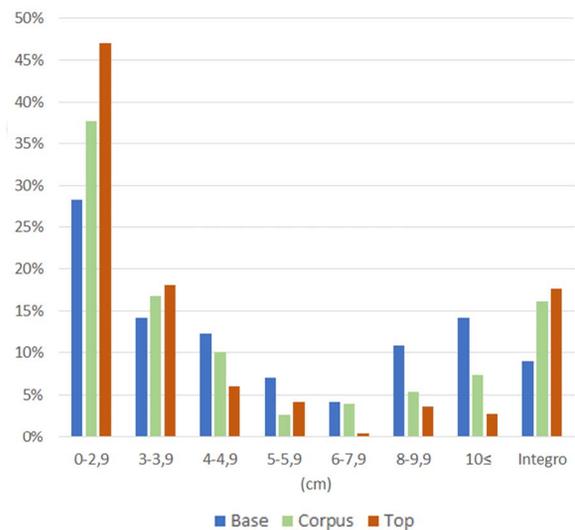
Fig. 4 - Percentage of fragmented remains (NR%) for each unit of Riparo Mochi sorted in seven classes according to their length.
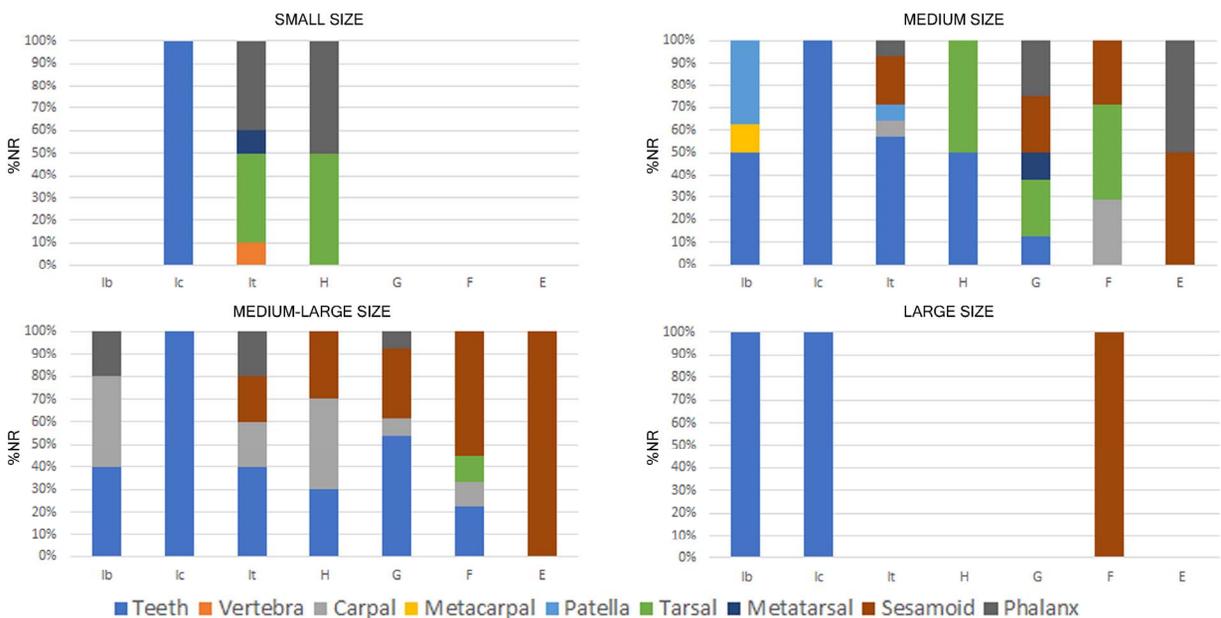
Fig. 5 - Percentage of whole remains divided according to the animal size in each unit of Riparo Mochi. Small size (small carnivores, Lagomorpha, Rodentia), Medium size (Capridae, small cervids, *Sus scrofa*), Medium-large size (*Cervus elaphus*, Ursidae), Large size (Equidae, Rhinocerontidae, *Alces alces*, *Megaloceros giganteus*).
