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Initial and Lower Magdalenian Large Mammal Faunas and Human Subsistence at El Mirón Cave (Cantabria, Spain)

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Abstract

In late Upper Paleolithic Cantabrian Spain, humans developed sophisticated territorial systems, used specialized lithic and osseous tools and weapons, and were skilled hunters of red deer and ibex while also depending increasingly on supplementary food resources, as means of adapting to climatic and environmental change after the Last Glacial Maximum. However, the specific effects of the environment on hunting decisions are not well understood for the early Magdalenian. Was subsistence specialization a byproduct of environmental change, does it reflect human population pressure and preferences, or are hunting strategies dictated by the geographic setting of El Mirón? In this paper, we present the results of taphonomic and zooarchaeological analyses of Initial and Lower Magdalenian faunas from levels 119.2, 119, and 115 from El Mirón, a large cave site in the Asón River valley of montane eastern Cantabria. We assess the human role in accumulation of these faunal assemblages and then explore whether there were differences in subsistence between the Initial and Lower Magdalenian. The results of this study complement analyses of other Magdalenian assemblages from El Mirón and support the patterns of general continuity observed for the Cantabrian Magdalenian at several other regional sites.

Keywords Cantabria · Zooarchaeology · Initial Magdalenian · Lower Magdalenian · El Mirón Cave

Introduction

How did human behavior change as the Late Glacial Maximum (LGM) transitioned into the terminal phases of the Pleistocene? While many investigations into this

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question focus on the people who lived during the LGM (e.g., Bourgeon et al. 2017; Liu et al. 2013; Ray and Adams 2001; Schmidt et al. 2019; Straus 1991), others turn their attention to the period that followed it (e.g., Goebel et al. 2011; Bicho et al. 2011), during which the world warmed slowly and in pulses. In Western Europe, this period comprises the early (i.e., pre-harpoon) Magdalenian period (de Sonneville-Bordes 1963; Weniger 1989). The transition between the Solutrean, the period that includes the LGM, and the early Magdalenian has generated considerable debate. Did this transition constitute a gradual change in human technology and subsistence, or was it abrupt? How are the phases of the early Magdalenian defined in different regions, and are they valid categories (Aura et al. 2012; Straus et al. 2012)? To some extent, these questions remain unresolved (e.g., Ríos-Garaizar et al. 2008; Straus 2000).

In the northern Iberian region of Cantabria, although there is general agreement over a trend of continuity in technology and subsistence from the Solutrean (c. 24.5–21 k cal BP) and into the Magdalenian (Marín-Arroyo 2009a; Straus et al. 2002), specifics concerning the two earliest phases of the Magdalenian, Initial (c. 21–20 k cal BP) and Lower (c. 20–18.5 k cal BP), are more contentious. Subtle changes in technology (differences in antler projectile types, portable art forms, and use of local lithic raw materials) and subsistence (increasing intensification to include more marine/riverine resources, subtle differences in ungulate exploitation) at most Cantabrian sites distinguish Initial from Lower Magdalenian assemblages (Straus et al. 2014), but what these changes mean and how general or site-specific they may have been are unclear. Explanations include responses to increasing regional demographic pressures (Marín-Arroyo 2009b; Straus 2019), social connections to and influences from Magdalenian (or Badegoulian) populations in southwestern France (Bosselin and Djindjian 1999; Fontes et al. 2016), responses to the ameliorating climate (Straus 2018; Stevens et al. 2014), and shifts in the decision-making of Upper Paleolithic hunters (Marín-Arroyo 2009c; Straus 1990). In addition, technological variation within the Lower Magdalenian has caused some to speculate at times that the Initial Magdalenian might in fact be more accurately described as an activity-related early Lower Magdalenian facies, rather than its own distinct cultural unit (e.g., Straus 2013: 244).

In this paper, we use the macro-mammalian faunas from two Initial Magdalenian and one Lower Magdalenian levels of El Mirón Cave, a Magdalenian-rich Paleolithic site in Cantabrian Spain (e.g., Fontes et al. 2015, 2016, 2018; Geiling et al. 2016, 2018; González Morales and Straus 2005, 2009; González Morales et al. 2007; Marín-Arroyo 2010; Nakazawa et al. 2009; Straus and González Morales 2007a, b, 2012, 2018, 2019, 2020; Straus et al. 2008, 2014, 2015a, 2016, 2018), to explore the relationship between these two phases. We present taphonomic, taxonomic, and skeletal element data from levels 119.2 and 119 (Initial Magdalenian) and 115 (Lower Magdalenian), and use these to demonstrate some of the range of variability in Cantabrian Initial and Lower Magdalenian subsistence practices and in human uses of this cave during Oldest Dryas.

Human Adaptations in Early Magdalenian Cantabria

Cantabrian Spain contains one of the strongest expressions of the Magdalenian in southwestern Europe (Straus 1992, 2005, 2018; Straus et al. 2002). The large number of archaeological sites in this region provide a rich record of all phases of the

Magdalenian (e.g., Álvarez Alonso and Arrizabalaga 2012; Corchón 1995, 2005; Corchón et al. 2008, 2009; Fortea 1989; González Echegaray and Barandiarán 1981; González Sainz 1989; González Sainz and González Urquijo 2004; González Sainz and Utrilla 2005; Moure and Cano 1979; Utrilla 1981, 1996, 2004). There are some chronological issues that cloud our understanding of the earliest Magdalenian phases, namely climate-related erosional events, stratigraphic mixing that may have resulted in a relative lack of datable deposits for early phases compared to those of the later Magdalenian (Hoyos 1994), and the fact that as of a decade ago, roughly 60% of the available dates had been obtained using conventional radiocarbon methods rather than now-standard accelerator mass spectrometry (Aura et al. 2012). Nonetheless, a rich body of research has allowed general characterization of the Cantabrian Initial and especially Lower Magdalenian. Here, we review the current understanding of these two phases.

Cantabrian Initial Magdalenian

The Cantabrian Initial (or Archaic) Magdalenian dates roughly from 21 to 20 ky cal BP (González Sainz and Utrilla 2005; see also Álvarez Alonso and Arrizabalaga 2012; Bosselin and Djindjian 1999; Bosselin 2000; Corchón 1994; Sauvet et al. 2008; Straus 2013; Straus and Clark 2000; Utrilla 2004) and corresponds with the start of Greenland Stadial 2b (also known as the Lascaux oscillation). This was a short, pulse-like period of slightly warmer climate and more temperate conditions towards the end of the extremely cold and dry LGM, although climate remained very much glacial (Straus 1990, 2018). More detailed information of the environment during the Initial Magdalenian is limited, and this may be because of the limited number of Initial Magdalenian assemblages in the region: El Rascaño Level 5, Urtiaga Level F, and El Mirón levels 117–119.3 (Altuna 1972; Aura et al. 2012; González Echegaray and Barandiarán 1981; Straus et al. 2014). However, the general consensus is that climate remained more or less the same in the Initial Magdalenian and Lower Magdalenian (Straus 2013). The Early (Initial and Lower) Magdalenian archaeological record is marked by a slow, steady increase in the number of sites (Straus and González Morales 2012; Straus 1990). Although the few known Initial Magdalenian sites are located in locations similar to the more abundant preceding Solutrean ones, they sometimes differ in their occupation intensity. Some Cantabrian Initial Magdalenian deposits are thick and rich, reflecting repeated and intense occupations (Straus and González Morales 2012; Straus 2018). Potential explanations for this increased intensity include demographic pressure (e.g., Straus 2019) and changing forager mobility strategies (e.g., Jones 2015, 2016, 2019), but these remain a matter of debate. Initial Magdalenian technology in Cantabria corresponds with a period of technological “desolutreanization” during which large, fragile, invasively retouched foliate and shouldered projectile points were progressively replaced by composite weapons comprised of expendable or “cheap” backed bladelets slotted into durable antler sagaies (Straus 1983, 2000). Subsistence patterns appear generally similar to those of the Solutrean, with most faunal assemblages suggesting some degree of specialization, or a subsistence strategy that focuses overwhelmingly on one or two taxa, in the hunting of particular ungulate taxa (Altuna 1972; Clark and Yi 1983; Clark 1986; Freeman 1973; González Sainz 1989; Jones 2015; Straus 1977, 1992; Yravedra 2001). Red deer (*Cervus elaphus*) and ibex (*Capra pyrenaica*) appear to have been most frequently exploited, but other taxa, such as chamois (*Rupicapra rupicapra*), horse (*Equus* spp.), aurochs (*Bos primigenius*), bison (*Bison priscus*), wild boar (*Sus scrofa*), and roe deer (*Capreolus capreolus*) also appear in varying, but small or trace quantities (Altuna 1990; Clark and Straus 1983; Straus 1992, 1996, 2005; Straus and Clark 1986; Yravedra 2001).

