



Subsistence Strategies in the Lower Magdalenian at El Cierro Cave (Ribadesella, Asturias, Spain)

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Abstract

El Cierro Cave (Ribadesella, Asturias, Spain) possesses one of the most complete Upper Palaeolithic stratigraphic sequences in northern Spain. Magdalenian occupations, particularly the lower Magdalenian, are well represented in its full sequence. This article presents the zooarchaeological analysis of the levels Cierro G1, Cierro G and Cierro F, dated by ¹⁴C to between 20,000 and 17,000 cal BP. The remains correspond to vertebrates (mainly large mammals and to a lesser extent fish and birds) and invertebrates (almost exclusively marine molluscs). The taphonomic analysis of the bones and shells has determined the role that the different animal resources played in the diet of the Magdalenian hunter-gatherers at El Cierro. The results obtained in each level of the sequence are compared and included in their regional context. This study also considers the way in which the Magdalenian groups at El Cierro processed the meat and fat of the different animal species and establishes the operational chain in the strategies of procurement, preparation and consumption of the prey.

Keywords Zooarchaeology · Taphonomy · Upper Palaeolithic · Lower Magdalenian · Cantabrian Spain

Introduction

The animal resources that formed part of the diet of the human groups that lived in northern Spain between ca. 20,000 and 17,000 cal BP have been a common topic of study since the 1970s (e.g. Altuna, 1972 and 1976; Castaños, 1980; Eastham, 1984; Morales, 1984; Madariaga & Fernández, 1987). Although taphonomic analyses were not carried out in the region before the 1990s and were little developed until the change of millennium, several studies are now available

about the strategies involved in hunting large mammals (e.g. Carvalho et al., 2021; Portero, 2022; Portero et al., 2019 and 2024), gathering molluscs (e.g. Álvarez-Fernández, 2011 and 2017), fishing (e.g. Pereda & Doadrio, 2016; Roselló & Morales, 2017) and fowling (e.g. Elorza, 2014; Llorente & Morales, 2016; Rufà et al., 2022) during the above-mentioned period in the north of Spain.

This research has succeeded in determining the importance of the different animal resources in the diet of the hunter-gatherers, although few of them offer a picture that encompasses all

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the zoological resources they consumed (Álvarez-Fernández et al., 2019, 2020 and 2022a; Martínez-Villa et al., 2022). Similarly, few works analyse the role of terrestrial and marine fauna in the diet of Magdalenian groups and most of them form part of the integral study of particular archaeological levels (e.g. Álvarez-Fernández et al., 2019, for Cova Rosa, and Arias et al., 2005, for La Garma A). Additionally, no studies have explored changes in subsistence strategies in the course of a Magdalenian sequence in a deposit and compared the intra-site results.

The present study provides new data about subsistence at El Cierro Cave (Ribadesella, Asturias, Spain) obtained from three lower Magdalenian levels (Cierro G1, Cierro G and Cierro F) through zooarchaeological and taphonomic analysis of vertebrates (large mammals, fish and birds) and invertebrates (marine molluscs). The results obtained in the three levels are compared with the information available from other contexts in the Cantabrian region of Spain that are dated to the lower Magdalenian.

El Cierro Cave (Ribadesella, Asturias, Spain)

El Cierro is a limestone cave at the eastern end of the Asturian Massif in the Cantabrian Mountains (Fig. 1). It is located at 83 m above sea level in a pre-littoral depression. The cave has two entrances that are connected to each other behind a doline.

The roof of the main room, where the site is located, collapsed, which led to the opening of a zenithal window that allows sunlight to enter. When the cave was discovered at the end of the 1950s, the main room was partially filled with archaeological deposits crowned by a shell midden (Álvarez-Fernández et al., 2016; Jordá Pardo et al., 2018a).

El Cierro is located 3.1 km from the mouth of the river Sella and 2.1 km from the modern coastline. During the lower Magdalenian, the marine regression, about 75 m below the current one, would place El Cierro cave at 6 km from the coast (Jordá Pardo et al., 2018b). Paleoenvironmental and anthracological studies carried out at the site suggest the presence of an open landscape and a cold climate in the area of El Cierro during the lower Magdalenian, due to the presence of moor taxa, particularly Leguminosae, and rodents such as the water rat and the field vole (Uzquiano, 2019; García-Ibaibarriaga et al., 2019; Álvarez-Fernández et al., 2022a). However, the presence of several forested areas can also be deduced from the existence of micromammals such as *Sorex araneus-coronatus* in other nearby sites (García-Ibaibarriaga et al., 2019). Regarding climate, isotopic studies ($\delta^{13}\text{C}$ and $\delta^{18}\text{O}$) of the Magdalenian levels indicate that the average annual precipitation during this period was above 500 mm year^{-1} , and the temperature was between 5 and 8 °C less than the current temperature (Lecuyer et al., 2021).

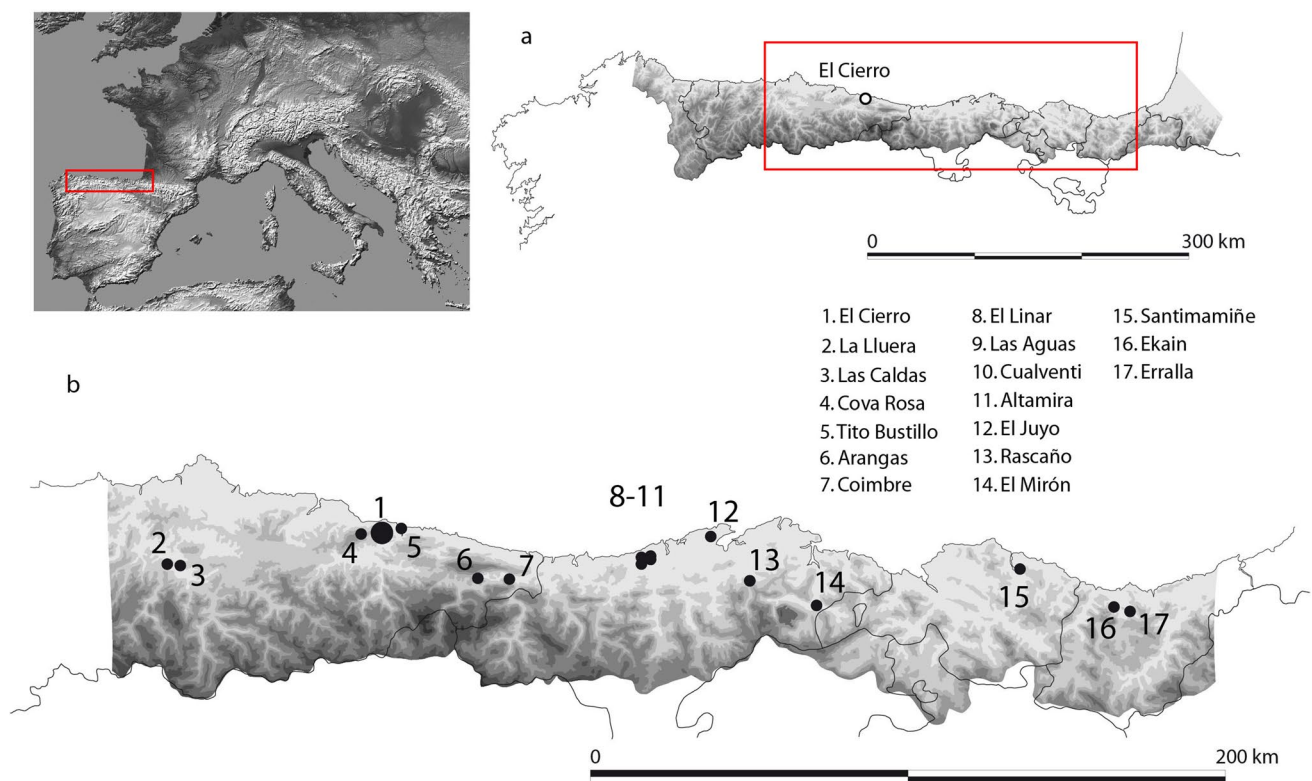


Fig. 1 a) Map showing the location of the El Cierro Cave in Cantabrian Spain. b) Map of the Magdalenian sites mentioned in the text

The lower Magdalenian faunal remains studied here come from the excavations performed by F. Jordá Cerdá and A. Gómez Fuentes from 1977 to 1979. This excavation was carried out in the main room, which has an extension of about 4×5 m where the Magdalenian habitat at El Cierro was located. Given the characteristics of the intervention area, the excavation was carried out in the northwest area of the room, in an area of 200×60 cm; they excavated to a depth of about 50 cm below the shell midden that forms the top of the sequence. This intervention area, although it is a marginal area of the site, was well protected from the erosive processes resulting from the entry of water through the zenithal opening of the room (Álvarez-Fernández et al., 2016; Jordá Pardo et al., 2018a).

The excavated sediment was screened with 5 to 2 cm mesh sizes (Álvarez-Fernández et al., 2016). The stratigraphic sequence obtained in this excavation was composed of 14 stratigraphic levels that were identified with letters from B to N (Fig. 2) (Álvarez-Fernández et al., 2018a; Jordá Pardo et al., 2018a).

In 2014, an intervention was carried out on a core from the excavation of the 1970s in order to determine the characteristics of the occupations, for which, among other works, the lithostratigraphic sequence was revised and different samples were taken (pollen, sedimentology and biotic samples for radiocarbon dating) (Álvarez-Fernández et al., 2018a, 2022a).

These samples led to the appearance of, among others, faunal remains that will also be studied in this work.