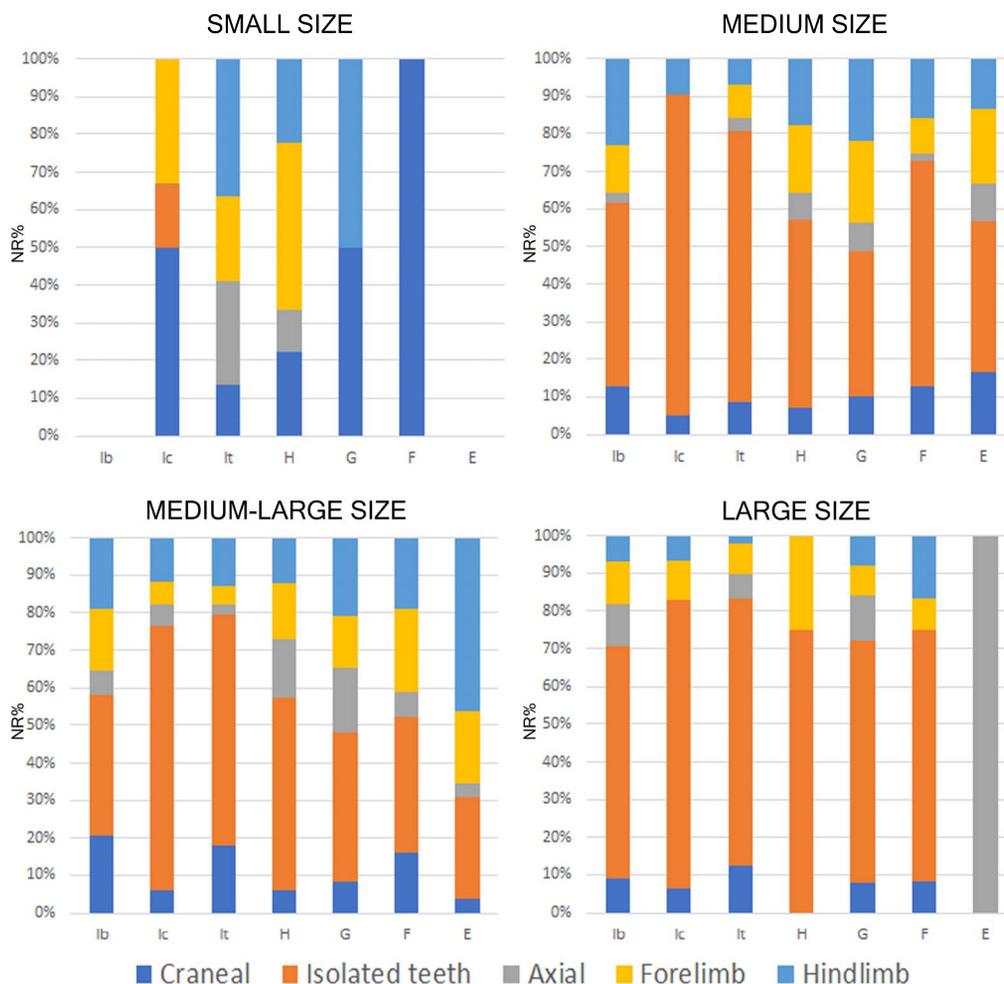
Fig. 6 - Percentage of remains belonging to a specific anatomical portion in each unit of Riparo Mochi. Data are divided according to the size of the animal: Small size (small carnivores, Lagomorpha, Rodentia), Medium size (Capridae, small cervids, *Sus scrofa*), Medium-large size (*Cervus elaphus*, Ursidae), Large size (Equidae, Rhinocerontidae, *Alces alces*, *Megaloceros giganteus*)