Cantabrian Lower Magdalenian

Unlike in other parts of Spain, where there seems to be a hiatus between the Initial and Lower Magdalenian, in Cantabria, there seems to be some degree of overlap between these two phases (Aura et al. 2012). The Cantabrian Lower Magdalenian in this region was first excavated by Obermaier in El Castillo and Altamira a century ago, formally defined 60 years ago by González Echegaray and Jordá at the sites of El Juyo and La Lloseta, respectively, and systematically studied by Utrilla 40 years ago. It appeared around 20 ky cal BP and ended at 18.5 ky cal BP (Straus 2013). The climate during this period was similar to that of the Initial Magdalenian during relatively temperate pulses (Ramil-Rego et al. 2001). Pollen and microfaunal records from Lower Magdalenian deposits of El Mirón and other contemporaneous sites in Cantabria suggest a mosaic landscape dominated by open, steppe-grassland vegetation with limited arboreal vegetation (scattered pines, junipers and birches (González-Sampériz et al. 2010: 444 with references)). In some coastal zone sites, like El Juyo, higher frequencies of woodland and even relatively temperate taxa are encountered at times (Boyer-Klein and Leroi-Gourhan 1985). However, the presence of taxa associated with water-rich environments such as humid, marshy fields and banks of rivers or streams and the presence of cold-adapted taxa such as the snow vole, that inhabit rocky alpine habitat, and root vole, that inhabit tundra habitat in conjunction with the absence of woodland-dwelling rodents such as the field mouse suggest particularly cold and locally humid conditions (Cuenca-Bescós et al. 2009a, b, 2012; Iriarte-Chiapusso et al. 2015). In a few cases (notably El Rascaño and El Mirón in Cantabria and Urtiaga in Guipúzcoa), Lower Magdalenian deposits lie atop Initial Magdalenian deposits (Straus 1990), and the geographic distribution of sites does not appear to have significantly changed between these two phases, although there are far more known Lower than Initial Magdalenian deposits, perhaps for lack of stratigraphic discernment during excavations and scarcity of radiocarbon dates. The differences between Initial and Lower Magdalenian assemblages are largely in details of lithic and osseous technology, as well as in portable artworks. Square-section sagaies and bladelets increase in frequency during the latter period (Straus 2018, 2019), and chipped stone assemblages reflect what some have called a greater technological stability (Cazals and Bracco 2007; Utrilla 2004). There is variability in Cantabrian Lower Magdalenian lithic assemblages; some archaeologists split these assemblages into three groups or facies, arguing that these reflect groups with different territories and economic specializations (Utrilla 1981). The Lower Magdalenian is marked by some highly specialized hunting sites, in which hunters seem to have focused their efforts on slaughtering herds of female red deer or ibex and their young (Altuna 1981, 1986; Altuna and Mariezkurrena 1984, Altuna et al. 1985; Klein and Cruz Uribe 1985; Soto 1984; Straus 1992), characterized as “wild harvesting” by Freeman (1973). Faunal analyses of Lower Magdalenian assemblages suggest intensive processing, with highly fragmented assemblages and a high frequency of bone surface modifications such as burning, percussion marks indicative of marrow extraction, and cut marks (Geiling 2020; Marín-Arroyo 2009c).

Directional Change or Consistent Variability?

In many ways, the transition from the Initial to the Lower Magdalenian in Cantabria appears to be a subtle shift along a spectrum of possible adaptations rather than an abrupt change. On this spectrum are two forms of animal resource intensification during the Magdalenian: specialization (e.g., Freeman 1973; Straus 1987; Marín-Arroyo 2009c; Castaños and Castaños 2011; Portero et al. 2019) and diversification (e.g., Straus and Clark 1986; Altuna and Mariezkurrena 2017; Álvarez-Fernández et al. 2020). Subsistence specialization in this region is perhaps most evident in the faunal data available for Magdalenian deposits of El Juyo, El Rascaño, La Paloma, Tito Bustillo, La Riera, El Cierro, Las Caldas, and Altamira, among others, where a general trend towards specialization in the Initial Magdalenian develops into what appears to be a region-wide focus on highly specialized red deer and ibex hunting in the Lower Magdalenian (Freeman 1973; Straus 1987; Altuna 1995; Klein and Cruz-Uribe 1985). Whether a site shows specialization on red deer versus ibex is likely attributable to its surrounding orography (Marín-Arroyo 2009a), with sites in more alpine environments usually showing a predominance of ibex, while sites located in lower altitudes closer to the floor of broad river valleys or on the coastal plain have assemblages typically dominated by red deer (Straus 1992). However, not all Magdalenian sites in Cantabria follow this trend. Diversification, a form of subsistence intensification wherein hunters procured a wide variety of taxa, hunting medium-sized ungulates typically ignored in earlier phases of the Upper Paleolithic as well as the inclusion of marine resources and possibly birds such as at La Riera (Straus 1990, 1991, 1992, 1986; Straus and Clark 1986), was also common in this time period, as evidenced in the Magdalenian deposits of Las Caldas (Altuna and Mariezkurrena 2017), La Güelga (Menéndez et al. 2014), or Arangas (Cueto et al. 2015; Álvarez-Fernández et al. 2020). But whether the Lower Magdalenian faunal record reflects the endpoint of a trend towards specialization, diversification, and/or increased partitioning in human exploitation of the environment, or rather is just a particular point along a spectrum of consistent variability has yet to be explored. The Initial and Lower Magdalenian faunal assemblages from El Mirón provide a new case with which to do so.

El Mirón

El Mirón, a large cave situated at 260 m above sea level on the northern edge of the Cantabrian Cordillera (Fig. 1) about 25 km from the Late Glacial shore and surrounded by summits of ≤1000 m above present sea level, has one of most complete and chronologically secure Upper Paleolithic records in the region, with a long, high-resolution stratigraphic sequence and 93 radiocarbon dates that place the excavated cave sediments in between roughly 48,000 BP and AD 1400 (Straus and González

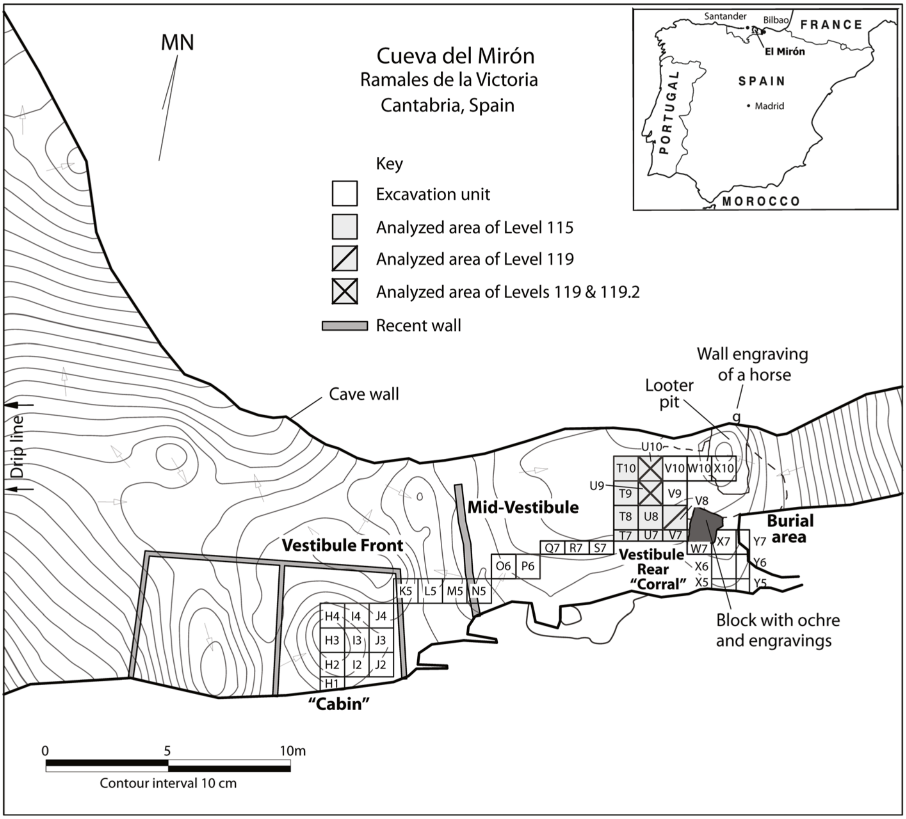

Fig. 1 Plan view of El Mirón with inset showing site location within SW Europe (figure by L.G. Straus and R.L. Stauber; cave topography by E. Torres)

Morales 2003, 2007a, 2010, 2016; Straus et al. 2015a; Hopkins et al. n.d.). The most intensive Paleolithic human occupations at El Mirón date to the Magdalenian with substantial Initial and Lower and less massive Middle, Upper, and Epi-(Azilian)Magdalenian archaeological assemblages (Fontes et al. 2015, 2016, 2018; González Morales and Straus 2005, 2009; González Morales et al. 2007; Nakazawa et al. 2009; Straus and González Morales 2007b, 2012, 2018, 2019, 2020; Straus et al. 2008, 2014, 2015a, 2016, 2018) contrast sharply with the sparse pre- and Upper Magdalenian levels (Marín-Arroyo 2008, 2010; González Morales and Straus 2012; Straus and González Morales 2019). Previous research (Geiling and Marín-Arroyo 2015; Geiling et al. 2016; Marín-Arroyo 2009c, 2010; Marín-Arroyo and Geiling 2015; Straus et al. 2013, 2015b) indicates that humans were the primary accumulators of the ungulates at El Mirón (Marín-Arroyo et al. 2020; Straus et al. 2013), with minor inputs from carnivores and predatory birds such as the bearded vulture (*Gypaetus barbatus* (Marín-Arroyo et al. 2009)) when humans did not inhabit the cave.