The three stratigraphic units belonging to the lower Magdalenian display the following lithostratigraphic characteristics, from the base to the top of the sequence (Álvarez-Fernández et al., 2018a; Jordá Pardo et al., 2018a):

- Cierro G1: formed by rounded fine and very fine quartz sand, with black silt and clay. It is 30 cm thick to the west and 20 cm to the east. In the west, a large autochthonous limestone boulder 125 cm long and 60 cm thick deforms the unit
- Cierro G: formed by two pockets of sediment up to 30 cm thick that are intercalated with Level F
- Cierro F: level formed by light brown silt and clay with fine rounded quartz sand. It contains clasts of autochthonous limestone with angular and rounded edges in a chaotic arrangement. The level forms an irregular pocket between the two layers of Cierro G

Four AMS radiocarbon dates have been obtained at Oxford Radiocarbon Accelerator Unit for these three levels. One of these is a new date not published previously (Table 1). They indicate a period between 19,735 and 18,504 cal BP, which is similar to the age of other deposits, such as Levels

Fig. 2 Drawing of the stratigraphic section in El Cierro Cave by Francisco Jordá Cerda and Alejandro Gómez Fuentes, in which the studied levels are highlighted (*apud* Álvarez-Fernández et al., 2016)

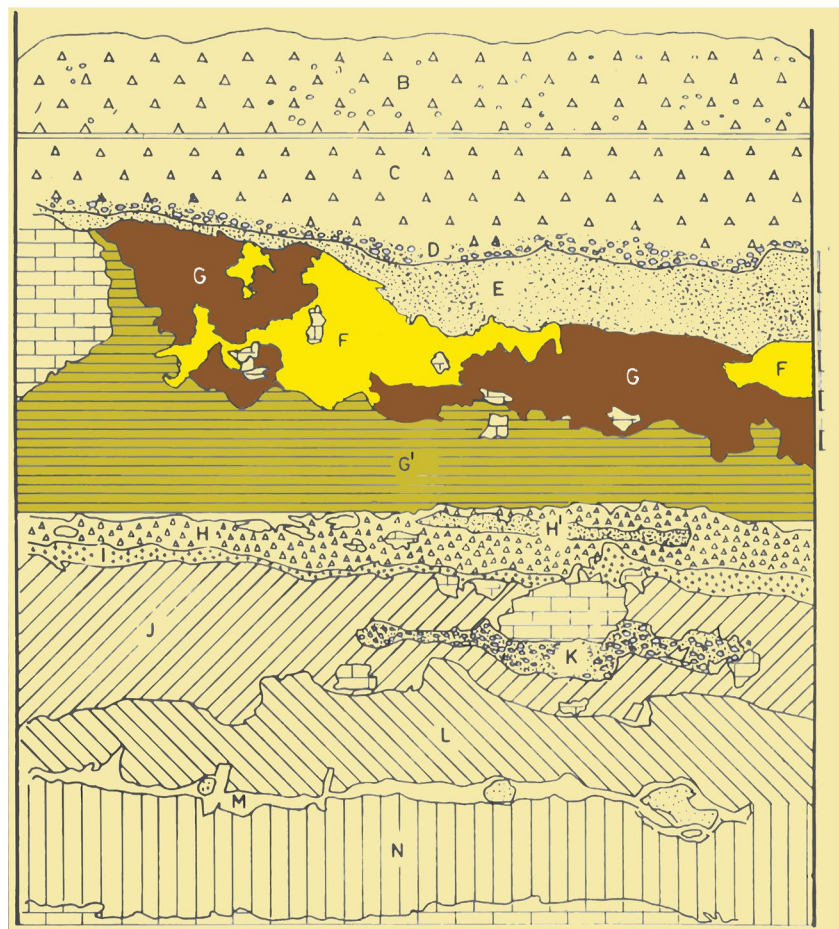


Table 1 Radiocarbon dates for the Magdalenian levels in El Cierro Cave, indicating the material that was dated, the lab code, radiocarbon age (BP) and calibrated date (cal. BP) to 2σ at 95.4%, obtained with the IntCal20 curve (Reimer et al., 2020) and Marine 20 curve

Level	Material	Species	Lab. ref	Date BP	Cal. BP 2σ	^{13}C	^{15}N	References
Cierro G1	Marine shell	<i>Littorina littorea</i>	OxA-27871	16,360 ± 55	19,085–18,655	0.2	-	Álvarez-Fernández et al. (2016)
Cierro G1	Bone	<i>Cervus elaphus</i> (with cutmarks)	OxA-31853	15,565 ± 70	18,978–18,730	-20.3	4.2	This paper
Cierro G	Bone	<i>Cervus elaphus</i> (with cutmarks)	OxA-27870	15,580 ± 75	19,011–19,735	-20.2	4.3	Álvarez-Fernández et al. (2016)
Cierro F	Bone	<i>Cervus elaphus</i> (with cutmarks)	OxA-27869	15,460 ± 75	18,901–18,648	-20.6	3.8	Álvarez-Fernández et al. (2016)

(Heaton et al., 2020) and the OxCal v.4.4. programme, the ^{13}C and ^{15}N parameters and references to the literature. The reservoir effect of 117 ± 70 established for the Cantabrian Sea (Monge Soares et al., 2016) was employed in the case of the marine sample

CR2 and CR1 at Cova Rosa (Álvarez-Fernández et al., 2021) in the same Sella valley as El Cierro and in other caves in Asturias, like Level B4 in the cave of Coímbre B (Álvarez-Alonso & Jordá Pardo, 2017), Levels G and F in Arangas Cave in the Cares valley (Álvarez-Fernández et al., 2020) and Levels XII and XI in Chamber II in Las Caldas Cave in the Nalón valley (Corchón, 2017a). In Cantabria, the dates are closely correlated with, for example, Levels 19 and 17 in the outer vestibule in El Mirón Cave (Hopkins et al., 2021), Levels 3 to 5 in El Rascaño Cave (Barandiarán & González Echegaray, 1981), Levels 4 to 11 in El Juyo Cave (González Echegaray, 1987) and Level 2 at Altamira, 3c at El Linar, Level B in Las Aguas Cave and Level E at Cualventi (Rasines del Río, 2016). In the Basque Country, these lower Magdalenian dates resemble the chronology of the occupations in Santimamiñe Cave (Level Csn-Camr) (López Quintana & Guenga, 2011), in Ekain Cave (Level VII) (Altuna, 1984 and 2012) and in Erralla Cave (Level V) (Altuna, 1985a).

Method

All the faunal remains recovered in the 1970s excavations and in 2014 have been studied. However, it should be noted that the sediment extracted in the 1977–1979 fieldwork was not screened with small mesh sizes, unlike in the 2014 fieldwork in which 1 mm and 0.5 mm mesh were used, and therefore, the information about small vertebrates and invertebrates is partial (Álvarez-Fernández et al., 2022a).

The large mammals were identified anatomically and taxonomically using the reference collections in the Zooarchaeology Laboratories at the University of Salamanca and Aranzadi Science Society and with different anatomical atlases for large mammals (Barone, 1966; Schmid, 1972; Pales & Garcia, 1981; Varela & Rodríguez, 2004; Hillson, 2005; López-Plana et al., 2011), birds (Bacher, 1967; Kraft, 1972; Hoyo et al., 1992) and fish (Le Gall, 1984). Uniquely, for the taxonomic identification of three teeth from Cierro G, the peptide fingerprint was identified with the ZooMS

method (Buckley et al., 2009) at the Autonomous University of Barcelona.

For the study of the skeletal profiles, the remains were classified into anatomical regions, differentiating between cranial elements (antler, skull, maxilla and mandible), axial elements (vertebra, rib, sternum, scapula, pelvis, sacrum and flat bone), anterior appendicular elements (humerus, radius, ulna, carpal and metacarpal) and posterior elements (femur, patella, tibia, fibula, tarsal and metatarsal). When the appendicular region could not be determined, the bone was included in the generic category of limb (metapodial, phalanx, sesamoid and long bone shaft or epiphysis) (Yravedra, 2006). In those cases when the faunal remain could not be assigned a taxonomic and anatomic classification, it was included in one of three mammal size categories: large mammals (> 300 kg), medium-size (100–300 kg) and small (5–100 kg), based on criteria of the thickness and robustness of the cortical bone (Bunn & Kroll, 1986; Yravedra, 2006; Portero, 2022).

The nomenclature of FAUNA EUROPAEA was followed for large mammals, birds and fishes (De Jong et al., 2014). Fish classification followed Fishbase (Froese & Pauly, 2024).

The terrestrial faunal assemblages were quantified in terms of the number of remains (NR) (Reitz & Wing, 2003), number of identified specimens (NISP) (Grayson, 1984; Lyman, 2019), minimum number of elements (MNE) (Bunn, 1983; Marean & Spencer, 1991) and minimum number of individuals (MNI) (Lyman, 1994).

To determine whether the skeletal representation of ungulates responds to the selective transport of certain anatomical elements (e.g. Grayson, 1989; Costamagno, 2002; Madrigal & Holt, 2002; Faith & Gordon, 2007; Saladié et al., 2011), we calculated Pearson's correlation coefficient between the percentage of the skeletal representation of ungulates and the minimum animal units (MAU), the modified general utility index (MGUI) and the meat, marrow and grease indices for caribou and sheep, which we have applied to red deer and Iberian ibex in this work, as these are the most abundant taxa at El Cierro. For the red deer, we have also used the standardized food utility index (SFUI)

proposed by Metcalfe & Jones (1988). From these correlations, we have determined the type of relationship between the variables, the strength of the relationship and whether it is statistically significant (p -value < 0.05).

The age of death of the mammals was established based on the patterns of tooth eruption and wear and epiphysis fusion for the different species (Noddle, 1974; Grigson, 1982; Levine, 1982; Mariezkurrena, 1983; Mariezkurrena & Altuna, 1983; Wegrzyn & Serwatka, 1984; Eisenmann et al., 1988; Pérez Ripoll, 1988; Brown & Chapman, 1991; Azorit et al., 2002 and 2003; Steele, 2002; Tomé & Vigne, 2003). For the birds, the studies of Bacher (1967) and Kraft (1972) have been followed.

Once the age of the individuals was established, we classified the mammals according to five age categories: neonate (deciduous dentition not yet fully erupted and without wear, or bones with early ossification), immature (animals with complete deciduous dentition and/or with permanent teeth germs and epiphyses of long bones not yet fused), juvenile (some deciduous teeth present, but also with permanent teeth with little wear, and the bones do not have fused epiphyses and/or maintain the fusion line of the epiphyses), adult (animals with complete permanent dentition and fully fused epiphyses) and senile (individuals whose permanent dentition shows a high degree of wear). In order to establish the mortality patterns of the prey hunted by the Magdalenian groups of El Cierro, we grouped the mortality profiles based on ternary graphs (Stiner, 1990), taking into account the four zonations established by Discamps & Costamagno (2015) and adapted to the life cycle of each species:

- “JPO” (juvenile-prime-old) zone: includes sites with the following ratio: juvenile > adult > senile. Mainly refers to L-shaped mortality profiles (but also to a small U-shaped group)
- “JOP” (juvenile-old-prime) zone: determined by the following class ratio: juveniles > senile > adults. Characteristic of the attritional profiles (“U” shape)
- “P” (prime) zone: dominated by adult individuals
- “O” (old) zone: includes age profiles showing a mortality pattern with a predominance of senile animals

The seasonality of the Magdalenian occupations was estimated based on the age profiles and reproduction biological cycles of modern wild species, considering the times of mating, gestation, birth, growth and life expectancy of those species (e.g. Costamagno, 1999; Discamps & Costamagno, 2015).