or absence of whole remains belonging to small animals in the other units it might confirm the intrusive nature of Lepus sp. in these levels. Overall, the skeleton of small faunas is mainly represented by fore and hindlimb in Units It and H (Fig. 6), while the cranial portion is the only represented part in F. Isolated teeth are rare and only observed in Ic. The scarce representation of small faunas throught the stratigraphic sequence could be the result of a heavier fragmentation of these elements. Medium (caprids, canids, suids) and medium-large (red deer, ursids) size animal bones share a similar distribution (Fig. 5, Fig. 6). For both the size classes whole remains are mainly represented by isolated teeth, small fat bearing bones such as carpals, tarsals, sesamoid and falanges (Fig. 5). The major variations in the stratigraphy are observed in Ic, where theeth are the only whole specimens, and in It in which the representation of short limb bones increases (Fig. 5). This variation is observable also in the representation of the anatomical parts (Fig. 6). The cranial skeleton of both size classes starts to decrease in unit H, reaching its minimum in unit
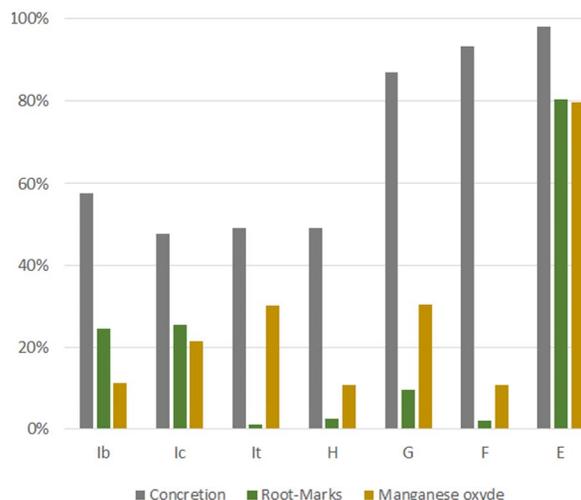
Fig. 7 - Percentage of remains bearing concretions, manganese oxide and root-etching in each unit of Riparo Mochi.
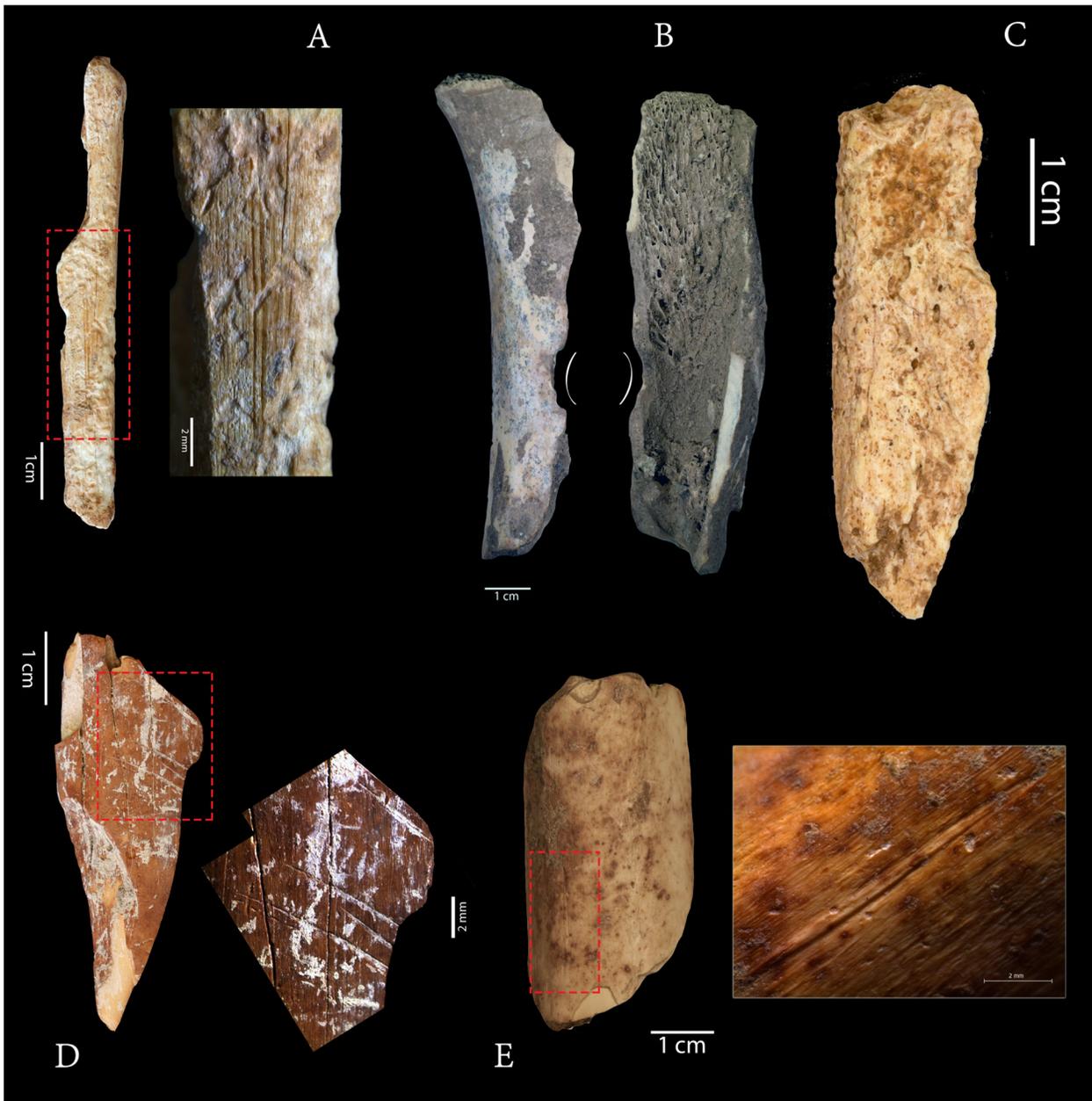
Fig. 8 - Remains showing anthropic and carnivore modifications. A: *Capreolus capreolus* metatarsal with scraping marks on its diaphysis side (Unit I). B: *Cervus elaphus* humerus with impact point on its diaphysis (Unit G). C: an unidentified long bone fragment corroded by carnivore digestion (Unit I). D: Unidentified long bone diaphysis of a medium-large size mammal with multiple cut-marks (Unit F). E: *Cervus elaphus* metacarpal fragment with a single cut-mark (Unit F).