These factors, combined with the presence of substantial post-LGM (Oldest Dryas) Magdalenian deposits, make El Mirón an ideal location at which to explore the nature of subsistence in the Cantabrian Initial and Lower Magdalenian. In this study, we focus

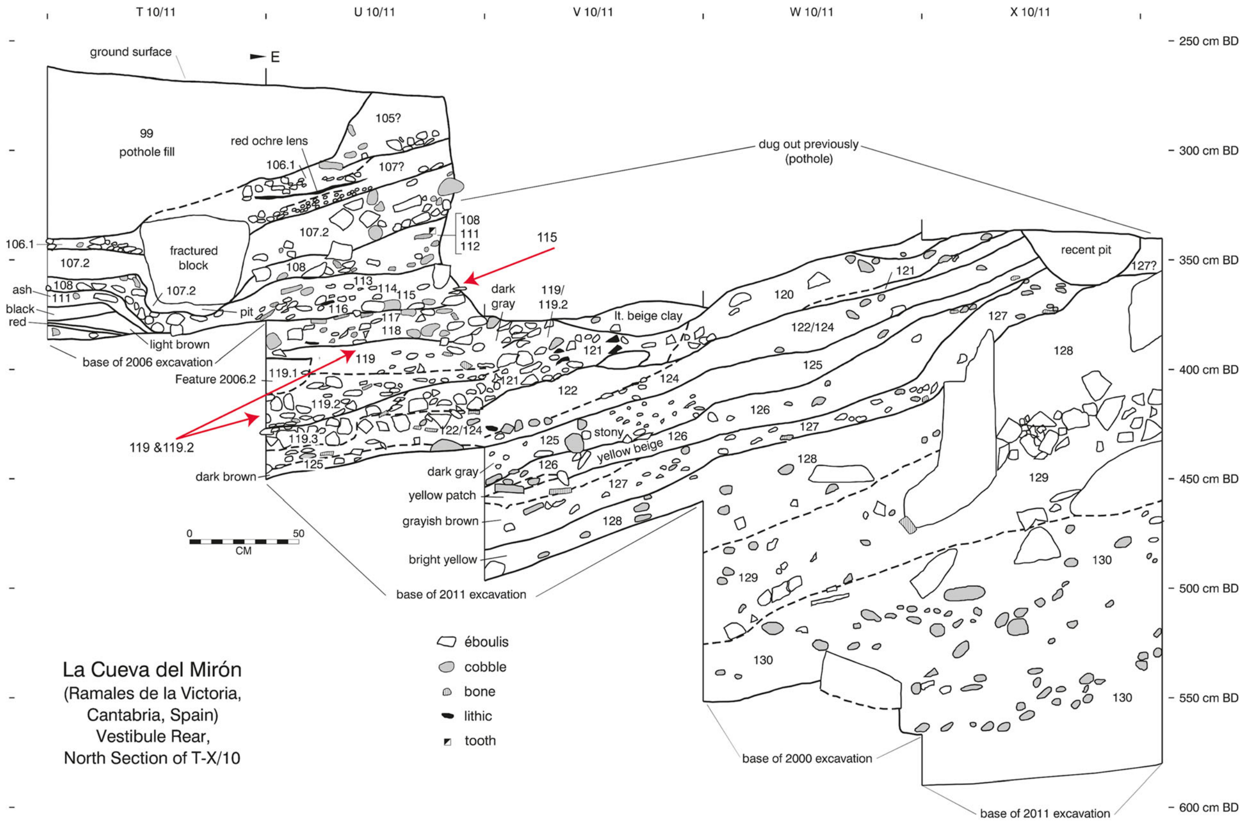

Fig. 2 Stratigraphic plan showing levels 119.2, 119, and 115 in the Corral area in the vestibule rear area of El Mirón Cave (figure by L.G. Straus and R.L. Stauber)

Table 1 Chronological information for levels 119, 119.2, and 115 (after Straus and González Morales 2003, 2007a, 2010, 2019; Hopkins et al. n.d.). All dates were determined using C14 AMS with the exception of the level 115 date shown with an asterisk (*). Calibrations were done using IntCal20 (Reimer et al. 2020) and ranges are given at a 95.4% confidence interval (±2σ). Dates obtained from Center for Applied Isotope Studies at the University of Georgia (UGAMS) Geochron Laboratories in association with Lawrence Livermore Laboratories (GX)

Level	Sample type	Sample ID	Calibrated date ranges (BP) ± 2σ
115	Bone collagen	UGAMS-31472	20,420–20,100
115	Bone collagen from many fragments	GX-23394*	18,880–14,230
119	Bone collagen	UGAMS-15182	20,920–20,600
119	Charcoal	GX-25858	20,760–20,290
119.2	Bone collagen	GX-32656	20,170–19,290
119.2 base	Bone collagen	UGAMS-15182	21,400–21,040

on the macro-mammalian remains recovered from levels 119.2, 119, and 115 in the vestibule rear, or “Corral” excavation area, of the cave (Fig. 2).

Level 119.2

Excavation of this 5–15-cm-thick stratigraphic layer was limited to two meter-square units. It was differentiated from 119 (of which it is the basal part) by minor differences in sedimentary matrix and color (it includes many fine, beige, greenish-grey and reddish silt lenses). In about a third of the area excavated, there was a hearth pit filled with loose, charcoal-rich sediments (labelled 119.1), whose faunal materials were not analyzed for lack of time (see Fig. 2). The base of level 119.2 has been AMS C14-dated on bone collagen to 21,440–21,040 cal BP (Table 1; Straus and González Morales 2003, 2007a, 2010, 2019; Hopkins et al. n.d.), placing it squarely at the beginning of the Initial Magdalenian after the Solutrean (represented in El Mirón by levels 121–127 (120 not being a real intact layer)); this attribution is further supported by the artifact assemblages recovered from this deposit. Activities at El Mirón during the time that level 119.2 was deposited appear to include stone tool knapping and maintenance, carcass processing, and artistic activity as evidenced by a carved slate pendant with the image of a horse head that may have broken during production (González Morales and Straus 2013; Straus and González Morales 2019).

Level 119

For level 119, two AMS radiocarbon assays (one on bone collagen, the other on charcoal) give this deposit an age range of 20,760–20,290 cal BP (Table 1; see also Straus and González Morales 2003, 2007a, 2010, 2019; Hopkins et al. n.d.). It was excavated in three square meter units. The sediment is characterized by brown to orange-brown clayey silt with abundant medium–large weathered limestone clasts, and like all the early Magdalenian levels, this roughly 10–15-cm-thick level consists of dark, organic-rich, highly anthropogenic sediments that contrast the lighter sediments above the Initial and Lower Magdalenian levels (Straus et al. 2001). Hearth features and masses of charcoal were identified (Straus and González Morales 2019). The lithic assemblage from level 119 is extremely abundant, with c. 42,249 items of debris (debitage—mostly microdebitage—and cores), and 464 retouched tools or weapon elements recovered (Straus et al. 2014). The myriad "chips" along with cores and core remnants suggest that stone-knapping took place in situ. Blades, flakes, and bladelets are well represented, as are retouched tools and "mousteroid" flake tool types, but the raclettes characteristic of the French Badegoulian are absent from this level. Raw materials include local quartzite, limestone, and mudstone along with non-local flints that were carried to the cave from outcrops in the coastal zone (Straus and González Morales 2019). The osseous artifacts include whole and fragmentary antler points including large, round-section types, and there was on-site production of antler points as evidenced by the presence of blanks. The diversity of stone tool types in this level suggest that at the time it was deposited, the cave was used for a variety of activities including hunting and carcass processing, tool and weapon manufacture and maintenance, and other activities such as hide-working and sewing (Straus and González Morales 2019).

Level 115

Level 115, one of several Lower Magdalenian deposits at El Mirón (including level 504 which contained a human burial (Straus et al. 2015a)), is approximately 5–7 cm thick and was found across 9 meter square units (Fig. 1). It was characterized by blackish-brown to light gray silt with large weathered éboulis (Straus et al. 2001) . Two disparate radiocarbon dates place it at either 18,880–14,230 cal BP based on a conventional date on several bone fragments with an unreliably large standard deviation that is incoherent with dates from under- and over-lying levels, or 20,420–20,100 cal BP, an AMS date on bone collagen. Calibration of the latter determination at $\pm 1\sigma$ suggests very rapid depositional rates during the interval between levels 119.2 and 115 (Table 1; Straus and González Morales 2003, 2007a, 2010). The abundant lithic assemblage (n=24,675) associated with this level is characteristic of the classic Cantabrian Lower Magdalenian with pyramidal nucleiform endscraper/bladelet cores, large quantities of debitage and microdebitage, and various formal tools, notably, backed bladelets. There is also a rich osseous industry including square-section antler points, bone needles and (from a similarly dated level in the Vestibule Front) a spear thrower, as well as regionally and temporally distinctive striation-engraved images of red deer hinds on red deer scapulae (González Morales et al. 2007; González Morales and Straus 2009; Straus and González Morales 2019). Raw materials were transported mostly from coastal zone flysch flint outcrops, notably the Barrika source roughly 60 km distant from the site, in the Bilbao area, but also from flint sources in the trans-Cordilleran Basque Country including the Castilian enclave of Treviño, and even extreme southwestern France (Straus and González Morales 2019). Local raw materials were also used, including mudstone, quartzite, and limestone (Straus and González Morales 2019). Ash- and charcoal-rich hearths, lenses of red and yellow ochre, fire-cracked rocks, pits, and a possible stone wall all suggest intensive, multi-function human occupations that deposited this level (González Morales and Straus 2005, 2009; González Morales et al. 2007; Straus and González Morales 2003, 2007b, 2010, 2018, 2019; Straus et al. 2008, 2011).