For the taphonomic analysis, the bone surfaces were observed with hand magnifying glasses of different magnifications ($\times 5$, $\times 10$ and $\times 15$), combined with a Leica EZ4 HD microscope (6.5–32 \times). Cutmarks were analysed in terms of their morphology, location and orientation on the bone in order to determine their function in the butchery process

(e.g. Binford, 1981; Shipman & Rose, 1983; Bunn & Kroll, 1986; Yravedra, 2006; Costamagno et al., 2019). To establish the butchery processes, the classification proposed by Binford (1981) was followed, and each cut mark on the bone was counted individually, and where possible the position was indicated on anatomical templates.

The frequency of the cutmarks was also analysed based on the NISP to determine which elements were most often processed for each species and size category. The anthropogenic breakage of the bones considered the angle, line and type of fracture as well as the shape of the percussion marks (Villa & Mahieu, 1991; Pickering & Egeland, 2006; Vettese et al., 2020). Wherever possible, the exact position of the impact on the bone was noted to detect any breakage standardised patterns (Masset et al., 2016). The degree of burning of the bones was calculated from their colour (Stiner et al., 1995), which is a proxy for the temperature they were exposed to (Nicholson, 1993). The burnt remains have been grouped into six categories according to the degree of burning as proposed by Stiner et al. (1995):

- Grade 1: partially burned with brown hue (< from half of the bone)
- Grade 2: burnt with brownish hue (> of half of the bone)
- Grade 3: completely charred (black shade)
- Grade 4: black and white shade (< half charred)
- Grade 5: black and white shade (> half charred)
- Grade 6: completely charred (totally white)

Differential thermal alteration processes have also been documented by noting bones with two or three colours on the same surfaces, as well as their position on the bone and the number of surfaces with those alterations. This can help to determine the function of the exposure to fire: either roasting meat (Cáceres et al., 2002; Costamagno et al., 2005; McKinley, 2008 and 2016) or use of bones as fuel (Costamagno et al., 2005; Yravedra et al., 2005; Yravedra & Uzquiano, 2013).

Marks caused by carnivores were also taken into account, classifying them according to their morphology (Haynes, 1980; Selvaggio, 1994). Finally, alterations related to the formation of the archaeological deposit have been considered, such as weathering, precipitation of calcium carbonate, the presence of manganese oxide and post-depositional processes (root marks, trampling and polish) (Behrensmeyer, 1978; Andrews & Cook, 1985; Behrensmeyer et al., 1986; Fernández-Jalvo & Andrews, 2016).

The taxonomic classification of the marine molluscs was carried out with the reference collection in the Zooarchaeology Laboratory at the University of Salamanca and publications that specify the habitat of the species living on the northern Spanish coast today (e.g. Palacios & Vega, 1997; Trigo et al., 2018). WoRMS nomenclature was used for the marine invertebrates (WoRMS Editorial Board, 2024).

The molluscs were classified to species level, wherever possible, based on their general attributes (shape, ornamentations, etc.), and the MNI was calculated from the NR and NISP, taking into account the different fragmentation categories. To calculate the MNI, the apices of the *Patella* genus were counted, and the apex and umbilical zone in the case of the other genera (e.g. Madariaga, 1975a and 1975b; Moreno, 1994; Álvarez-Fernández, 2009 and 2013; Álvarez Fernández et al., 2019).

The various alterations to the shells, caused by epifauna, marine perforating organisms, marine erosion, anthropogenic action, etc. (e.g. Fretter & Graham, 1962; O'Connor & Lamont, 1978; Laukner, 1980; Baxter, 1984; Fernández López, 1998; Álvarez-Fernández, 2006 and 2013; Southward, 2008) were noted to discern whether the molluscs were taken to the site as food or for other purposes, such as raw material to make objects of adornment.

Results

The study has documented a total of 40,940 remains of vertebrates (mammals, birds and fish) and invertebrates (marine molluscs and a crustacean) from the lower Magdalenian levels in El Cierro Cave. Of these, 98.2% come from the 1977–1979 excavations, while 1.8% come from the 2014 intervention. A total of 23,023 (56% of the total) come from Cierro G1: remains of large mammals are the most numerous (NR = 15,281), followed by molluscs (NR = 7729), fish (NR = 10) and birds (NR = 3). From Cierro G, 8608 remains (21% of the total) consist of 8151 remains of mammals, 456 of molluscs and one of a bird. The 9309 remains (23% of the total) from Cierro F correspond to mammals (NR = 8890), molluscs (NR = 417), one bird and one crustacean. No remains of fish were identified in this level (Tables 2 and 3).

Table 2 Number of identified specimens (NISP), percentage of number of identified specimens (%NISP), minimum number of elements (MNE) and minimum number of individuals (MNI) of identified ani-

mal remains documented in the lower Magdalenian levels in El Cierro Cave (totals and subtotals are presented in bold)

	Cierro G1				Cierro G				Cierro F			
	NISP	%NISP	MNE	MNI	NISP	%NISP	MNE	MNI	NISP	%NISP	MNE	MNI
<i>Cervus elaphus</i>	2363	91.17	1425	48	509	91.22	371	11	1005	92.37	695	8
<i>Capreolus capreolus</i>	23	0.89	21	4	6	1.08	5	1	7	0.64	6	2
<i>Capra pyrenaica</i>	139	5.36	89	6	34	6.09	18	2	70	6.43	52	2
<i>Bos/Bison</i> spp.	51	1.97	45	3	6	1.08	5	1	6	0.56	6	1
<i>Equus ferus</i>	14	0.54	12	1	3	0.54	2	1	-	-	-	-
<i>Canis</i> sp.	2	0.08	2	1	-	-	-	-	-	-	-	-
Subtotal large mammals	2592	100	1594	63	558	100	401	16	1088	100	759	13
<i>Patella vulgata</i>	69	0.89	-	60	-	-	-	-	-	-	-	-
<i>Patella</i> sp.	1586	20.52	-	127	55	12.06	-	15	141	33.81	-	28
<i>Littorina littorea</i>	6070	78.54	-	1724	400	87.72	-	79	274	65.71	-	86
<i>Littorina obtusata</i>	1	0.01	-	1	-	-	-	-	1	0.24	-	1
<i>Mytilus</i> sp.	2	0.03	-	1	1	0.22	-	1	-	-	-	-
<i>Nucella lapillus</i>	1	0.01	-	1	-	-	-	-	1	0.24	-	1
Subtotal molluscs	7729	100	-	1914	456	100	-	95	417	100	-	116
<i>Anser/Branta</i> sp.	1	50	1	1	-	-	-	-	-	-	-	-
<i>Perdix perdix</i>	1	50	1	1	1	100	1	1	-	-	-	-
<i>Corvus corax</i>	-	-	-	-	-	-	-	-	1	100	1	1
Subtotal birds	2	100	2	2	1	100	1	1	1	100	1	1
<i>Semibalanus balanoides</i>	-	-	-	-	-	-	-	-	1	100	-	1
Subtotal crustaceans	-	-	-	-	-	-	-	-	1	100	-	1
Salmonidae	3	100	3	1	-	-	-	-	-	-	-	-
Subtotal fishes	3	100	3	1	-	-	-	-	-	-	-	-
Total	10326	-	1599	1980	1015	-	402	112	1507	-	760	131

Table 3 Number of remains (NR), minimum number of elements (MNE) and minimum number of individuals (MNI) of mammal's categories and unidentified animal remains in the lower Magdalenian levels in El Cierro Cave (totals are presented in bold)

	Cierro G1			Cierro G			Cierro F		
	NR	MNE	MNI	NR	MNE	MNI	NR	MNE	MNI
Large size mammal	88	43	2	29	10	1	9	8	1
Medium size mammal	3212	528	20	1295	289	6	498	120	2
Small size mammal	835	234	14	271	54	4	357	97	2
Indet. mammal	8554	-	-	5998	-	-	6938	-	-
Indet. bird	1	1	-	-	-	-	-	-	-
Indet. fish	7	7	-	-	-	-	-	-	-
Total	12697	813	36	7593	353	11	7802	225	5

Vertebrates

Large Mammals

In Cierro G1, 2592 remains (17%) were identified to taxonomic level, and the rest were assigned to their corresponding size categories. Based on the NISP, red deer is the most common animal, with 2363 remains (91.2%), followed by Iberian ibex with 139 (5.4%), large bovids with 51 (2%), roe deer with 23 (0.9%) and horse with 14 (0.5%). Carnivores are present with two elements belonging to a canid. In the size categories, medium-sized mammals are most abundant (NR = 3212) followed by the small (NR = 835) and large categories (NR = 88).

In Cierro G, 6.8% (NR = 558) of the remains were identified taxonomically. Red deer is the best represented species in the NISP, with 509 remains (91.2%), followed by Iberian ibex with 34 (6.1%), roe deer and Bos/bison with six remains each and horse with three. In this level, three teeth were initially thought to belong to an indeterminate marine mammal (Portero et al., 2019). However, ZooMS analyses of one of them concluded that they correspond to a cervid species other than reindeer. The morphology of the teeth resembles the first premolar of red deer (Mech et al., 1970), a dental anomaly that is absent in most modern animals and which may explain their scarcity in this archaeological deposit. In the size categories, medium-sized mammals are the most abundant (NR = 1295), followed by small (NR = 271) and large animals (NR = 29).

In Cierro F, 1088 remains (12.2%) were classified taxonomically. Red deer is again the main species, with 1005 remains (92.4% of the NISP), followed by Iberian ibex with 70 (6.4%), roe deer with seven (0.6%) and large bovid with six (0.5%). Medium-sized mammals are again the most abundant in the size categories (NR = 498), followed by small (NR = 357) and large animals (NR = 9).