G (less than 50% of the total NR%). Also the axial skeleton, rarest than the other anatomical parts, increase is frequency in the UP levels. A different variation is observed in Unit E where the representation of the cranial skeleton is highest for the medium size animals than for the medium-large (Fig. 6). Lastly, whole remains of large size animals are composed by isolated teeth concentrated in Ib and Ic and sesamoid in F (Fig. 5). The cranial skeleton, mainly represented by teeth, is the most abundant anatomical part in every archaeological unit, with the exception of unit E (Fig. 6). Cranial skeleton of large

faunas presents a decrease in unit H and elements of the forelimb and hindlimb increase in number in unit G-F. Is also observed a higher presence of the axial skeleton, which becomes the only anatomical portion present in unit E. Medium, medium-large and large sized remains seem to have been subject to a similar attrition due to intense fragmentation processes. It cannot be excluded that the skeletal representation are also due to anthropic activity, which may have concentrated on the intentional breakage of bones. Traces of percussion are in fact the most attested anthropic traces in the entire

assemblage, especially on long bones of medium-large size animals (Tab. 5). Furthermore, the presence of all the anatomical portions might suggest a complete transport of the carcasses, which occurred continuously between MP and UP.

The preservation of bone surfaces is low as a high presence of concretions (Fig. 7), which affects almost half of the total remains in Units I and H (Ib: 58%, Ic: 48%, It: 49%, H: 49%), is observed; it highly increases from Unit G to Unit E (G: 87%, F: 93%, E: 98%). Manganese dendrites are observed in each unit, with a major abundance in Units I, G, and E. Root-etching is scarce except in Unit E, but, like the manganese oxides, the scarce amount of remains in this unit could lead to an overrepresentation of the data.

Carnivore modifications are present in Units I and G but they are extremely rare and observed only on the 0.03% of remains (Tab. 5, Fig. 8). Pits and scores are the main alteration made by carnivores and only one remain shows digestion marks. Among the identified *taxa*, a *Cervus elaphus* metacarpal and a Cervidae metapodial show carnivore modifications, while other nine remains belong to medium-size mammals. No rodent marks are observed. Traces of anthropogenic activity on animal remains are rare but present throughout the stratigraphic sequence (Tab. 5). Among the identified species, the most exploited remains belong to the *Cervus elaphus*, whose remains show few percussion marks and cut marks. The exploitation of red deer appears to be continuous, from the Mousterian to the Early Aurignacian. Only in Unit I, rare anthropogenic modifications are observed on *Capreolus capreolus* and *Sus scrofa* remains. Nevertheless, along the entire site sequence, anthropic modifications are mostly observed on diaphysis of medium-large unidentified mammals. Burnt remains are abundant in all units, predominantly indeterminate bone fragments. However, there are few remains of *Bos/Bison*, *Cervus elaphus*, *Capreolus capreolus*, *Capra ibex*, *Sus scrofa* and *Lepus* sp. showing traces of combustion.

4.4. Skeletal representation

Skeletal representation data covers only those species with abundant remains, throughout the whole stratigraphy, which are not uniquely teeth. Those well-represented species are *Bos/Bison* sp., *Cervus elaphus*, *Capreolus capreolus*, *Capra ibex* and *Sus scrofa*. One can observe how cranial elements are frequent throughout the sequence, especially mandibles, except for units Ic and H. Such abundance is coherent with the high number of cranial elements and isolated teeth in the entire faunal assemblage (Fig. 6). The axial skeleton is almost entirely absent (Fig. 9), with scarcely frequent ribs from *Bos/Bison* sp. (G: 8% MAU) and *Cervus elaphus* (G: 2% MAU; F: 2% MAU; E: 2% MAU) in the up-

Tab. 5 - Anthropic and carnivore modifications observed on the fossil assemblage. Cut-mark (Cm), percussion-mark (Pm), cut-mark + percussion-mark (Cm+Pm), burned bones (B), calcinated bones (C), percentage of anthropic modifications (%Ant), carnivore modifications (Car), percentage of carnivore modifications (%Car).

per levels, and totally absent for unit I and H. The limb skeleton is well represented: the hindlimb, specifically the tibia and metapodials, are quite frequent throughout the whole stratigraphy. The main variation of the skeletal representation is in between and MP and UP. In fact, in Unit H, the number of limb elements represented in the skeletal profile increases, with a high frequency of hindlimb bones, such as tibias, tarsals, phalanges. The increase in the latter could be related to a general increase of short limb bones observed already in Unit It (Fig. 5). In unit G and F there is a higher number of elements of the proximal forelimb, such as scapula, humerus and radio-ulna, as well as of the hindlimb, such as tibia and astragalus, and a high number of both core and hind metapodials. Large sized animals, as the *Bos/Bison*, are represented by radio-ulna, femur and tibia, while for the Medium-large and medium animals, like red deer, ibex, wild boar and roe deer, we have every limb element, in particular the forelimbs. This data, together with the scarcity of elements of the axial skeleton, might suggest a differentiated transport and exploitation of preys defined by their weight size. Nevertheless, the high frequency of mandibles (Fig. 9) and the presence of all anatomical parts in the whole archaeological assemblage (Fig. 6), suggests that the carcass was transported as a whole inside the site. In this case, the absence of fragile and low-density bones, such as vertebrae, ribs and cranial bones may be due to intense taphonomical processes which have caused a high fragmentation of these elements (Fig. 4).