Methods

For this study, we studied the piece-plotted macro-mammal assemblages from levels 119.2, 119 (both Initial Magdalenian, analyzed by Carvalho), and 115 (Lower Magdalenian, analyzed by Jones). Identification of the faunal assemblages took place at the Laboratorio de Bioarqueología at the Instituto Internacional de Investigaciones Prehistóricas de Cantabria (Universidad de Cantabria) and was done in consistent fashion and with the assistance of Marín-Arroyo and Geiling. For taxonomic and anatomical identifications, we used the Laboratorio's osteological collection, supplemented by atlases (e.g., Alimen and Lavocat 1966; Hillson 1996; Pales and Lambert 1971; Schmid 1972). We completed a basic taxonomic and anatomical inventory, identifying to the lowest possible taxonomic level, and recorded portion, side, landmarks, epiphyseal fusion, and dental eruption. Data were recorded in a Microsoft Access database designed by Geiling. We present NSP (number of specimens), NISP (number of identified specimens; specimens were considered identifiable if they could be assigned to taxonomic class or lower), and MNI (minimum number of individuals; calculated following Gifford-Gonzalez 2018). Using NISP as our primary analytic unit (following Grayson 1984; Lyman 2008), we use the resulting dataset to address two questions: (1) to what extent were the Lower and Initial Magdalenian faunas deposited by humans as opposed to some other agent(s)? and (2) is there a difference in faunal representation between the Lower and Initial Magdalenian faunas? All statistics were computed in PAST (Hammer et al. 2001).

To what extent were the Lower and Initial Magdalenian faunas deposited by humans as opposed to some other agent(s)?

Previous analyses indicate that other Epi, Upper, Middle, and Lower Magdalenian faunal assemblages from El Mirón were mainly the products of human activities (Geiling and Marín-Arroyo 2015, Geiling et al. 2016;Marín-Arroyo 2009c, 2010; Marín-Arroyo and Geiling 2015; Straus et al. 2013). However, the presence of carnivore remains (albeit in very small quantities) and analyst observations of carnivore traces on some bones (such as gnawing and digestive corrosion) in deposits both under- and over-lying levels 119.2, 119, and 115 indicate that non-humans sometimes did contribute to or modify these assemblages (Cuenca-Bescós et al. 2009a, b; Marín-Arroyo 2008, b, c, 2010). To address the possibility that carnivore activity might be influencing our data, we made observations of bone surface modification and bone condition that provide clues about how they were deposited. These include anthropogenic cut marks, anthropogenic impact marks, skeletal element breakage patterns, degree of fragmentation, burning, digestive traces, and carnivore activity (e.g., Blumenschine 1988; Pérez Ripoll 1992; Fisher 1995). Observations of such bone surface modifications provide a first line of evidence for assessing the depositional agents responsible for the accumulation of animal remains at the site, even in palimpsest contexts.

Cut marks (typically defined as incisions that are V-shaped in cross-section) on bones that represent butchering and other carcass processing activities are one indicator by which zooarchaeologists recognize anthropogenic activity in a faunal assemblage (e.g., Binford et al. 1988; Bunn 1991; Domínguez-Rodrigo et al. 2010). However, the identification of such bone surface modifications is not unproblematic.

Recent studies show that identifying cut marks on a bone surface is not a straightforward process; the lack of standardized terminology coupled with the fact that post-depositional processes can produce V-shaped incisions on bones (e.g., trampling) means that there is very little consistency in the ways analysts identify and interpret cut marks (e.g., Blumenschine et al. 1996; Domínguez-Rodrigo et al. 2017; Merritt et al. 2019). There are also other problems with using cut marks as the primary indicator of anthropogenic activity: experienced butchers and certain types of tools may leave fewer cut marks than others (Dewbury and Russell 2007; Egeland et al. 2014), and post-depositional modification of bone may obscure bone surfaces, making identification of cut marks, or any other bone surface modifications, impossible. For these reasons among others, cut marks cannot be used as the sole marker of human manipulation of bone in an assemblage. In this study, we did record cut marks, but we are intentionally conservative in our use of them as taphonomic markers. We only considered bone surface modifications as such after inspection under a Leica (S8 APO) microscope. The frequency of cut marks we observe is therefore likely to be lower than that in other studies.

We recorded various traces of anthropogenic impact marks, or percussion marks, on the bone surface such as conchoidal fractures, notch marks, or chop marks. These have been studied as a marker of human activities such as marrow extraction for over 100 years (see discussion in Vettese et al. 2020). As with cut marks, the identification of impact marks can be problematic: such marks can be the result of multiple taphonomic agents; there is wide variation in analyst observations of these marks (Blumenschine et al. 1996; Merritt et al. 2019), and post-depositional processes (e.g., stone blocks falling from the cave ceiling) and other taphonomic agents (e.g., Fernández-Jalvo and Andrews 2016) can modify bone in ways that appear similar to impact marks. In this study, we followed Fernández-Jalvo and Andrews’ (2016) protocol for the identification of anthropogenic impact marks, and, once again, we interpret their frequencies conservatively.

Breakage profile patterns of archaeofaunal assemblages can provide taphonomic clues regarding depositional agents and post-depositional processes. Anthropogenic archaeofaunal assemblages often display breakage patterns dominated by fresh fractures, also known as green fractures, a breakage pattern that indicates perimortem manipulation of bones consistent with marrow extraction techniques (e.g., Villa and Mahieu 1991). On the other hand, dry fractures, or fractures on bone indicating postmortem breakage, are usually associated with carnivore and post-depositional activities (Villa and Mahieu 1991). As a second line of evidence for marrow extraction activities, when possible, we record breakage profiles of specimens in the following categories: green, dry, green and dry, modern, and two-phase old fractures, indicating a lag in time between one fracture type and another. If there are other independent lines of evidence suggesting marrow extraction activities, higher degrees of fragmentation (i.e., smaller specimen size) can also support this type of human activity. Higher degrees of fragmentation could suggest more intensive human manipulation of bones (e.g., Binford 1978). We thus record specimen size of fragmented remains as well.

Burnt bone can be an indicator of human activities such as roasting or using bones for fuel (e.g., Binford 1978; Costamagno et al. 2005; David 1990). However, non-anthropogenic fires can also cause burn marks on bones (e.g., Asmussen 2009), and post-depositional processes (e.g., fungal activity, stains from humic acid or oxidized soils) can cause discoloration that may resemble burning (Fernández-Jalvo and Andrews

2016; Marín-Arroyo et al. 2008). The latter is observed in other Magdalenian layers at El Mirón, where faunal assemblages have been heavily modified by manganese oxide/hydroxide staining due to prolonged contact with sediments that have become humic due to human activity (Marín-Arroyo et al. 2008). For these reasons, we were also conservative in our identification of burning—only bones that showed both discoloration and degradation of the bone surface when viewed under a microscope were considered burned and we again are cautious in our interpretation of these results.

Digestive traces (polishing and shallow pitting on the bone surface, sharpening and/or smoothing of bone fracture edges) and carnivore activity (gnawing, tooth punctures, and crush marks) usually point to non-human taphonomic agents such as carnivores and predatory or scavenging birds (Andrews 1990; Cruz-Uribe 1991; Fisher 1995; Hockett 1996; Lyman 1994). It is also possible that carnivores scavenging animal tissues left behind by humans in cave settings may leave traces on bones with anthropic bone surface modifications. In these cases, if superimposed, it is possible to tease out whether the carnivore or human bone surface modifications happened first via assessment under a microscope. We accordingly observed all specimens with such traces under a microscope and recorded them as part of our taphonomic study.

We use these different lines of evidence, taken together, to assess if humans, some other taphonomic agent(s), or both were responsible for the faunal assemblages in levels 119.2, 119, and 115. If non-humans were responsible for the deposition of a majority of the faunal assemblage, we would expect to observe higher incidences of non-human marks (carnivore activity, digestive traces, dry fractures) than anthropogenic ones (anthropogenic cut marks and impact marks, green fractures, burning). If the opposite is true, we would expect higher incidences of anthropogenic marks than non-human ones.

Is there a difference in faunal representation between the Lower and Initial Magdalenian faunas?

To understand the degree to which hunting may have focused on different prey species in the Initial Magdalenian and Lower Magdalenian at El Mirón, we compare the taxonomic distributions from the faunal assemblages in levels 119.2, 119, and 115. We use three methods for this comparison: evenness, or the degree to which taxa are evenly distributed across taxonomic categories, measured by the reciprocal of Simpson's Dominance Index (Simpson 1949); a chi-square-based analysis of a multidimensional contingency table (accompanied by Cramér's *V* as a measure of effect size; see Cronk 2012:131; Wolverton et al. 2016); and Spearman's rank order correlation.

Zooarchaeologists frequently use taxonomic evenness, or the degree to which specimens are evenly distributed across taxonomic categories, as a means of understanding changing taxonomic diversity in zooarchaeological assemblages (e.g., Grayson and Delpech 2002; Lyman 2008; Starkovich 2017; Stiner 2001). Differences in evenness may indicate differences in seasonality, in hunting strategy, and/or in environmental conditions (Jones 2004). Here, we calculate the reciprocal of Simpson's Dominance Index (1/D) to assess evenness (Faith and Du 2017; Simpson 1949) in levels 119.2, 119, and 115. Differences in 1/D between these three assemblages would suggest that faunal representation does vary between the levels; conversely, if 1/D remains constant, it would suggest continuity rather than change.