The MNE displays a very similar distribution to the NISP in the three levels as red deer is the species with the largest number of elements, followed by Iberian ibex, large bovid, roe deer, horse and canid. All the skeletal parts of red deer are represented in the three levels and cranial elements

(mainly teeth) and the hind limbs are the most abundant in all of them while axial elements are the least well-represented. For Iberian ibex, the representation patterns differ considerably from one level to the other. In Cierro G and Cierro G1, cranial elements are abundant, as teeth are very common. However, in Cierro F the best represented elements are the limbs, especially the hind limbs, and no axial elements have been recorded. Similarly, in Cierro G and Cierro G1, a high percentage of cranial elements of roe deer have been documented, mainly teeth and mandibles, whereas in Cierro F only limb elements were identified. In the three levels, distal appendicular elements of this animal are very abundant, especially the phalanges. Large bovids are represented mainly by distal appendicular elements, mostly phalanges and carpal and tarsal bones. Cranial elements are abundant in Cierro G1 and F, but absent in Cierro G. Horse, present in Cierro G and G1, is represented mainly by teeth.

In the size categories, the medium and small mammals are represented by a large number of axial elements, mainly ribs and vertebrae, although limb elements are also quite abundant and in the majority in Cierro G. A large number of appendicular elements are observed in the large mammal category, mostly long bone shafts. Axial elements are also abundant, whereas cranial remains are very scarce (Table 4).

In terms of the MNI, red deer is the most abundant species in all levels. The mortality patterns indicate that animals of practically all age ranges are present. Although young adults are most common in all levels, there is a significant number of infantile and juvenile individuals. This indicates that hunting focused mainly on younger animals. Iberian ibex, the second most common species, is represented by both adult and juvenile individuals, except in Cierro F, with only two adult individuals. For the few individuals of roe deer and large bovids, there is only an immature individual of each taxon in Cierro G, and the rest are young adults. All the remains of horse and canid in Cierro G1 belong to adult animals. In the size categories, the medium and small mammals are represented by a large number of young adults and immature individuals. No senile animals have been identified in those categories. For the large mammals, except for an immature specimen in Cierro G1, the other remains

Table 4 Skeletal remains of the different large mammals documented in the Magdalenian levels at El Cierro

Element	<i>Cervus elaphus</i>			<i>Capreolus capreolus</i>			<i>Capra pyrenaica</i>			<i>Bos/Bison</i> spp.			<i>Equus ferus</i>		<i>Canis</i> sp.	Large size mammal			Medium size mammal			Small size mammal						
	G1	G	F	G1	G	F	G1	G	F	G1	G	F	G1	G	G1	G1	G	F	G1	G	F	G1	G	F	G1	G	F	
Antler	98	5	22	-	-	-	14	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Skull	61	-	15	1	-	-	2	-	-	-	-	-	-	-	-	1	-	-	157	5	34	25	6	-	-	-	-	
Tooth	318	124	86	5	3	-	20	6	3	8	-	-	8	3	-	3	-	-	54	8	-	3	2	-	-	-	-	
Mandible	139	10	60	6	-	-	5	-	-	2	-	-	1	-	-	2	-	-	146	17	10	24	4	-	-	-	-	
Hyoid	15	-	6	-	-	-	-	-	-	-	-	2	-	-	-	-	-	3	-	-	1	-	-	-	-	-	-	
Atlas	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	1	-	-	-	-	-	-	
Axis	2	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	2	3	-	-	-	-	-	-	-	-	
Cervical v	4	6	1	-	-	-	-	1	-	-	-	-	-	-	-	2	-	-	97	22	-	34	-	-	-	-	-	
Thoracic v	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	103	-	-	21	-	-	-	-	-	-	
Lumbar v	7	4	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	134	30	-	23	-	-	-	-	-	
Caudal v	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	2	-	-	-	-	-	-	-	-	
Vertebrae ind	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	3	-	338	73	68	149	17	79	-	-	-	
Rib	16	11	5	-	-	-	-	8	-	-	-	-	-	-	-	4	1	-	441	92	155	179	72	111	-	-	-	
Sternum	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	1	-	-	-	-	-	-	-	-	
Pelvis	54	3	20	-	-	-	5	-	-	-	-	-	-	-	-	1	-	-	51	4	-	22	2	5	-	-	-	
Sacrum	7	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	1	-	1	4	-	-	-	-	-	
Scapulae	36	6	7	-	-	-	2	-	-	-	-	-	-	-	-	2	-	-	73	10	-	44	8	4	-	-	-	
Flat bone ind	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	1	-	364	186	-	66	41	-	-	-	-	
Humerus	49	5	48	-	-	-	2	-	-	1	-	-	-	-	-	3	2	-	51	21	-	5	3	9	-	-	-	
Radius	94	3	36	-	1	1	6	-	-	-	1	-	1	-	-	3	-	-	58	15	-	22	5	15	-	-	-	
Ulnae	81	7	21	1	-	-	1	-	10	3	-	-	-	-	-	1	1	-	15	4	-	5	-	5	-	-	-	
Carpal	114	29	25	1	-	2	5	1	-	15	-	-	-	-	-	1	-	-	8	1	-	-	-	-	-	-	-	
Metacarpal	144	44	114	-	-	-	8	-	-	3	-	1	1	-	-	-	-	34	19	-	8	1	5	-	-	-	-	
Femur	78	5	52	-	-	-	4	-	22	-	-	-	-	-	-	6	-	-	67	24	13	12	3	13	-	-	-	
Patella	4	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	
Tibiae	90	11	100	1	-	-	6	-	-	1	-	1	-	-	-	3	-	-	75	15	-	14	1	5	-	-	-	
Talus	39	6	-	-	-	-	2	-	-	-	-	-	1	-	-	-	-	6	1	-	1	-	-	-	-	-	-	
Calcaneum	40	3	-	-	-	-	2	-	-	-	-	-	1	-	-	-	-	6	1	-	-	-	-	-	-	-	-	
Tarsal	105	32	65	2	-	-	9	2	4	3	2	1	1	-	-	-	-	6	4	-	-	-	6	-	-	-	6	
Metatarsal	120	41	74	-	-	2	6	-	3	3	-	-	-	-	-	-	1	-	36	25	-	6	1	7	-	-	-	
Metapodial	84	10	76	-	-	-	3	2	4	2	2	1	-	-	-	3	-	-	160	70	-	32	3	23	-	-	-	
Metapodial lat	32	14	-	-	-	-	2	-	-	-	-	-	-	-	-	-	1	-	3	-	-	2	-	-	-	-	-	
Long bone ind	2	-	10	-	-	-	-	-	-	2	-	-	-	-	-	41	17	9	609	586	204	106	75	55	-	-	-	
Phalanx 1	199	40	62	3	-	2	15	-	15	5	-	-	-	-	-	1	-	-	29	9	-	6	4	7	-	-	-	
Phalanx 2	147	40	58	2	2	-	8	1	-	3	1	-	-	-	1	-	1	16	18	-	8	4	8	-	-	-	-	
Phalanx 3	86	19	19	1	-	-	3	3	9	-	3	-	-	-	1	-	1	23	19	14	12	11	-	-	-	-	-	
Phalanx ind	2	3	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20	9	-	2	4	-	-	-	-	-	
Sesamoid	78	22	-	-	-	-	7	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

belong to adult individuals, as observed in the case of large bovid and horse (Table 5).

The population distribution of the different species and size categories based on the zonations established by Discamps & Costamagno (2015) for ternary diagrams (Stiner, 1990) shows for Cierro G1 a general “JPO” type profile. The mortality of young and adult individuals dominates over senile individuals, except for the roe deer, which presents a

“P” profile, with adults predominating over the rest of the age categories. In the case of Cierro G, we have a “JPO” profile where the mortality of young and adult individuals predominates over that of senile individuals. Outside this profile, we have the species represented by a single adult or juvenile individual and the small mammals that show a “P” profile, with young adults predominating over immature and senile individuals. For Cierro F, we find a general profile

Table 5 MNI of the taxa and size categories according to age groups in the lower Magdalenian levels at El Cierro (totals are presented in bold)

	Cierro G1					Cierro G				Cierro F			
	NN	IMM	JU	AD	SE	IMM	JU	AD	SE	IMM	JU	AD	SE
<i>Cervus elaphus</i>	1	11	8	26	2	3	1	5	2	2	1	4	1
<i>Capreolus capreolus</i>	-	1	-	3	-	-	-	1	-	-	-	2	-
<i>Capra pyrenaica</i>	-	1	1	4	-	1	-	1	-	-	-	2	-
<i>Bos/Bison</i> spp.	-	1	-	2	-	-	-	1	-	-	-	1	-
<i>Equus ferus</i>	-	-	-	1	-	-	-	1	-	-	-	-	-
<i>Canis</i> sp.	-	-	-	1	-	-	-	-	-	-	-	-	-
Large size mammal	-	1	-	1	-	-	-	1	-	-	-	1	-
Medium size mammal	-	5	3	12	-	2	-	4	-	1	-	1	-
Small size mammal	-	3	3	8	-	1	-	3	-	1	-	1	-
Total	1	23	15	58	2	7	1	17	2	4	1	12	1

NN neonate, IMM immature, JU juvenile, SE senile

where the mortality of adult individuals predominates over juveniles and senile individuals. Outside this range would be roe deer and Bos/bison consisting only of adult individuals (Fig. s1, s2 and s3).

The correlation analysis between %MAU and the different general utility indices (MGUI and SFUI) in Cierro G1 shows a negative coefficient of weak intensity ($r < 0$) for the red deer, while for the marrow and fat utility indices the relationships are direct and of moderate and weak intensity, respectively. These indices could reveal the transport to the cavity of those skeletal elements with higher marrow and grease utilisation. In this sense, the only relationship that shows statistical significance (p -value < 0.001) is the one that relates %MAU with the marrow index (Table s1 and Fig. s4). For Iberian ibex, all correlation data with utility indices are direct. In the case of grease and marrow utility, the intensity of the relationship is weak, while for MGUI and the meat utility index, the intensity is moderate. Only for the correlation between %MAU and meat utility index we have a p -value < 0.05 (Table s4 and Fig. s7).

In Cierro G, red deer show an inverse and weak relationship between the general food utility indices (MGUI and SFUI) and the percentage of anatomical representation (%MAU). This negative relationship holds for meat utility values and becomes positive, but not very strong for grease and marrow utility values. For this taxon, none of the correlations is statistically significant (Table s2 and Fig. s5). For Iberian ibex, we find a weak to moderate inverse relationship between food utility indices and anatomical representation. However, none of the resulting correlations is statistically significant (Table s5 and Fig. s8).