5. DISCUSSION

5.1. Faunal variability and palaeoenvironmental scenario

The zooarchaeological data allow a better interpretation of a possible environmental context during which the Riparo Mochi archaeological deposit was formed. Generally speaking, the fauna spectrum all along the Riparo Mochi sequence - from the MP to the Initial UP - seems to reflect the presence of a landscape characterized by a high variety of ecosystems (Fig. 3; Tab. 3).

5.1.1. Unit I

Base: The earliest phase of the Mousterian of Riparo Mochi is characterised by a great faunal diversity (Fig. 3). The copresence of species preferring open grassland environments such as *Bison priscus* and *Equus* sp. (McDonald, 1981; Berger, 1986), or ones more akin to temperate forest environments such as *Capreolus capreolus* (Danilkin, 1995), as well as alpine *taxon* such as *Capra ibex*, probably reflects great variety of habitats present in the region surrounding the site at the end of MIS 4. Carnivores are rare, but the presence of coprolites from Ib and Ic (spits from 39 to 64) and
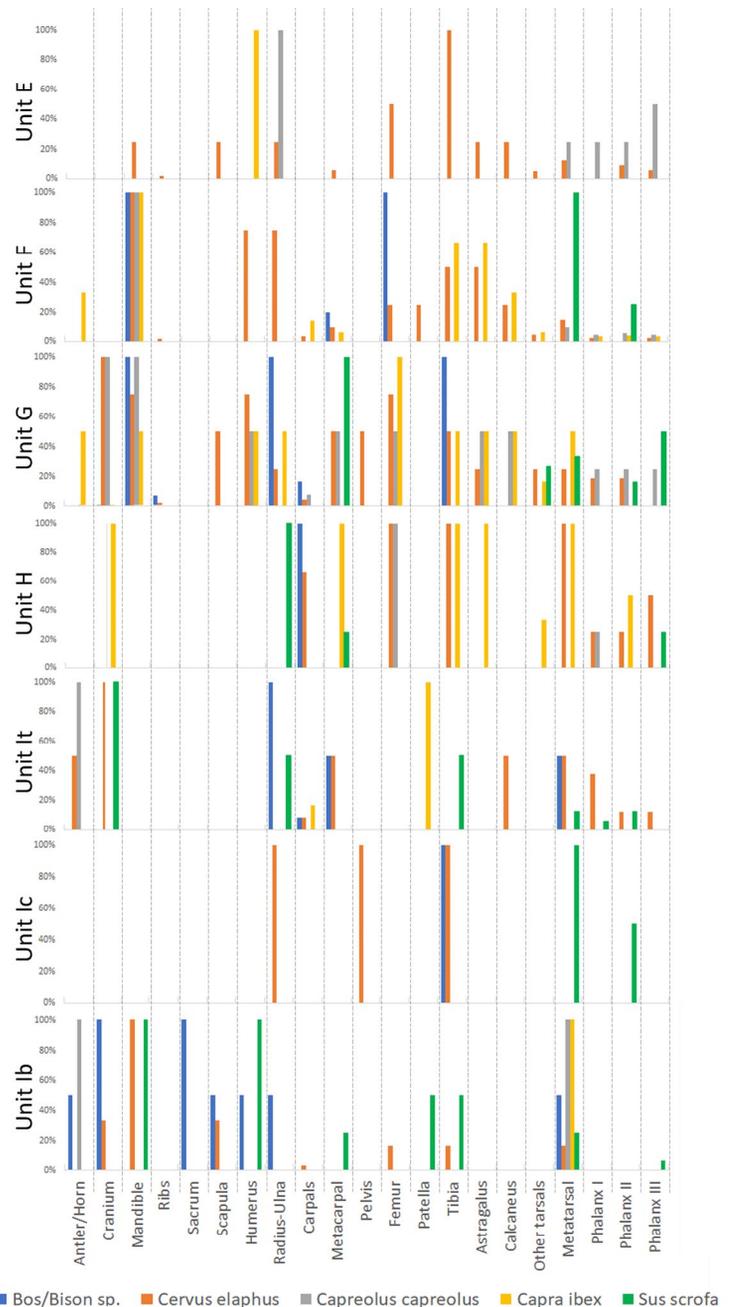
Fig. 9 - Percentage of Minimum Anatomical Units of *Bos/Bison*, *Cervus elaphus*, *Capreolus capreolus*, *Capra ibex* and *Sus scrofa* in each unit of Riparo Mochi.

undetermined remains with traces of digestions in unit It (Tab. 5) could indirectly suggest a occupation of the site by large predators such as hyenas (Tab.2). The presence of young *Sus scrofa* individuals, which are largely present in Ib, as well as throughout the entire Mousterian sequence (Tab. 4), could reflect a high environmental richness. Considering that this species can breed twice a year under favourable conditions (Mauget, 1981), we could suggest a high presence of wild boar at regional level, whose high reproductive rate could have been favoured by milder environmental conditions which

seem to have been maintained in Liguria even in periods of general cooling and climatic dryness (Negrino and Tozzi, 2008; Berto et al., 2019). The faunal assemblage from Ib fits reasonably well into the Ligurian archaeozoological palimpsest straddling MIS 4 and the beginning of MIS 3. Sites such as Madonna dell'Arma, Arma delle Manie, Santa Lucia Superiore and San Francesco (Valensi & Psathi, 2004), where anthropogenic accumulation is widely attested, are also characterised by a similar level of faunal diversity (Tab. 3).