Chi-square analysis of contingency tables is widely used by archaeologists to compare frequencies of associations (VanPool and Leonard 2011); however, two issues make this a difficult method in this particular case. The first is that faunal assemblages from the Cantabrian Magdalenian (and indeed from many times and places) are frequently dominated by a few taxa, with all other taxa appearing only sporadically. This may result in a matrix in which many fields contain a value lower than 5, which is problematic for chi-square analysis (Zar 1999:505-6). At the same time, a multidimensional zooarchaeological contingency table is typically too large and complex to employ Fisher's exact test, the usual remedy for a matrix with small frequencies. The second is that at the same time that some categories usually have low frequencies, overall the relatively large number of zooarchaeological remains can cause a statistically significant but low-effect chi-square result (Wolverton et al. 2016). A statistically significant chi-square result in such a situation may merely reflect the large numbers of individual specimens; it may not indicate that there is any practical association between the deposits and the distribution of taxa. We accordingly use chi-square here not as an inferential statistic, but as an exploratory one. To avoid the low-frequency issue, we restrict our chi-square analysis to a comparison of the ungulate taxa, which are more regularly represented than other taxa in our dataset. We expect that the chi-square analysis will identify a statistically significant but low-effect difference in taxonomic distribution between levels 119.2, 119, and 115. While we do report the chi-square statistic and *p*-value as well as the effect size, our primary interest in this test is in the analysis of adjusted chi-square residuals, which provide insight into the sources of variation in a contingency matrix (Zar 1999). We use these residuals to identify whether the variation in our matrix is driven by differences between the Initial (119.2 and 119) and Lower (115) Magdalenian assemblages, as would be expected in a case of directional change, or not.

For an inferential statistic, we rely on Spearman's rank order correlation. This powerful non-parametric test uses the variation in the rank order of two variables to determine if the rankings of the two variables are significantly correlated (VanPool and Leonard 2011). We use this test to compare the rank order of taxa in the level 119.2, 119, and 115 assemblages. If Initial and Lower Magdalenian hunters were targeting different taxa, we would expect the level 115 faunal assemblage not to correlate with that of either level 119.2 or level 119. If, by contrast, hunting strategies were largely consistent across these three levels, we would expect all assemblages to correlate with each other.

It is however true that hunting strategies can change even while the taxa targeted remain the same. Changes in carcass transport and butchery may be reflected in patterns of skeletal representation. To test for such a possibility, we compare the skeletal representation using the NISP of specific skeletal elements of both red deer and ibex in levels 119.2, 119, and 115. We again use Spearman's rank order correlation. If Initial and Lower Magdalenian hunters were transporting these taxa in different ways, we expect level 115 not to correlate with either level 119.2 or level 119. If, by contrast, hunting strategies were largely consistent across these three levels, we expect skeletal representation to be correlated in all cases.

Another way in which hunting strategies reflected by archaeofaunal assemblages might have changed is by season. Faunal studies of Middle, Upper Magdalenian, and Azilian levels in the outer and mid-vestibule area of El Mirón (levels 108–102, 308–305, 14–11) suggest alternating long-term residential occupations and sporadic, ephemeral occupations of this site, the latter especially in the late Upper Magdalenian and Azilian (Marín-Arroyo 2009a, 2010). The longer-term residential occupations of the cave in the Middle and Upper

Magdalenian mainly took place during late spring-early summer, but an ephemeral Final Magdalenian/Azilian layer (11) also has some evidence of fall kills. In contrast, analyses of the Initial and Lower Magdalenian faunas from the outer vestibule and human burial areas of the cave suggest that possibly Initial Magdalenian faunas (in levels 21–18) were primarily hunted in winter/spring, while the Lower Magdalenian faunas (in levels 17–15 and 504) reflect longer and/or multiple, closely repeated stays in the cave, including evidence of both cold- and warm-season hunting (Geiling 2020:356). The faunal assemblages from 119.2, 119, and 115 are not large enough to conduct full seasonality analyses, but we can use a chi-square analysis of the proportions of young animals, measured through bone fusion and tooth eruption (Mariezkurrena 1983; Vigal and Machordom 1985; Azorit et al. 2002; Serrano et al. 2004) to test for an increase in their representation between levels 119.2 and 119 (Initial Magdalenian) and 115 (Lower Magdalenian). To do this, we used the NISP of skeletal elements of each taxon, observing unfused epiphyses and unerupted or deciduous teeth as juvenile individuals. While such an increase could be caused by numerous factors, given the previously published results from the Initial and Lower Magdalenian from El Mirón, a significant increase in the frequency of young ibex and red deer between levels 119.2 and 115 would complement the previous seasonality results, and would suggest that periods of residence at El Mirón may have increasingly (but not exclusively) included warm-season (e.g., spring/summer/autumn) stays in the Lower Magdalenian relative to the Initial Magdalenian. Since there is limited evidence suggesting mainly cold-season use of the cave by hunting parties during the underlying Solutrean levels (Last Glacial Maximum) (Geiling 2020), the overall trend may indicate a long-term shift toward more use of the cave during the warm season throughout the course of the Magdalenian culminating in the most recent Paleolithic levels.

Table 2 Numbers of identified specimens (NISP) and minimum number of individuals (MNI) of taxa identified in levels 119.2, 119, and 115

	NISP 119.2	MNI 119.2	NISP 119	MNI 119	NISP 115	MNI 115
Equus ferus	2	1	12	1	12	1
Bison priscus/Bos primigenius	9	2	6	1	10	1
Capra pyrenaica	122	12	378	24	259	12
Rupicapra rupicapra	12	1	20	2	20	4
Cervus elaphus	151	8	289	12	245	16
Capreolus capreolus	2	1	2	1	6	1
Lepus sp.	1	1	0	-	0	-
Vulpes vulpes	0	-	0	-	1	1
Lynx pardinus	0	-	2	1	0	-
Ursus sp.	1	1	0	-	0	-
Canis lupus	0	-	2	1	0	-
Indeterminate Caprinae	3	-	2	-	5	-
Indeterminate ungulate	196	-	195	-	213	-
Indeterminate mammal	403	-	696	-	393	-
Indeterminate	118	-	83	-	47	-
Total	1020	27	1688	43	1211	36

Table 3 Number of specimens with bone surface modifications, by level. Percentages indicate the proportion of specimens with the taphonomic observation in that category to total number of specimens (NSP)

	Level 119.2	Level 119	Level 115
Anthropogenic cut marks	90 (8.82%)	259 (15.34%)	50 (4.13%)
Anthropogenic impact marks	58 (5.69%)	137 (8.12%)	125 (10.33%)
Burning	179 (17.55%)	285 (16.88%)	61 (5.04%)

Results

Our analyses identified 3917 total specimens: 1020 from level 119.2, 1688 from level 119, and 1210 from level 115 (Table 2). Of these, 300 in level 119.2, 712 in level 119, and 553 in level 115 were identified to a taxonomic level lower than size class. All assemblages were dominated by red deer and ibex, with lower representation of other ungulates including aurochs/bison, horse, chamois, and roe deer and occasional representation of carnivores, insectivores, and leporids (Fig. 4).

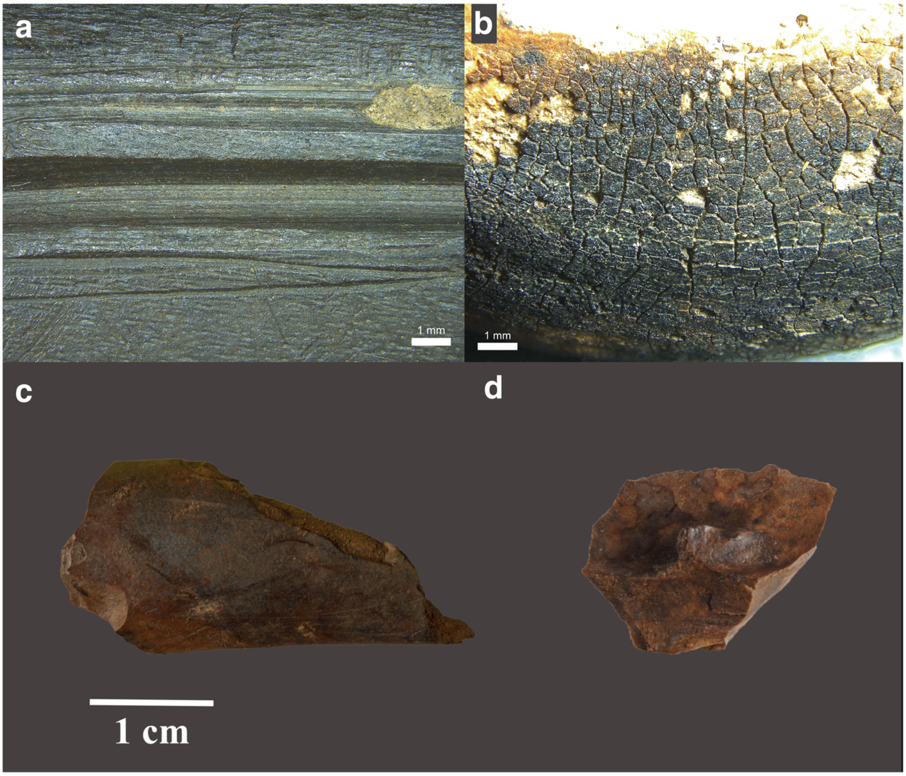

Fig. 3 Bones with cut marks (**a**), burning (**b**), impact marks (**c**), and bone flake (**d**), product of percussion (all from level 119)