Red deer shows in all cases a direct relationship between the different utility indices and the anatomical representation in Cierro F. This relationship is practically null between the %MAU, the general utility indices (MGUI and SFUI) and the meat utility index. This relationship is stronger when correlating %MAU and medullary utility, the latter being the

only one that is also statistically significant (p -value < 0.01) (Table s3 and Fig. s6). For Iberian ibex, we observed a direct correlation between the general utility indices and %MAU. In this taxon, only the relationship between %MAU and grease utility index is statistically significant (p -value < 0.05) (Table s6 and Fig. s9).

The taphonomic study revealed the extent of the anthropogenic manipulation of these faunal remains, attested by cutmarks, intentional breakage of bones and heat alteration processes (Fig. 3 and Table 6). Cutmarks have been documented on 11.6% of the NISP from Cierro G1, 11.4% in Cierro G and 6% in Cierro F. The processing of carcasses has been observed on the remains of red deer, Iberian ibex, roe deer, large bovid and horse, and also on the large, medium and small mammals.

Red deer was the main prey processed in all the Magdalenian levels. The abundance of the anthropogenic marks has enabled an appreciation of the specific treatment given to this ungulate. Evidence has been observed of the complete processing of all the anatomical parts of the animal (cranial, axial and appendicular). The tasks involved skinning, disarticulating, dismembering and defleshing the body and also scraping the periosteum before breaking the bones to access the marrow (Table 7). Most of the cutmarks in these levels are located on the autopodia; even though in Cierro F most marks are on the tibiae and femora, the autopodia also display a large percentage of them (Fig. s10, s11 and s12). The percentages of the frequencies of cutmarks on red deer bones show that in Cierro G1, axial elements display a high proportion of marks. This may indicate that the axial skeleton was also processed intensely although, owing to the low NISP of those skeletal elements, they may be over-represented. In Cierro G and F, cutmarks are most frequent on autopodia and zeugopodia (Fig. s13).

For the mammals in the medium-size category, the butchery patterns are similar to those of red deer in all the Magdalenian levels. In this case, owing to the large number of long

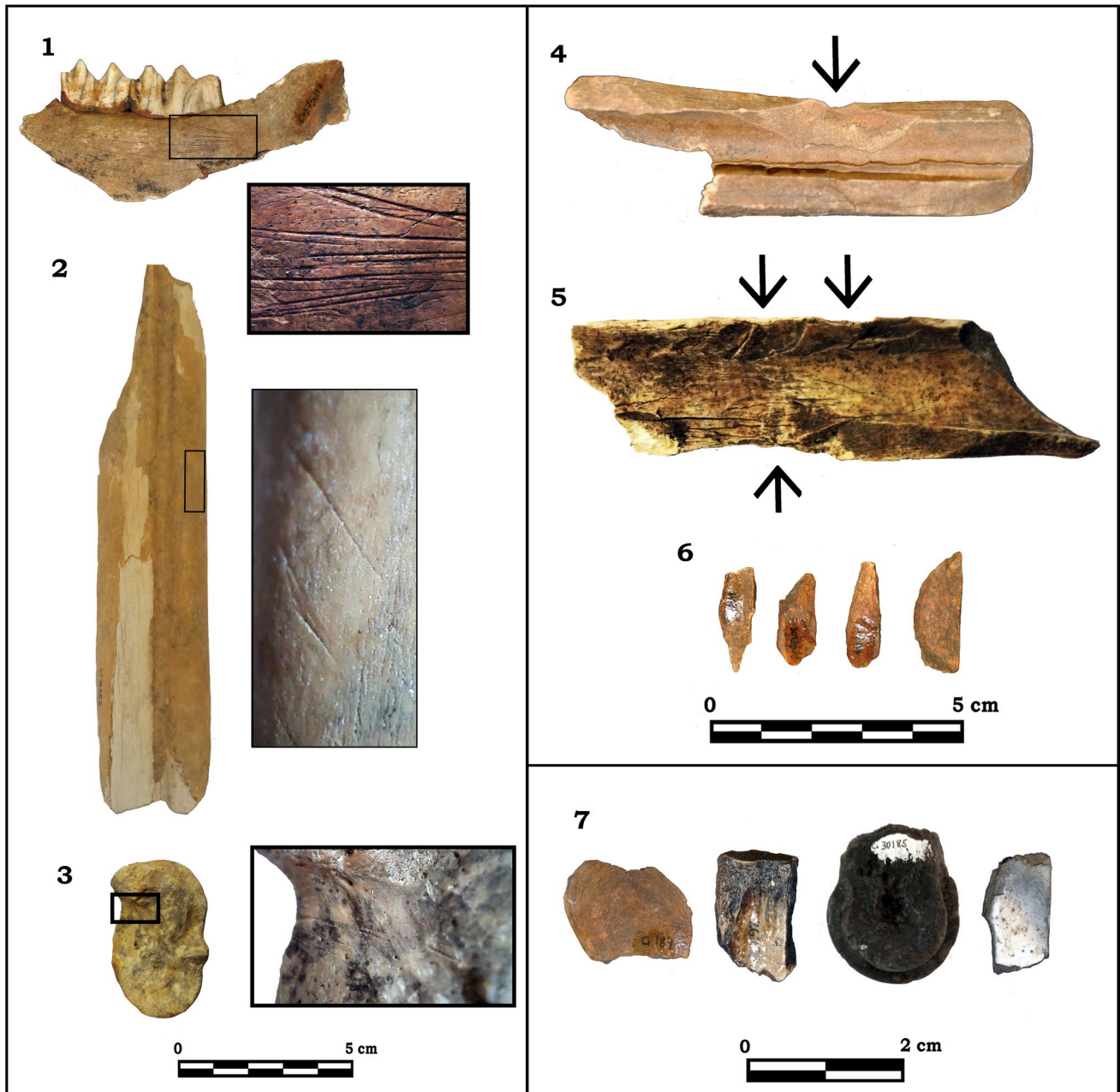


Fig. 3 Anthropogenic marks on remains from the lower Magdalenian levels in El Cierro. **1** Red deer mandible with evisceration marks (Cierro G1). **2** Red deer metatarsal with defleshing marks (Cierro G). **3** Roe deer astragalus with disarticulation marks (Cierro F). **4** Red

deer metacarpal with a percussion mark (Cierro G). **5** Red deer tibia with consecutive percussion marks and an opposite notch (Cierro F). **6** Flakes (Cierro G1). **7** Burnt bones with different tones of colour

bone shafts and ribs, those are the elements with the largest percentage of cutmarks. However, according to the frequency of the marks, femora and metapodia display a high percentage of marks (Fig. s14). As in the case of red deer, tasks of skinning, evisceration, disarticulation, dismembering, filleting and scraping the periosteum have been identified.

Few Iberian ibex remains display cutmarks in the three levels (NR = 17). They are mainly defleshing marks on femur

shafts and vertebrae and of disarticulation on the pelvis and phalanges. Only three marks have been recognised on roe deer remains: disarticulation marks on a talus and a phalanx and a defleshing mark on a metatarsal.

The whole meat-processing sequence is present in the small mammal category in the three levels. They appear in all the skeletal regions, although they are most usual on ribs, vertebrae and long bones. According to the frequency of

these cutmarks, limb bones are, in many cases, processed more often than axial and cranial elements (Fig. s15).

The few cutmarks documented on large bovid remains (NR = 10) are located on the autopodia and are disarticulation and filleting marks on the limbs of animals from Cierro G1 and G. In contrast, the only cutmarks identified on horse remains are on cranial elements (NR = 2) from Cierro G1. Mammals in the large size category display a similar pattern to that of large bovid, as mostly defleshing marks are observed on long bones and appendicular elements, i.e. the

elements that provide the most meat on the animal. Only one rib with evisceration marks was documented.

In addition to the butchery process, the intentional breakage of fresh bones to access the marrow has been observed in the three levels. These fractures were made by humans, as shown by the angles, planes, texture and direction of the fractures, and above all by the impact notches, percussion pits, opposite notches and bone flakes documented on the long bones of red deer, Iberian ibex and large bovid, and on remains in the large, medium and small categories (Table 8).

Table 6 Number of remains with anthropogenic marks and their percentage by taxa and size categories (totals are presented in bold)

	Cutmarks						Percussion marks						Thermoalteration					
	G1	%	G	%	F	%	G1	%	G	%	F	%	G1	%	G	%	F	%
<i>Cervus elaphus</i>	382	49.5	73	29.7	62	53	368	52.4	85	36.5	190	74.5	228	37	24	10	88	44.4
<i>Capreolus capreolus</i>	1	0.1	-	-	2	1.7	1	0.1	-	-	-	-	-	-	-	-	2	1.0
<i>Capra pyrenaica</i>	12	1.6	2	0.8	3	2.6	9	1.3	2	0.9	6	2.4	8	1.3	-	-	5	2.5
<i>Bos/Bison</i> spp.	8	1.0	2	0.8	-	-	9	1.3	1	0.4	1	0.4	1	0.2	1	0.4	-	-
<i>Equus ferus</i>	2	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Large size mammal	303	39.2	3	1.2	3	2.6	24	3.4	4	1.7	2	0.8	9	1.5	4	1.7	-	-
Medium size mammal	62	8.0	141	57.3	26	22.2	267	38.0	123	52.8	35	13.7	292	47.3	168	69.7	42	21.2
Small size mammal	10	1.3	25	10.2	21	17.9	24	3.4	18	7.7	21	8.2	79	12.8	44	18.3	61	30.8
Total	772	100	246	100	117	100	702	100	233	100	255	100	617	37.0	241	100	198	100

Table 7 Typology of the cutmarks on the different taxa and size categories in each lower Magdalenian level at El Cierro

	Skinning			Evisceration			Disarticulation/dismembering			Filleting marks			Scraping of periosteum		
	G1	G	F	G1	G	F	G1	G	F	G1	G	F	G1	G	F
<i>Cervus elaphus</i>	18	1	-	5	1	-	117	37	16	241	34	45	1	-	1
<i>Capreolus capreolus</i>	-	-	-	-	-	-	1	-	1	-	-	1	-	-	-
<i>Capra pyrenaica</i>	-	-	-	-	-	-	-	-	-	2	2	3	10	-	-
<i>Bos/Bison</i> spp.	-	-	-	-	-	-	3	1	-	5	1	-	-	-	-
<i>Equus ferus</i>	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-
Large size mammal	-	-	-	1	-	-	-	-	-	-	3	3	-	-	-
Medium size mammal	12	7	-	5	4	5	22	5	5	251	125	14	13	-	2
Small size mammal	1	1	-	3	-	4	6	3	1	50	21	9	2	-	1