Corpus: The main variation observed in the Mousterian levels is in Ic. Here, several features allow to detect an environmental change, towards dryer and colder conditions (Tab. 3). In fact, it is shown an abrupt increase of *Equus* sp. and a general decrease in the presence of other species; the absence of roe deer, of which the primary habitat is forest clearings, hedges, and woodland edges (Mauget, 1981; Danilkin, 1995), may support the hypothesis of a colder and less tree-covered environment during this phase. Finally, the presence of *Alces/Megaloceros* could also reflect colder environmental conditions. Due to its chronology, this part of the Mousterian sequence seems to fall into a the Greenland Stadial 15.1 (Rasmussen et al., 2014) which could have led to a decrease in temperature and a consequent regression of temperate *taxa*. Unfortunately, no palaeoecological nor archaeobotanical data are available neither for Ic nor for Ib phases. As in the previous Mousterian layers, hyena coprolites have been found and the presence of carnivores such as *Panthera* sp., a high presence of *Sus scrofa*, and a high MNI 1/D value, may be a proxy for a wide biodiversity (Tab. 3).

Top: Similarly, to what happens in Ib as well as palaeoenvironmental data also suggested (Renault-Miskovsky, 1972; Berto et al., 2019), the region surrounding the site was characterized by a patchwork of habitats of open and forested areas with a cold-humid environment during the final phase of the Mousterian at Riparo Mochi. The inverse Simpsons' index is the highest for the Mousterian Unit (Fig. 3), showing a wide diversity in the faunal composition. Moreover, this diversity has been also recognized in the Mousterian level "M" of the nearby site of Riparo Bombrini (Holt et al., 2019), where a NISP 1/D appears to be very similar to what has been found in It of Riparo Mochi (Tab. 3). This data confirms how the region's great environmental variety persists during the coldest climatic phases.

5.1.2. Unit H

As far as the assemblage coming from Cardini's Unit H is concerned as a whole, it is worth to mention that few remains were clearly identified showing few anthropogenic modifications. Generally speaking, the data coming from this Unit are very close to the later Unit G (see below). A general decrease in the faunal spectrum diversity is observed (Fig. 3), particularly with species such as *Equus* sp. and *Sus scrofa* (Tab. 2). Similarly, this evidence is also present in the semi-sterile 'MS' levels of Riparo Bombrini (Holt et al., 2019) (Tab. 4). Other studies show a rise in temperatures and a change in the rainfall regime which should have led to a reduction in forest cover in favour of an expansion of open meadows (Berto et al., 2019). As this change is

also observed in the later Unit G, it is therefore difficult to determine whether the variation in the faunal spectrum observed at the beginning of the Protoaurignacian level was mainly caused by a change in environmental conditions or by a change in hunting strategies that occurred with the arrival of the first AMHs at the site.

5.1.3. Unit G

As seen in Unit H, the large fauna assemblage of the Protoaurignacian Unit G has a minor diversity than the Unit I (Fig. 3). Variability between the two Units is mainly represented by the presence of *Rupicapra rupicapra*, by a greater presence of *Cervus elaphus* and *Capra ibex* as well as an increase in the number of anthropogenic modifications in Unit G. As shown by small fauna studies (Berto et al., 2019), the general warming and reduction of forestall cover seen in unit H is still in progress during the formation of Unit G. The lower diversity of the faunal spectrum (Fig. 3, Tab. 3) as well as the decreasing presence of *Equus* sp. and *Sus scrofa* remains (Tab. 2), may testify a mutation of the biodiversity of the region, maybe characterized by more presence of alpine faunas (as suggested by the higher frequence ibex and chamois remains). As seen in the oldest archaeological units, the remains of carnivores are still rare; moreover, the absence of coprolites from these levels could indicate a reduced frequentation of the site by hyenas.

5.1.4. Unit F

No major changes are observed in the species represented in Unit F. Although small mammals and palynological data indicate a colder and drier environment in Unit F than in Unit G (Renault-Miskovsky, 1972; Berto et al., 2019), the representation of species appears constant through the UP sequence. Nevertheless, the faunal assemblage shows an increasing loss of diversity, which reaches the lowest value in Unit F (Fig. 3). Another interesting value is the lack of carnivores (Tab. 2) that could be speculatively explained by a more intense human occupation, which is also supported by a higher number of anthropogenic modifications observed on bone remains (Tab. 5). *Cervus elaphus*, *Capra ibex*, and *Capreolus capreolus* are the main *taxa* found in the early Aurignacian unit. The coexistence of ibex and roe deer - species that frequent alpine grassland and wooded areas, respectively - may indicate the persistence of different environments, relatively close to each other, in the Riparo Mochi region. However, the presence of chamois, already found in Unit G, may reflect a greater presence of mountain faunas in the UP units than seen in the MP unit.