Table 4 Number of specimens in each category of fragmentation size, breakage profile, and non-human activity. The three categories shown here, All specimens, *Capra pyrenaica*, and *Cervus elaphus*, are the ones on which taphonomic observations were most common

Fragmentation																		
	All specimens						*Capra pyrenaica*						*Cervus elaphus*					
	119.2	%	119	%	115	%	119.2	%	119	%	115	%	119.2	%	119	%	115	%
(cm)																		
0–2	272	28.66	243	16.39	28	5.87	47	41.23	64	19.45	5	7.14	20	13.70	40	14.23	4	3.54
3–5	489	51.53	848	57.18	175	36.69	42	36.84	186	56.53	34	48.57	62	42.47	123	43.77	25	22.12
6–10	176	18.55	375	25.29	264	55.35	24	21.05	78	23.71	31	44.29	62	42.47	108	38.43	75	66.37
11+	12	1.26	17	1.15	10	2.10	1	0.88	1	0.30	0	0	2	1.37	10	3.56	9	7.96
Breakage profile																		
	All specimens						*Capra pyrenaica*						*Cervus elaphus*					
	119.2	%	119	%	115	%	119.2	%	119	%	115	%	119.2	%	119	%	115	%
Green	624	70.35	1090	71.71	340	53.04	77	81.91	221	77.00	60	48.78	122	88.41	216	84.17	87	65.41
Dry	133	14.99	233	15.33	178	27.77	5	5.32	39	13.59	34	27.64	10	7.25	23	9.02	26	19.55
Green and dry	30	3.38	51	3.36	43	6.71	3	3.19	10	3.48	7	5.69	1	0.72	6	2.35	11	8.27
Recent	45	5.07	53	3.49	33	5.15	7	7.45	5	1.74	6	4.88	4	2.90	4	1.57	4	3.01
Old fracture (2 phases)	3	0.34	7	0.46	4	0.62	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Ind.	52	5.86	86	5.66	43	6.71	2	2.13	12	4.18	16	13.01	1	0.72	6	2.35	5	3.76
Non-human activity																		
	All specimens						*Capra pyrenaica*						*Cervus elaphus*					
	119.2	%	119	%	115	%	119.2	%	119	%	115	%	119.2	%	119	%	115	%
Digested	52	5.06	30	1.76	20	1.66	7	5.80	6	1.60	8	3.10	4	2.65	3	1.04	5	2.04
Carnivore activity	11	1.07	10	0.59	11	0.91	2	1.70	0	0.00	3	1.20	1	0.66	4	1.38	3	1.22
Total	63	6.13	40	2.34	31	2.57	9	7.50	6	1.60	11	4.30	5	3.31	7	2.42	8	3.27

Table 5 Anthropogenic cut marks by skeletal element for *C. pyrenaica*, *C. elaphus*, and indeterminate M-L size categories per level, the three most common categories on which cut marks were encountered

	Capra pyrenaica			*Cervus elaphus*			Ind. M-L		
	119.2	119	115	119.2	119	115	119.2	119	115
Crania		3			1				1
Antler/horn core					1				
Mandible		6			2		2	1	1
Individual teeth									
Hyoid									
Atlas									
Axis									
Cervical								2	
Thoracic							2	3	
Lumbar		1			1		1		1
Sacrum									
Indet. vertebra				1				1	
Rib		1			2	1	3	14	1
Sternabra								1	
Scapula				6					1
Humerus	1	9	4	2	12	1		1	2
Radius		1	1		3	1	2	1	
Ulna									
Radioulna		1	1	5					
Metacarpals		1	2		2			1	2
Carpals									
Innominate				2					
Femur	5	16			11	5	3	4	1
Patella				4					
Tibia	2	9		1	11	3	2	14	1
Metatarsals	2	7			3	1			
Tarsals				1					
Long bone fragments		1		1	5	1	25	62	11
Indet. metapodia	1				3		4	5	1
Phalanges		2	1		1				
Sesamoids									
Ind.								10	1
Total	11	58	9	23	58	13	44	120	24

To what extent were the Lower and Initial Magdalenian faunas deposited by humans as opposed to some other agent(s)?

Our taphonomic observations suggest that anthropogenic marks are more common in the archaeofaunas from levels 119.2, 119, and 115 (Table 3). The specimens from the

Table 6 Anthropogenic impact marks by skeletal element for *C. pyrenaica*, *C. elaphus*, and indeterminate M-L size categories per level, the three most common categories on which impact marks were encountered

	Capra pyrenaica			*Cervus elaphus*			Ind. M-L		
	119.2	119	115	119.2	119	115	119.2	119	115
Crania									
Horn/horn core									1
Mandible								2	1
Individual teeth									
Hyoid									
Atlas									
Axis									
Cervical									
Thoracic									
Lumbar									
Sacrum									
Indet. vertebra									
Rib									1
Sternabra									
Scapula									
Humerus	1	6	5	2	9	4		2	2
Radius		1	2	4		3		1	2
Ulna			1		1				
Radioulna			1						
Metacarpals		1	2	2	2	3		2	5
Carpals									
Innominate									
Femur	6	11	2		6	6	1	3	2
Patella									
Tibia	1	4		6	10	4	1	6	2
Metatarsals	2	2		2	4	4			
Tarsals									
Long bone fragments		1		1	4	6	18	40	44
Indet. metapodia	1	2			1	2	2	3	2
Phalanges		3	1		2	1			
Sesamoids									
Ind.								1	2
Total	11	31	14	17	39	33	22	60	64

119.2 and 119 assemblages displayed high rates of green fractures, with 70.35% of specimens showing only green fractures (Table 4). Level 115 had less green fractures, with 27.77% of specimens displaying dry fractures. Similar patterns are observed for the ibex and red deer categories, where remains in level 119.2 show the most green fractures, followed closely by level 119 while 48.78% of the ibex and 65.41% of the

Table 7 Skeletal elements that were burned for *C. pyrenaica*, *C. elaphus*, and indeterminate M-L size categories per level, the three most common categories on which evidence of burning was encountered

	Capra pyrenaica			*Cervus elaphus*			Ind. M-L		
	119.2	119	115	119.2	119	115	119.2	119	115
Crania		1					1	3	
Horn/horn core				5	5				
Mandible	1	5			2			1	
Individual teeth			1		1				
Hyoid									
Atlas				1					
Axis							2		
Cervical		3			2		2	2	
Thoracic	1	1			1		2	1	
Lumbar		2			2		4	4	1
Sacrum		1					1	1	
Indet. vertebra						1	1	4	3
Rib		4		2	1		7	17	
Sternabra									
Scapula		1							
Humerus	1	6		1	6	2	4	4	1
Radius		3			1				
Ulna		3			1		1		
Radioulna		1							
Metacarpals	1	3	2	4	5			1	
Carpals	2	7	1	3	2				
Innominate		1		1	1		1	1	
Femur	6	10	1	3	5	1	2	2	1
Patella	1	2							
Tibia	5	4			4		2	2	1
Metatarsals	2	7	1	2	2	1	1		
Tarsals		4			2	1			1
Long bone fragments		1			1		38	42	15
Indet. metapodia		6		3	4	1		5	2
Phalanges	3	6	7	2	3	4		1	
Sesamoids	1	1				1			
Ind.							20	22	3
Total	24	83	13	27	51	12	89	113	28

red deer remains displaying green fractures in level 115. Unambiguous cut marks, impact marks, and burning, indicators of human activity, were present in all levels in higher frequencies than non-human traces (Table 3, Fig. 3). Anthropic traces were most commonly observed on red deer, ibex, and indeterminate M-L mammal remains in all levels (Tables 5, 6, and 7). Cut marks were most common in level 119 for ibex, red deer, and indeterminate M-L size specimens, with the highest incidences encountered in the indeterminate M-L size category. Location of cut marks is observed in mostly appendicular portions of the skeleton. In red deer and ibex remains, level 119 had the most impact marks, followed by levels 115 and 119.2 (Table 6). In the indeterminate M-L category, anthropogenic impact marks are most commonly encountered in levels 115 and 119, and to a lesser extent level 119.2. In the ibex, red deer, and indeterminate M-L size categories, impact marks are concentrated on appendicular portions of the skeleton as well. The degree of fragmentation is highest in level 119.2, followed by levels 119 and 115, respectively, with less than 1.30% of remains in the all specimens and ibex categories measuring to 11 cm or more; however, for red deer, ~8% of specimens were larger or equal to 11 cm in level 115. The number of burned elements for these three categories is highest in level 119, followed by level 119.2, and then level 115 (Table 7). In contrast to cut marks and impact marks, burn marks were identified on all portions of the skeleton in all three levels. The remainder of anthropic remains came from mostly indeterminate specimens; however, negligible quantities (*n*=<3) of specimens identified to Bos/Bison and chamois in level 119.2, Bos/Bison and horse in level 119, and Bos/Bison and chamois in level 115.