Table 8 Percussion notches and opposite notches, pits and striations and peeling on the different taxa and size categories in each lower Magdalenian level at El Cierro

	Percussion notches			Opposite percussion notch			Percussion pits and striations			Peeling		
	G1	G	F	G1	G	F	G1	G	F	G1	G	F
<i>Cervus elaphus</i>	360	89	226	70	5	78	5	2	6	5	2	-
<i>Capreolus capreolus</i>	1	-	-	-	-	-	-	-	-	-	-	-
<i>Capra pyrenaica</i>	10	2	6	1	-	3	1	-	-	-	-	-
<i>Bos/Bison</i> spp.	9	1	2	2	-	-	-	-	-	-	-	-
Large size mammal	23	4	2	6	1	1	1	-	-	1	-	-
Medium size mammal	240	107	33	81	14	8	2	8	-	24	6	2
Small size mammal	21	14	19	7	3	5	-	-	-	2	2	2

The fractures appear mainly on metapodia and first and second phalanges, which display a large number of percussion notches (in 19.4% of metacarpal, 18.8% of metatarsal, 11.6% of metapods, 19.2% of first phalanges and 16% of second phalanges). However, a wide variety of axial and cranial elements, mostly mandibles and ribs were also broken; the latter by bending them by hand. The number of remains that were fractured, especially of red deer, has enabled a systematisation of the way that the marrow was extracted from each bone, by analysing the morphology and location of the impact. In addition, percussion notches have been observed repeatedly on specific sides and portions of bone within a high degree of standardisation (Fig. s16, s17 and s18).

Thus, red deer femora were mainly struck on both lateral faces of the shaft and less often on the anterior and posterior faces. Humeri were broken mostly on the anterior and posterior faces of the shaft and the metaphysis, in both its proximal part (mainly in Cierro G and F) and distal part (especially in Cierro G1). On the radii, the impacts were mainly applied to the anterior and posterior faces of the proximal part of the shaft. In Cierro G, the fracture pattern changes to the distal part, where both lateral faces were struck. Metapodia are the elements on which the most impacts were documented (NR = 235). Two types of breakage can be defined: one is a preference for striking the proximal part of the shaft and metaphysis on the upper face of the bone, near the longitudinal groove, while the other type is affected mainly by the sides of the shaft. Different fracture patterns are observed on the first and second phalanx. The first phalanx was struck mostly on the anterior and posterior faces of the shaft, which created longitudinal fracture planes. In contrast, the second phalanges were impacted mainly on the lateral faces, producing oblique fracture planes. A series of refits were made of fractured specimens, and this has shown how the marrow was extracted from those bone elements (Fig. 4). In some cases, an anvil was used to break long bones, which caused numerous opposite impacts on the bone shafts (on between 10 and 25% of the bones). Additionally, a large number of remains display isolated percussion notches, especially phalanges. A total of 271 flakes broken off bones during the percussion process were recovered from the three levels (Cierro G1 = 176; Cierro G = 25; Cierro F = 70).

Less evidence of fractures has been observed on the axial and cranial skeleton. Most of the fractures on cranial elements are in the mandible ramus, mainly in the vestibular region beneath the molar line. The objective was to break the lower part of the ramus crosswise. Less often, the mandible was broken longitudinally after the third molar, separating the ramus from the gonion. On the axial skeleton, the fractures appear mainly on parts of the pelvis and the neck of scapulae.

Ribs and flat bones were also broken by flexion. However, owing to the difficulty in the taxonomic identification of those elements, most of them were included in the medium-size category.

For Iberian ibex, roe deer and large bovid, although some elements were fractured intentionally, they are not sufficient in number to establish fracture patterns. All the Iberian ibex remains with impact marks correspond to limb bones, mainly femora, phalanges and metapodia. All the fractured large bovid bones are limb bones, particularly autopodia, whereas for roe deer only a mandible from Cierro G1 displays a percussion mark.

In the size categories, although fractured elements are very common among the medium and small mammals, most percussion marks appear on limb bone shafts that are difficult to classify. On the few elements that could be studied, they do not differ in the form of breakage from the pattern observed for red deer and Iberian ibex. In contrast, among the large mammals, all the fractured elements are limb bones, except in Cierro G1, where a fractured mandible, pelvis and rib have been documented.

Thermal alterations have been observed on 7.9% of the remains from Cierro G1, 14% from Cierro G and 10.7% from Cierro F. They affect red deer, Iberian ibex, roe deer, large bovids and all size categories. Most of the altered bones display brown or brown-black colouring, which indicates exposure to low temperatures (Table 9). To be exact, between 54.5 and 67.4% of the burnt remains can be classified in stage 1 of Stiner et al. (1995). They would have been exposed to heat below 400 °C. While this alone is not evidence of roasting, and other factors influence the colour of a bone, it is compatible with the exposure of bones with soft tissue to sources of heat during a relatively short time.

Other taphonomic agents that have altered the remains include carnivores, which have affected between 5.1% and 10.6%. They left marks of scores, pits, furrowing, gnawing, crenulated edges and digestion on bones of red deer, Iberian ibex, roe deer, horse and large bovid. These marks equally appear in all the size categories (Tables 10 and 11). In over 40 cases, cutmarks and carnivore marks are seen on the same bone. The affected remains are mostly axial elements, including a considerable number of scapulae, vertebrae, pelvis and ribs. Rodents also modified the faunal remains and left faceted marks with their teeth on the surface of the bones.

Other modifications to the faunal record in all the Magdalenian levels at El Cierro are the vermiculations caused by roots, which have been documented on between 16 and 26.9% of the remains. These alterations have affected all the taxa and size categories and indicate the constant entry of light and humidity in the cave during the formation of the strata. In connection with the humidity, a large number of bones are rounded by water action (from 3.7 to 6.2% of



Fig. 4 Impacts on the anterior and posterior faces of the red deer first phalanges from Cierro G1 and their respective refits

Table 9 Degree of thermal alteration on different taxa and size categories in each level at El Cierro

	Grade 1			Grade 2			Grade 3			Grade 4			Grade 5			Grade 6			
	G1	G	F	G1	G	F	G1	G	F	G1	G	F	G1	G	F	G1	G	F	
<i>Cervus elaphus</i>	204	19	78	16	2	1	7	2	6	1	-	-	-	-	-	-	-	1	-
<i>Capreolus capreolus</i>	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Capra pyrenaica</i>	8	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Bos/Bison</i> spp.	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Large size mammal	6	3	-	3	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Medium size mammal	249	140	35	32	22	2	7	3	4	4	1	-	-	2	1	-	-	-	-
Small size mammal	67	42	54	7	-	-	5	2	5	-	-	-	-	-	-	-	-	-	2

the NR), although in most cases low energy flow that on very few occasions has totally polished their surface. Some remains have been documented with precipitated calcium

carbonate, or with manganese oxides that have stained them. Weathering has also been an important factor of alteration and has affected from 6.3 to 10.1% of all the remains

(Fig. s19). Finally, the activity of different biological agents in the cave has caused trampling marks in the form of fine and short striations distributed at random on the surface of a very small percentage of the bones (<3.5% of the NR).

The length and season of the year of the Magdalenian occupations differ depending on each level. In general terms, the occupations tended to take place in spring and summer in all levels. However, this tendency is conditioned

by the large number of fawns killed in their first months of life. Nonetheless, the wide age range of red deer in the three levels may indicate that hunting was carried out from the site throughout the year, even if it was more intense in the summer. The other taxa display age ranges that also cover the summer while some indicate from autumn to winter; in the latter case, an Iberian ibex in Cierro G was hunted between autumn and spring (Fig. 5).

Table 10 Number of remains of carnivore marks and its percentage on different taxa and size categories in each level at El Cierro (totals are presented in bold)

	Carnivore marks					
	G1	%	G	%	F	%
<i>Cervus elaphus</i>	215	37,7	50	21,9	53	53
<i>Capreolus capreolus</i>	-	-	1	0,4	2	2
<i>Capra pyrenaica</i>	12	2,1	3	1,3	-	-
<i>Bos/Bison</i> spp.	-	-	1	0,4	-	-
<i>Equus ferus</i>	1	0,2	-	-	-	-
Large size mammal	11	1,9	3	1,3	-	-
Medium size mammal	265	46,5	139	61,0	22	22
Small size mammal	49	8,6	32	14,0	22	22
Total	570	100	228	100	100	100

Table 11 Typology of carnivore marks on different taxa and size categories in each level at El Cierro

	Scores			Pits			Gnawing			Punctures			Crenulated edge			Furrowing			Digested		
	G1	G	F	G1	G	F	G1	G	F	G1	G	F	G1	G	F	G1	G	F	G1	G	F
<i>Cervus elaphus</i>	52	10	8	176	41	33	28	9	5	4	2	2	13	13	1	1	-	1	5	2	6
<i>Capreolus capreolus</i>	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
<i>Capra pyrenaica</i>	-	-	1	10	1	2	2	1	-	-	1	-	-	1	-	1	-	-	1	1	-
<i>Bos/Bison</i> spp.	3	-	-	4	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
<i>Equus ferus</i>	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Large size mammal	3	2	-	10	1	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	
Medium size mammal	81	34	4	194	148	14	33	37	1	8	3	-	23	20	2	2	1	1	4	1	-
Small size mammal	16	7	2	30	22	13	6	4	1	1	-	2	3	7	1	1	-	1	4	-	-

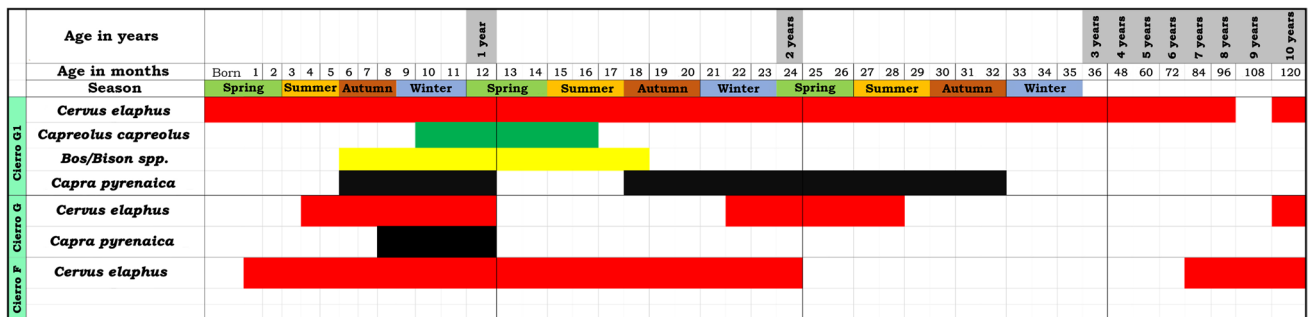


Fig. 5 Seasonality of the occupations based on the age of death of large mammals in the Magdalenian levels at El Cierro Cave

Birds

Birds have been documented in Cierro G1 through a grey partridge coracoid, another of *Anser/Branta* spp., and a tibiotarsal of an indeterminate bird (see Tables 2 and 3). Only a *Perdix perdix* coracoid was found in Cierro G and a carpometacarpal of *Corvus corax* in Cierro F. No taphonomic alterations have been identified on any of these remains that might suggest they were processed or cooked.