5.1.5. Unit E

Given the ephemeral nature of this deposit and the scarce presence of bone remains, Unit E may have been formed by an intrusion of materials from overlying and underlying units. It should be noted that Gravettian unit D has similar faunal data to units E and F (Tagliacozzo et al., 2012). In fact, the faunal spectrum of the Gravettian levels continues to be dominated by *Cervus elaphus* (37.69% NISP), and there is a similar proportion of *Capra ibex* remains (19.59% NISP) to that

observed for the ibex in Unit F (22.5% NISP). Unlike the older units, carnivores are present with a greater number of species: fox, wild cat and lynx but also *Panthera pardus* and *Crocuta crocuta*.

The faunas of the Gravettian unit continue to reflect a mosaic of environments, in which there is a co-presence of forest species such as deer and wild boar and 'cold' or alpine environment species such as chamois, ibex and marmot (Tagliacozzo et al. 2012), confirming that the climatic conditions of the region remain mild even with the cold and dry conditions present in the lower stage of Unit D (Berto et al. 2019).

5.2. Human-faunal interaction

5.2.1 Middle Palaeolithic

Despite the presence of hyena coprolites during the Ib and Ic phases, and the rare traces of digestion and fracturing by carnivores, human groups certainly acted as the main agent for the accumulation of bone remains of the site. Unfortunately, the concretions as well as the high rate of bone fragmentation hamper a clear recognition of the anthropogenic modifications, making archaeozoological interpretation difficult. Thus, traces of faunal exploitation are rare all along the Mousterian sequence of the Riparo Mochi. Without considering the abundant burnt bone fragments, anthropogenic traces are predominantly percussion marks; only one scraping mark, from the deeper spits, was recorded (Tab. 5). The skeletal representation observed in Unit I seems to indicate the arrival of the whole carcass at the site. Both medium, medium-large and large animals (Fig. 6) present anatomical elements from all anatomical portions, with a large presence of the cranial skeleton. Regarding the skeletal frequency of the most represented species (Fig. 9), we see a lower presence of anatomical elements in the Ic level compared to Ib and It. Thus, there does not appear to be a selection of specific anatomical elements in all three mousterian phases.

The Neanderthals who frequented Riparo Mochi had at their disposal a wide variety of prey, from large game such as horse to smaller game such as wild boar, the latter being extremely abundant according to the MNI in Unit I (Tab. 4). It does not seem to be possible to extrapolate data on a seasonal occupation of the site. The mere presence of young boar individuals (Tab. 4) does not allow to define a seasonality of death due to the animal's biological cycle, which doesn't give birth in a single time of the year (Mauget, 1981). In addiction, the sole presence of the fragments of cervid antlers, although distributed throughout the sequence, did not allow a seasonality of occupation of the site to be defined. Exploitation seems have a focus on *Cervus elaphus*, whose remains show the highest number of impact marks observed in the Mousterian unit. Further impact marks are observed mainly on the long bones of medium-large size mammals. As red deer belong to this size class, its exploitation by Neanderthals may be underestimated. The high presence of *Cervus elaphus* in the archaeological assemblage is a very common feature of Middle and Upper Pleistocene sites in the Ligurian region. In coeval sites such as Riparo Bombrini, Arma delle Manie, and San Francesco, red deer is the

main species among ungulates (Isetti, 1961; Valensi, 2000; Psathi, 2003; Valensi & Psathi, 2004; Holt et al., 2019) (Fig.1). A possible reason for this could be its high environmental adaptability, with a mix-feeder diet, plastic in its choice of habitats (Straus, 1981; Sommer et al., 2008), and the better "economical return" that this species could offer in terms of quality and quantity of the materials obtained, ease of hunting and/or transport (Valensi & Psathi, 2004). The Neanderthal economy at Riparo Mochi therefore seems to have focused on big game, a factor that seems to be common to coeval sites of Ligurian region. We also note the paucity of exploitation of small faunas such as birds or rodents; although it cannot be ruled out that such remains have not survived due to the intense taphonomic processes that characterise the site, this scanty evidence could be speculatively related to a possible distinctive cultural-economic difference between the Tyrrhenian and Po-Adriatic regions. Several sites of Adriatic region provide evidence of the exploitation of both avifauna (Fiore et al., 2004, 2016; Peresani et al., 2011; Romandini et al., 2014) and small fauna (Alhaique et al., 2004; Romandini et al., 2018). Currently, only at the French Pié-Lombard site (Pelletier et al., 2019), geographically close to Riparo Mochi and integrated into the Ligurian-Provençal region, provided Mousterian levels - dated to the MIS 5-4 transition - showing the exploitation of both avifauna and small mammals (specifically *Oryctolagus cuniculus*).