At the same time, while there is some variation across levels, carnivore traces (e.g., punctures, gnawing) are consistently low, with the highest signs of carnivore activity being slightly over 1% in level 119.2 for all specimens (Table 4). Digestive traces were slightly more common, with the highest incidence occurring in 119.2 with ~5% of the overall assemblage. Level 119.2 contained the highest degree of non-human activity with 6.13% of the assemblage displaying either traces of digestion or carnivore activity. Level 115 remains displayed the next highest degree of non-human activity traces (2.57%) followed closely by level 119 (2.34%). For ibex, carnivore traces were

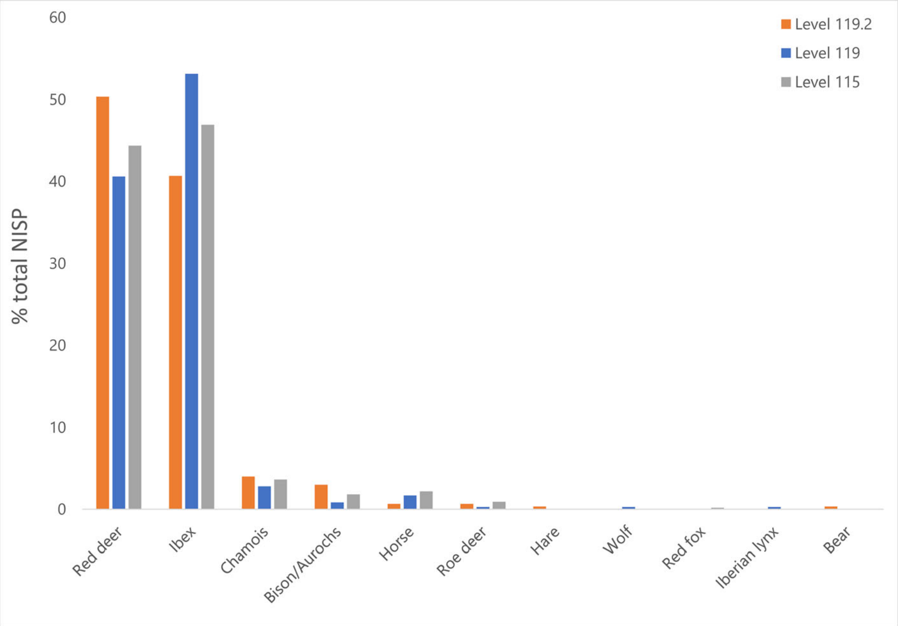

Fig. 4 Relative abundance of taxa in levels 119, 119.2, and 115

Table 8 Adjusted residuals for the taxonomic chi-square analysis. Values significant at the $\alpha = 0.05$ level are in bold italic

	Level 119.2	Level 119	Level 115
Horse	−1.50	0.07	1.16
Bison/aurochs	***2.16***	***−2.17***	0.49
Ibex	***−3.00***	***3.40***	−1.07
Chamois	0.73	−1.03	0.47
Red deer	***2.59***	***−2.26***	0.22
Roe deer	0.07	−1.62	1.63

encountered in higher frequencies in level 119.2 (7.50%), followed by level 115 (4.30%) with the smallest frequency in level 119 (1.60%). In all three levels, ~2–3% of red deer remains showed traces of non-human activity.

Is there a difference in faunal representation between the Lower and Initial Magdalenian faunas?

The taxonomic distribution of all three levels is dominated by ibex and red deer, followed by other ungulates and supplemented by a few carnivore, insectivore, and leporid remains (Fig. 4). The reciprocal of Simpson's Index suggests consistency in evenness in the assemblages with similar values for levels 119.2 (1/D = 2.38), 119 (1/D = 2.23), and 115 (1/D = 2.39). The chi-square analysis shows a statistically significant but—as predicted—low-effect difference in the relative frequency of ungulates between levels 119.2, 119, and 115 ($\chi^2 = 25.22$; $p = 0.01$; Cramér's $V = 0.09$). Surprisingly, the adjusted residuals suggest that this result is driven by differences in frequency in levels 119.2 and 119, rather than between level 115 and the two Initial Magdalenian levels (Table 8). However, the Spearman's rank order correlation analysis shows a significant correlation between all levels (Table 9), suggesting consistency in the taxa targeted across the Initial to Lower Magdalenian.

The distribution of skeletal elements of both red deer (Fig. 5a) and ibex (Fig. 5b) is likewise similar across all three levels, a result supported by the Spearman's rank order correlation analysis (Table 10). Full skeletal element distribution data are available in the supplemental files.

There is a low but consistent frequency of unfused elements/unerupted teeth in all three levels (Table 11). Representation of these indicators appears to increase through time, from around 3% of NISP in level 119.2 to just under 8% in level 115 ($\chi^2 = 19.01$;

Table 9 Spearman's rank order correlation values for taxonomic distributions

	r_s	p	Correlated?
Levels 115 and 119	0.86	0.00	Yes
Levels 115 and 119.2	0.89	0.00	Yes
Levels 119 and 119.2	0.79	0.00	Yes

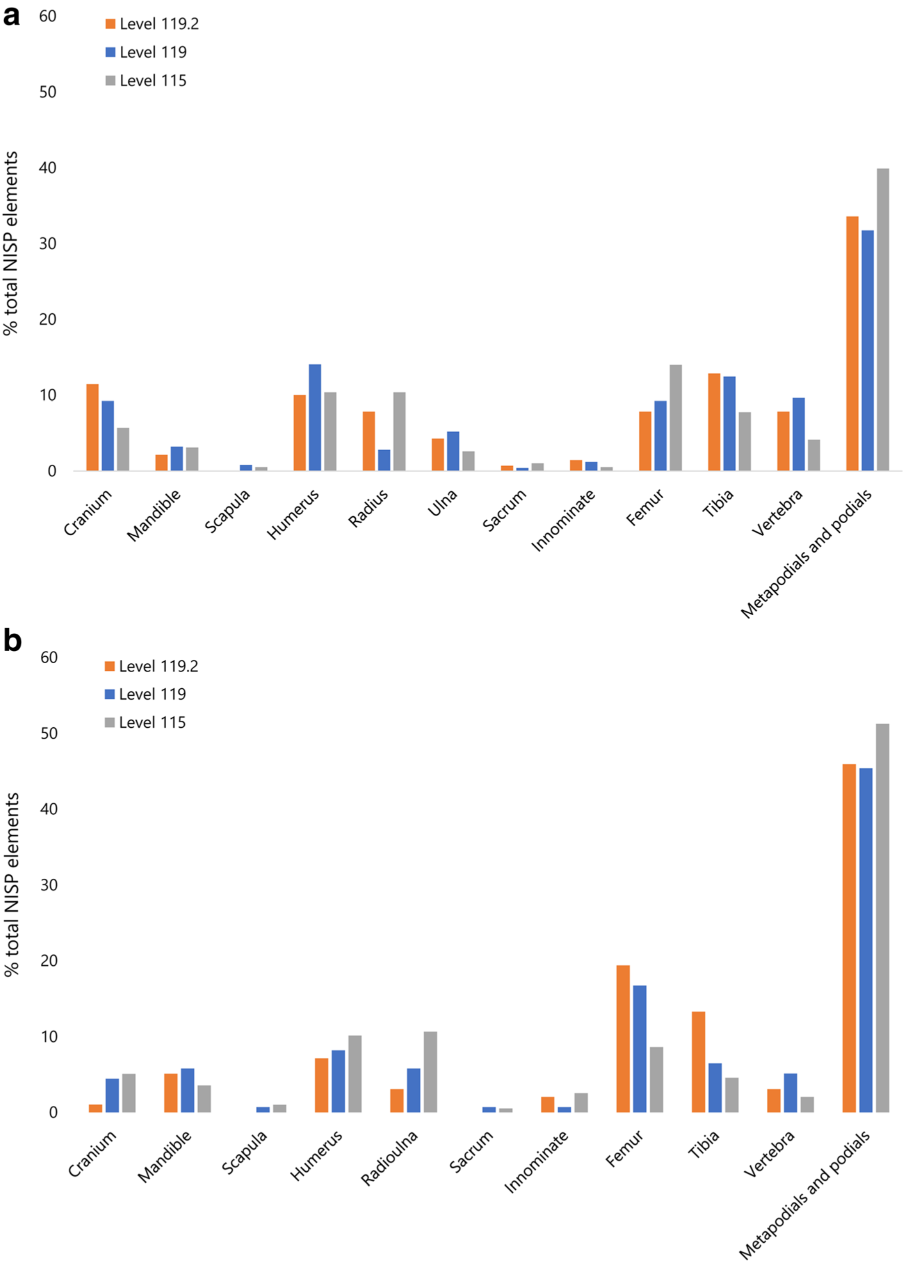

Fig. 5 Relative skeletal abundance of red deer (**a**) and ibex (**b**) in levels 119, 119.2, and 115

$p = 0.00$; Cramér's $V = 0.07$), although the effect size is low. However, chi-square failed to identify a significant change in the frequency of skeletal elements belonging to young when ibex ($\chi^2 = 1.68$; $p = 0.43$; Cramér's $V = 0.05$) and red deer ($\chi^2 = 2.89$; $p = 0.24$; Cramér's $V = 0.07$) were considered separately.