Fish

Of the few fish remains (NR = 10), all from Cierro G1, only two vertebrae have been identified as belonging to the salmonid family (Álvarez-Fernández et al., 2022a) (see Tables 2 and 3). As in the case of the birds, none of these remains displays evidence of anthropogenic handling.

Invertebrates

The invertebrate remains that were recovered are all shells of marine molluscs (gastropods and bivalves). They have been collected from rocky substrates in the intertidal zone, the area where all documented species currently live. The one exception is a small plate belonging to a crustacean (Balanidae) (see Tables 2 and 3).

Gastropods predominate almost absolutely. In Cierro G1, most of the remains are the common periwinkle *Littorina littorea* (78.5% of the NR) and limpet (*Patella* sp.) (21.4% of the NR). *Nucella lapillus* (dog whelk) and *Littorina obtusata* (flat periwinkle) (0.01% of the NR) are also represented minimally. The MNI exhibits a similar distribution to the NISP, as *Littorina littorea* is the most abundant species (MNI = 1724), followed by *Patella* sp. (MNI = 127) and *Patella vulgata* (MNI = 60). *Mytilus galloprovincialis* (mussel), *Nucella lapillus* and *Littorina obtusata* are each represented by a single specimen. The winkles and limpets in the three levels are of a large size. Biometrics could only be carried out on gastropods from the G1 level. In the case of *Littorina littorea*, the maximum height is 28 mm; in the case of *Patella vulgata*, 39.5 mm.

The proportion of molluscs is similar in Cierro G as periwinkles again predominate in both the NR (400) and MNI (79), followed by limpets (NR = 55; MNI = 15). In Cierro F, although the number of limpets increases (NR = 141; MNI = 28), *Littorina littorea* is still the most abundant species (NR = 274; MNI = 86). *Nucella lapillus* and *Littorina obtusata* only appear with a single remain in Cierro F and G. Bivalves are represented by a mussel shell in Cierro G.

The outer surface of three shells from Cierro G1 (one of *Littorina littorea* and two of *Patella vulgata*) are perforated by annelids (*Polydora* sp.). These perforations are small galleries with two holes that connect with each other on the

external surface but would not have harmed the live gastropods. A single plate of an acorn barnacle (*Semibalanus balanoides balanoides*) was found isolated in the sediment of Cierro F (Carrion & Álvarez-Fernández, 2015). It should be noted that the shells of the gastropod species *Littorina obtusata* and *Nucella lapillus*, both present in Cierro G and Cierro G1, are eroded by water action and sand and therefore were probably collected on a beach after the mollusc had died. Only the shells documented in Cierro G1 retain anthropogenic alterations. Thermal alteration is present only in <0.1% of the NR ($n=4$, one limpet and three periwinkles' shells), and fracturing of the edges of limpets produced when separating their shells from the rock is documented in <0.2% of the limpets shells (NR = 3). Shell surfaces documented in the three levels are corroded, powdery and whitish, probably because of a reaction to the conditions in which the shells have been buried. Very few displays precipitated calcium carbonate.

Discussion

The zooarchaeological data obtained from the Magdalenian sequence in El Cierro Cave shows that large mammals and, to a lesser extent, marine molluscs, were fundamental in the subsistence of the hunter-gatherer groups.

Red deer was the main prey in all levels, represented by over 90% of the NISP. In northern Spain, other sites with lower Magdalenian levels have been found to contain similar percentages of red deer, such as Las Caldas Level XIII (Altuna & Mariezkurrena, 2017), Cova Rosa Level B6 (Álvarez-Fernández et al., 2019), La Riera Level 19 (Altuna, 1986), El Linar Level 3c (Castaños, 2016), Las Aguas Level B (Castaños, 2016), Cualventi Level E (Castaños, 2016), Altamira Level 2 (Castaños & Castaños, 2014), El Juyo Levels 4 and 7 (Klein & Cruz Uribe, 1987) and Ekain Level VIII (Altuna & Mariezkurrena, 1984). Iberian ibex, roe deer, large bovid and horse were also present in the diet of the Magdalenian groups at El Cierro, but in small percentages. In northern Spain, sites with a significant predominance of red deer are usually located in open valleys near the modern coastline and at low altitudes (Portero et al., 2019).

All skeletal parts are represented among the red deer remains even though limb bones and those with larger marrow content are the most abundant. Regarding the transport strategy of this ungulate, we observe that the Magdalenian groups from El Cierro transported more frequently those elements with a higher medullary content. This is corroborated by the direct and statistically significant trend (except in Cierro G) between %MAU and marrow index. Furthermore, the correlation between %MAU and general utility indices is inverse for Cierro G1 and Cierro G and direct for Cierro F, although in neither case are they statistically

significant. Therefore, it does not seem that the parts with the highest feed utilisation are being transported frequently, since in that case, we would find a direct and significant relationship between these variables (Grayson, 1989).

In the case of Iberian ibex, in addition to dental pieces, the main elements that make up the sample are represented by hindlimb and autopodia, although as we have seen, the percentages of representation of this species vary greatly between levels. Furthermore, the correlation between %MAU and the general utility indices (MGUI and SFUI) for the Iberian ibex is direct and moderate in Cierro G1 and Cierro F, being inverse and moderate in Cierro G, although in no case are they statistically significant. The only level where we obtain a significant relationship between %MAU and meat utility index is in Cierro F, which could indicate a transport of those elements with higher meat utilisation.

The study of the age patterns shows that individuals of practically all age ranges are present in the case of red deer, from neonates to immature, juvenile, adult and senile animals. There is a predominance of young adults in all levels, but a significant number of infantile and juvenile individuals have been documented. This indicates that hunting concentrated mainly on younger individuals, with a mortality profile of the “L”-shaped catastrophic type (Discamps & Costamagno, 2015), as can be seen from the ternary graphs. This suggests that hunting focused on herds of hinds and their calves, as observed in lower Magdalenian levels at such sites as La Riera 19 (Altuna, 1986), El Linar 3C (Castaños, 2016), Ekain VII (Altuna & Mariezkurrena, 1984) and Erralla V (Altuna & Mariezkurrena, 1985). This selective strategy did not rule out the occasional capture of other prey in the area: Iberian ibex, roe deer, horse and large bovids in the case of El Cierro, but with no apparent strategy, based on the age profiles that have been documented.

Although El Cierro Cave may have been occupied throughout the year during the lower Magdalenian, according to the documented capture regime, there is an occupational trend during the spring and summer for all levels, and despite the large volume of remains documented in these levels, it is likely that these occupations were not of a lasting nature and were rather a set of seasonal accumulations over a prolonged period of time. This type of seasonal occupation strategy could be related to the hunting pressure on resources and the need for active mobility for the recovery of the environment (Portero et al., 2024). In this sense, some research has developed a series of predictive mathematical models based on the demographic data of current animal populations (Stiner et al., 1999 and 2008; Beaver, 2007; Merkle et al., 2015; Venkataraman et al., 2017). These models predict the maximum number of individuals that can be hunted annually in a location without the species becoming extinct over time. To do this, they establish two predictive ranges, one based on a favourable population growth rate

(high growth model - HGM) and the other on a population growth rate under unfavourable conditions (low growth model - LGM). An example applicable to this model on a population of 1000 red deer would indicate that only a total of 31 individuals could be hunted per year in a favourable population growth environment (HGM), whereas only ten individuals could be shot per year in an unfavourable growth environment (LGM) (Beaver, 2007).

However, the seasonality of occupations cannot be established very precisely solely by the age ranges of the individuals in the deposit, so we must be cautious with this type of interpretation.

The processing of the mammals found in the Magdalenian levels in El Cierro has been documented by cutmarks on the carcasses of red deer, roe deer, large bovids, horse and large, medium and small-sized animals. Red deer remains, as the main prey, display marks on all skeletal parts, and the whole processing chain can be followed from skinning to scraping the periosteum so as to access the marrow. While a large proportion of the cutmarks are related to the process of disarticulating the autopodia, in all levels, evidence of access to and consumption of the main sources of meat on femora and humeri have also been documented, as a large number of marks are observed in the places of the main muscles of the animals. Studies carried out in northern Spain at such sites as Coímbre and La Lluera have systematised the way in which large mammal carcasses were processed, based on the orientation, position and morphology of the cutmarks (López-Cisneros et al., 2019, 2020).

The intentional fracture of the bones while fresh to extract the marrow has been attested in the levels in El Cierro Cave through the impact marks on long bones and the flexion of flat bones. The large number of impacted remains, especially of red deer, has allowed a systematisation of how the marrow was obtained from each bone. This was carried out in a highly standardised way in the three Magdalenian levels. In general, the marrow of all the taxa was consumed intensely, and elements such as the phalanges and metapods of red deer were fractured repeatedly following a similar pattern in all levels. This frequent use might indicate a systematised strategy in the acquisition and conservation of this resource. Marrow is a very rich food in caloric energy and keeps in a suitable condition for consumption for weeks following the death of the animals (e.g. Mateos, 1999 and 2003; Blasco et al., 2019). Thus, the occupants of the cave may have consumed the soft parts and meat of the prey first and kept the elements with the largest marrow content to be eaten later or even stored for a period of time as a source of food in times of scarcity. Although the fracture of elements such as phalanges has been used as an indicator of nutritional stress in prehistoric peoples due to the low rate of caloric return (Binford, 1978; Jones & Metcalfe, 1988), experimental and ethnographic studies have shown that the presence of

broken phalanges by themselves cannot be taken as evidence of nutritional stress and that their exploitation may be due to their taste and soft texture or to symbolic aspects (Morin, 2007; Costamagno & David, 2009; Jin & Mills, 2011; Costamagno & Rigaud, 2014; Kuntz et al., 2016; Birouste, 2020).