5.2.2. Upper Palaeolithic

The beginning of the UP is marked by an increase of anthropogenic modifications that are mainly concentrated on the long bones of medium-large sized mammals; determined remains of *Cervus elaphus* bearing cut-marks and percussion marks are also present and, similarly to Unit I, the exploitation of red deer could be underestimated, a feature which seems to persist during the UP. It was not possible to determine a seasonality of occupation of the site due to the absence of juvenile individuals (Tab. 4) or antler fragments still in connection with the skull. Compared to the earlier Mousterian unit, the UP units display a more diversified and abundant skeletal profile (Fig. 6, Fig. 9). As in the MP, the skeleton appears to be complete, suggesting that the carcasses entered the site as whole (Fig. 6). Unlike the MP, elements of the limbs are more abundant. The skeletal representation of ungulates such as *Cervus elaphus*, *Capra ibex* and *Capreolus capreolus*, shows a higher frequency of specific elements such as tibiae and metatapodials (Fig. 9). In general, the posterior appendicular skeleton is highly represented, suggesting a selection of specific anatomical elements or a higher degree of preservation of these. The change in faunal composition from Unit I to Unit H-G may be linked to a shift of anthropogenic activity. In fact, if we accept the presence of a sterile layer within the former Unit H, see Grimaldi et al. (2014), the variation in the faunal spectrum that occurred in Unit G may be mainly caused by a change in hunting strategies linked to the arrival of the earliest AMHs, rather than by climatic and environmental variations. For this reason, it cannot be excluded that the general increase in the number of remains belonging to cervids (red deer, roe deer or other cervids) is evidence

of a selection of prey which becomes more evident in Unit F where the variety of the faunal spectrum is lower. To support this hypothesis, the finding of antler industry in Early Aurignacian Unit F (Tejero & Grimaldi, 2015), specifically related to the production of split-based points, should be remarked. The production of such tools, namely hunting-oriented specialised tools, may have largely influenced the selection of prey, also useful for obtaining the non-lithic raw-material. In addition, the increase of *Capra ibex* and *Capreolus capreolus* at the expense of species such as *Equus* sp. and *Sus scrofa*, which are widely present in the Mousterian levels, could testify the change in hunting strategies that occurred during the UP. Interestingly, from Unit G to Unit E, more distinctly alpine *taxa*, such as *Capra ibex* and *Rupicapra rupicapra*, are more abundant than in Unit I. The AMHs inhabitants of Riparo Mochi may have preferred to hunt prey at higher altitudes than the Neanderthals, probably facilitated by a milder climate that made more accessible the mountainous areas close to the site. Evidence of hunting focused on alpine species can also be observed in the upper Unit D. Although surface preservation is as 'bad' as that observed in the Unit I to E sequence, the Gravettian levels have yielded numerous traces of exploitation of ungulates such as red deer and ibex that seem to suggest the persistence of exploitation of mountain faunas (Tagliacozzo et al., 2012)

Cervus elaphus and *Capra ibex* are the most exploited species, together with other ungulates such as *Capreolus capreolus*, *Rupicapra rupicapra* and *Bos primigenius*. Unlike what was observed in the Unit I-E sequence, in Unit D anthropogenic traces are found on the remains of carnivores such as *Vulpes vulpes*, *Felis silvestris* and *Lynx lynx*. These traces are attributable to skinning activities and could indicate a further variation in the hunting spectrum also linked to the obtaining of specific resources. A more in-depth study of the anthropic exploitation of preys in the Aurignacian levels will shed light on possible similarities and divergences between Unit F and Unit D.

6. CONCLUSIONS

This research allows a more specific environmental contextualization of Riparo Mochi throughout the formation of the Mousterian, Proto-Aurignacian and Aurignacian archaeological deposits. Data from the Riparo Mochi fit well with the palaeoenvironmental framework today available for the Liguro-provençal arc during the MIS 4 and 3. Despite rapid climatic fluctuations, the region is characterized by more temperate environmental conditions during the MUPT, favouring the persistence of a mosaic of environments and relevant biodiversity of large fauna. This heterogeneity can be observed as early as the end of MIS 5 (Unit I-base) and persists until MIS 3 (Unit F). During the earliest phases of the Mousterian, the site was also occasionally occupied by carnivores, as evidenced by the finding of hyena coprolites. The Neanderthals that inhabited Riparo Mochi, although the presence of a wide range of prey, hunted mainly medium-large ungulates, in particular red deer. With the arrival of AMHs, attested since the top of Unit H - base of Unit G, a change in the composi-

tion of the faunal spectrum is observed with a decrease in diversity. Nevertheless, *Cervus elaphus* remains the most hunted species; this could be tentatively related to an ecological adaptation of the hunters, probably linked also to the production of antler tools. Future studies such as a fully developed functional analysis linking lithics and butchering marks, palynological analysis, malacological and microwear dental studies, will be useful for a wider palaeoenvironmental contextualization and will provide a better understanding of the different human-environment interactions that occurred in the archaeological units at the Riparo Mochi.

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