Table 10 Spearman's rank order correlation values for skeletal element distributions

Species	Levels	r_s	p	Correlated?
Red deer	115 and 119	0.76	0.00	Yes
	115 and 119.2	0.83	0.00	Yes
	119 and 119.2	0.90	0.00	Yes
Ibex	115 and 119	0.81	0.00	Yes
	115 and 119.2	0.72	0.01	Yes
	119 and 119.2	0.96	0.00	Yes

Discussion

The results of our analysis suggest continuity between the Initial and Lower Magdalenian archaeofaunas at El Mirón Cave. These archaeofaunas appear to reflect primarily human, rather than carnivore, activity: high incidences of green bone fractures, high degree of fragmentation, cut marks, burning, and impact marks were encountered in all of the assemblages studied here. While these taphonomic markers vary between assemblages, the observations made here suggest high degrees of anthropic manipulation of bones in level 119, and to a lesser degree in levels 119.2 and 115, respectively. Given that to a small degree non-human agents are responsible for the deposition of animal bones and the overwhelming evidence of human occupation in levels 119.2, 119, and 115 (i.e., large artifact assemblages, bone tools, hearths, etc.) taken together with the high incidences of anthropogenic bone surface modifications in these levels, the assemblages studied here were predominantly deposited by humans. The Initial Magdalenian assemblages had slightly more cut marks than the Lower Magdalenian assemblage; however, the latter also contained the highest occurrence of anthropogenic impact marks (Table 3). The small quantity of carnivore remains in conjunction with very few traces of carnivore or raptorial bird activity such as tooth gnawing and scoring or digestion, the latter of which has also been identified in other deposits of this cave (Marín-Arroyo et al. 2009), indicates that carnivores and/or raptorial birds had minimal contributions to the faunal assemblages. The presence of a few carnivores may reflect human procurement of these taxa; however, due to the small sample size of carnivore remains, it is difficult to assess whether this is the case.

We are therefore confident that these assemblages primarily reflect human hunting. This makes it notable that there are no significant differences in the representation of

Table 11 Frequency of unfused elements and unerupted/deciduous teeth

	Total NISP unfused elements + unerupted/ deciduous teeth	Red deer NISP unfused elements + unerupted/ deciduous teeth	Ibex NISP unfused elements + unerupted/ deciduous teeth
Level 115	88 (7.27%)	18 (7.38%)	20 (7.75%)
Level 119	87 (5.09%)	16 (5.54%)	21 (5.54%)
Level 119.2	32 (3.14%)	5 (3.43%)	6 (4.92%)

taxa and skeletal representation between them; it indicates that occupation of the cave was controlled by humans during this time (a situation radically different from the Middle Paleolithic and Early Upper Paleolithic-age levels at the site (Marín-Arroyo et al. 2020)). All assemblages were typical of the Cantabrian Magdalenian, with red deer and ibex dominating depending on the topographic location of the site. While the frequencies of these two taxa vary slightly, with more red deer in level 119.2, more ibex in level 119, and a nearly even split between the two in level 115, they are both significantly represented in all levels (Fig. 4). Notably, the differences that are present in taxonomic representation appear to be between the two Initial Magdalenian levels, 119.2 and 119, rather than between the Initial and Lower Magdalenian. Similarly, we did not detect any significant differences in skeletal element representation for red deer and ibex (Fig. 5); both Initial and Lower Magdalenian people seem to have had similar carcass transport strategies that favored limb elements over cranial and axial portions of the skeleton. However, the excavated area represented by the studied levels ranges between only 2 and 9 m^2 of a c. 250 m^2 total cave vestibule surface area, which shows more precisely that similar skeletal elements were discarded within this rather dark rear area of the large vestibule.

In short, it appears that at El Mirón in the first half of the Magdalenian, subsistence strategies more or less remained the same, at least between the levels studied here. There is no evidence of increased hunting specialization on a single species in the Lower Magdalenian, as has been recorded at other locations in Cantabria: red deer at such coastal plain sites as El Juyo or Altamira or ibex at the montane, cliff-side site of Rascaño (see Straus 1987, 1992, with references). It may be that these Initial and Lower Magdalenian faunal assemblages represent slight variations along a spectrum with high degrees of hunting specialization on one end (sites like El Juyo or El Rascaño), where hunters focused intensively on a single taxon, primarily due to each site's topographic position (Marín-Arroyo 2009c) and highly diversified resources, a pattern observed later in the Cantabrian Magdalenian (e.g., Straus and Clark 1986; Jones 2016), on the other. Both site-specific specialization and overall diversification were aspects of the overall intensification of subsistence during the course of the late Upper Paleolithic in the Cantabrian region. What we do not see is support for a directional change, in which sites become more specialized from the Initial to the Lower Magdalenian, because El Mirón habitants mainly practiced a dual-species exploitation system based on its topographic location (Marín-Arroyo 2009a). It is important to note that, while El Mirón is located on a steep, rocky mountainside (ideal ibex habitat), it is only about 150 m above the floor of a broad (1.25 × 2.5 km) middle (Ruesga) sector of the Asón River at the town of Ramales that would have been excellent red deer habitat. In other levels of the cave, skeletal element distributions differ between red deer and ibex, with ibex skeletal element distributions suggesting transport of full carcasses and red deer a focus on just meaty elements (Marín-Arroyo 2009c; Marín-Arroyo and Geiling 2015). We do not see this pattern in levels 119.2, 119, and 115 (Fig. 5, supplemental data), but this likely reflects the sample sizes and, particularly, the fragmentation of these samples rather than a lack of difference in carcass transport. It is notable, however, that there are some differences in the specimen fragment size and breakage profile patterns observed between levels 119.2, 119, and 115. The higher quantities of larger bone fragments for level 115, especially for red deer, combined with higher incidences of dry fractures overall in the same level suggest that there may be differences in carcass processing, but not transport, between the Initial and Lower Magdalenian. This could be due to differences in the human activities taking place between the Initial and Lower Magdalenian inside the cave, where focuses shift from more intense marrow extraction activities in the Initial Magdalenian to less intense marrow extraction techniques; however, the higher incidence of impact marks in level 115 contradicts this.

It can also be said that, unlike the pattern seen in other Magdalenian archaeofaunas in southern Iberia, there is no evidence of increased small mammals (lagomorphs) in these assemblages. Small mammals are simply very rare throughout the sequence of El Mirón (and in general in the northern Iberian Paleolithic sites), despite the fact that all sediments were water-screened through fine mesh, and those that are present do not show any signs of human manipulation.

If increasing specialization did not drive the results we see here, what did? It may be that environmental shifts or changing human decisions in terms of seasonal occupation and for what purposes humans resided at El Mirón Cave figure into the position of any given archaeofaunal assemblage on this spectrum. We note that the frequency of unfused elements/unerupted teeth does seem to increase between levels 119.2 and 119 and level 115, suggesting different representation of juveniles between the Initial and Lower Magdalenian (Table 7), a pattern seen in other faunal analyses from El Mirón (Geiling 2020). Without additional supporting data, we cannot draw secure conclusions about the causes of this increase. However, we do note that intensification seems an unlikely explanation, as we see no other signs of hunting stress, or indications that carcasses were intensively processed or exploitation of lower ranked prey, in these faunas. Increasing periods of occupation, as proposed by Geiling (2020), seem a likely explanation.

At the moment, the effects of climate versus human decision-making on Initial and Lower Magdalenian subsistence strategies are difficult to discern. The lack of significant differences in ecologically less-flexible species like horse or aurochs/bison between levels 119.2, 119, and 115 suggests that environments might not have significantly influenced hunting decisions at Mirón, but this remains a hypothesis to be tested. In addition, the study of the remaining skeletal remains recovered by screening at El Mirón may provide new insights into early Magdalenian subsistence. However, the results of this study suggest more continuity than change between the Initial and Lower Magdalenian at this site.

Conclusions

The zooarchaeological study of three Initial and Lower Magdalenian faunal assemblages from El Mirón Cave suggests that humans were the taphonomic agents responsible for the deposition of the vast majority of these assemblages and that subsistence in the Initial and Lower Magdalenian at El Mirón remained consistent, with no discernable directional change, except for subtle changes in seasonality of site occupation, as evidenced by the slight increase in juveniles through time. This supports the idea that Cantabrian Magdalenian subsistence strategies at this site (and more generally) were fairly stable. In addition, the continuity in the directions of both site-specific prey foci are key for understanding the processes which led up to the end of Upper Paleolithic lifeways and the transition to those of the regional Mesolithic which were highly coastal in nature. These results add to a limited body of subsistence information especially for the Initial Magdalenian, a period of time when people were adapting to the slowly but irregularly ameliorating conditions after the LGM, and they complement the studies of the Lower Magdalenian (Geiling 2020;

Marín-Arroyo and Geiling 2015) and Middle and Upper Magdalenian and Azilian (Marín-Arroyo 2010) faunas from levels in other sectors of El Mirón Cave.

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Author Contribution All authors contributed to the study conception and design. The analysis of the level 115 archaeofauna was conducted by Jones and that of the level 119 and 119.2 archaeofaunas was performed by Carvalho. The statistical analysis was done by Jones. The first draft of the manuscript was written by Carvalho and Jones; Straus extensively edited successive versions. Excavations in El Mirón were directed by Straus and González Morales, who provided all contextual information; Straus commissioned the studies. Marín-Arroyo provided access to the osteological comparative collection and laboratory facilities as well as identification consultation during the study. All authors read and approved the final manuscript.

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Declarations

Conflict of Interest The authors declare that they have no conflict of interest.

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