The alterations caused by heat observed on bones are compatible with roasting meat. A large number of bones burnt at low temperatures display double brown and black tones on the same surfaces, indicating the presence of soft tissue on them during their exposure to heat. These double colours have been detected in remains of red deer and large, medium and small mammals and are located mainly on autopodia and zeugopodia, i.e. the distal parts of the limbs. The double tones and their location mean that the burning of the bones after their burial can be ruled out (Bennett, 1999), and they are compatible with roasting the animals' meat. Moreover, the large number of phalanges and metapodia affected in this way suggests that they were roasted before the bones were broken to access the marrow.

The activity of carnivores at El Cierro has generated a sufficiently high percentage of marks on the determinable remains that sporadic occupation of the cave by these animals cannot be ruled out. The presence of two medium-sized canid remains in Cierro G1 and the size of the marks observed could suggest that these animals were the agents that sporadically modified the Magdalenian bones from El Cierro. In this sense, and although we have not detected any superimposition of carnivore marks over the cut marks, we have documented more than 40 remains with both cut and carnivore marks on the same bone. Most of them are axial elements, metapods and phalanges. This leads us to believe that carnivore access must have been secondary, given the high frequency of cut marks on the main richest elements at all levels and for the main species documented, and the higher incidence of carnivory on those elements of lesser nutritional value. The action of carnivores, although detected in all size categories, shows a greater abundance on medium-sized animals, which are also the most consumed by human groups, being less in the remains of small and large sizes. This leads us to think that these carnivores were secondary agents in the access to animal carcasses, once they had been exploited by human groups, especially considering that medium-sized canids (such as wolves and dogs) tend to have a commensal synanthropic behaviour (Blumenschine & Selvaggio, 1988; Stiner, 1994; Yravedra, 2006; Baumann, 2023).

The bird remains do not display signs of anthropogenic impact, and therefore, it cannot be affirmed that they were consumed by the human groups. Little information is available about anthropogenic processing of birds in the lower Magdalenian in the region, only evidence of cutmarks on a lagopod, an Anatidae and indeterminate bird in Levels 8 and 9 at El Juyo (Rufà et al., 2022), on the humerus of a sea

eagle from Cualventi E (Garcia Petit, 2016), on an Anatidae from El Linar 2 (Garcia Petit, 2016) and on an indeterminate bird from Level F at Arangas (Álvarez-Fernández et al., 2020). With a slightly more recent chronology, a *Lagopus mutus* remain with disarticulation marks was documented in Level ICS at Tito Bustillo Cave (Álvarez-Fernández et al., 2022b). Some thermally altered remains of birds may indicate their processing in the lower Magdalenian. This is the case of remains of a corvid, an Anatidae, one of *Lagopus lagopus* and three of indeterminate birds in Levels 4 to 8 at El Juyo (Rufà et al., 2022), an Anatidae remain from Cualventi E (Garcia Petit, 2016), and an *Alectoris* sp./*Perdix* sp. radius from Level 1C1 at Tito Bustillo and two Accipitridae phalanges from Level ICS in the same cave (Álvarez-Fernández et al., 2018b).

Fish would also have formed part of the diet of the occupants of El Cierro Cave as they would catch salmonids in the proximate River Sella, even though no taphonomic marks indicating their processing and consumption have been noted. Nor have we observed the alteration by other agents (Guillaud et al., 2021). No evidence has been found of the processing of fish at lower Magdalenian sites in north Spain, apart from some bones affected by heat. In Cova Rosa B6, salmonid and eel remains were altered thermally (Álvarez-Fernández et al., 2019), and two burnt remains of salmonids were found in Level ICS at Tito Bustillo (Álvarez-Fernández et al., 2018b).

Molluscs were a complement in the diet of the Magdalenian groups at El Cierro. Although the energy intake of these animals is lower than that of mammals, molluscs may have played an important role in the diet of the groups given their high content of protein, vitamins, carbohydrates and polyunsaturated fatty acids such as omega-3 (Santhanam, 2018). These resource high salt levels may have provided a favourable dietary quality for human groups from an organoleptic point of view. In addition, the ease of harvesting makes seafood an accessible resource.

Periwinkles (*L. littorea*) and limpets (*P. vulgata*) were selected on rocky substrates. These are both cold-climate species that live on sheltered weed-covered shores. The presence of annelid perforations on three specimens from Cierro G1 shows that they were collected in sheltered areas. The presence of a plate of *S. balanoides balanoides*, a boreo-arctic species that lives in cold surface waters, indicates that the water temperature on the coast of Ribadesella was much colder than at present. This crustacean reached the deposit adhered to the surface of a shell and the plate became detached later (Carriol & Álvarez-Fernández, 2015).

The larger proportion of winkles than limpets in the three levels at El Cierro is unusual in northern Spain. Thus, in Layer B6 at Cova Rosa (Álvarez-Fernández et al., 2019), Levels 18–20 at La Riera (Ortea, 1986), Levels 1 and 2 at Altamira (Álvarez-Fernández, 2009), Levels 9 to 4 at El

Juyo (Madariaga & Fernández, 1987) and Level V at Erralla (Altuna, 1985b), *P. vulgata* and *L. littorea* represent nearly 99% of the mollusc remains, but the former always predominates over the latter. They are all characterised by the selection of large (adult) (Álvarez Fernández, 2011).

Gastropod Shells at El Cierro were collected by hand without difficulty on the rocky shore. In the case of limpets, their shells would be separated from the rocks with poorly elaborate tools (fragments of bones or lithics), causing fractures on their edges. Its form of consumption was not the result of direct contact with fire, given the few remains that are thermoaltered. Perhaps they were consumed boiled or raw. The post-depositional alterations that the remains present, particularly the decalcification, prevent obtaining more information about the collection strategies and their consumption.

This subsistence strategy detected by the faunal resources in the Magdalenian levels at El Cierro resembles the situation at sites in the Sella valley, such as Cova Rosa (Álvarez-Fernández et al., 2019), and at other sites in northern Spain, like Las Caldas (Corchón, 2017b), Arangas (Álvarez-Fernández et al., 2020), Santimamiñe (López Quintana, 2011) and Erralla (Altuna et al., 1985). In all of them, large mammals were the main source of food, while fish, molluscs and birds were complementary resources in the diet of the hunter-gatherer groups.

It should be noted that plant resources were also widely exploited for subsistence by human groups during the lower Magdalenian, as demonstrated by anthracological studies carried out at Cierro G1 (Uzquiano, 2019), which indicate the use of Fabaceae collected in valley areas, especially in siliceous soils. The importance of plant foods in subsistence has also been highlighted for this period based on the analysis of phytoliths (Zurro, 2010) and the analysis of dental calculi from human teeth (Power et al., 2015).

Conclusion

The importance of animal resources in the subsistence of the Magdalenian inhabitants of Levels G1, G and F in El Cierro Cave has been documented through their remains. The data obtained show that in the lower Magdalenian, the hunting strategy focused on red deer as the main prey. This is indicated by both the high percentage of remains and the taphonomic evidence of their use. Other species, like Iberian ibex, roe deer, horse and large bovinds, were also consumed. Molluscs and fish were a complement to the part of the diet with an animal origin, as a small number of individuals have been documented compared with the abundance of large mammals. No evidence of anthropogenic manipulation of avifauna supports the processing and consumption of birds.

The taphonomic study has determined that the accumulation of large mammal remains in the lower Magdalenian is the result of anthropogenic activity, since the complete operational chain of the processing of the prey has been documented, including skinning, evisceration, disarticulation, dismembering, filleting and scraping the periosteum, especially of red deer. In addition to the consumption of the meat, the present study has determined a systematic approach to the acquisition of the marrow inside the bones, mainly the long limb bones of ungulates. The pattern is similar in the three levels, which indicates continuity in the way of acquiring and processing animal fats, which would have been of great importance in the diet of the groups because marrow stays in good condition longer than meat and is therefore a resource that can be stored to be consumed when necessary.

Fire was used in the processing of meat, as shown by thermally altered bones in shades of colour associated with exposure to low temperatures. The double colours on many distal and proximal limb bones are due to the variable quantity of meat tissue on those elements during the roasting process.

The zooarchaeological study has also taken into consideration the time of the seasonal occupation of the cave. The levels in the sequence at El Cierro are the result of several occupations during the period from spring to autumn. In those occupations, the hunting strategy concentrated on herds of young adult red deer and their calves, whose complete carcasses could be transported to the site. However, these impressions are based only on the data provided by the skeletal age of the mammals and need to be confirmed more precisely by other seasonality studies in the future (e.g. cementochronology, dental mesowear and microwear analysis, isotopic analysis).

Finally, this study has shown the importance of studying all the biotic resources in a deposit as a whole, as this is the only way to obtain a full panorama of the subsistence strategies of past human groups. It enables an assessment of the relative importance of each of the animal resources in the diet, the way of obtaining nutrients, the places in which the resources were obtained and the complexity of the processing and consumption of animals by the groups.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s41982-024-00179-x>.

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Author contributions R.P.: Conceptualization, Formal analysis, Data curation, prepared figures and tables, Writing – original draft, Writing – review & editing. M.C.: Formal analysis, Data curation, prepared figures, Writing – review. M.E.: Formal analysis, Data curation, Writing – review. A.M.: Formal analysis, Writing – review. J.J.P.: Formal analysis, Data curation, Writing – review. E.A-F.: Formal analysis, Data curation, Writing – review & editing.

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Data Availability The data generated and analysed during the present study are available on request from the corresponding author. The faunal remains studied are preserved in the Museo Arqueológico de Asturias (Oviedo).

Declarations

Ethical Approval Not applicable.

Consent to Participate All authors consent to participate.

Consent for Publication All authors consent to publish.

Competing Interests The authors declare no competing interests.

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