

## RESEARCH PAPER

# A Spatial Distribution Study of Faunal Remains from Two Lower Magdalenian Occupation Levels in El Mirón Cave, Cantabria, Spain

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Human behaviour can be reconstructed by analysing specific activities and campsite organization using spatial analysis. The dense occupation layers of the Lower Cantabrian Magdalenian in the Northern Spain reveal varied aspects of Upper Palaeolithic lifeways, including evidence of specific localized activities. The outer vestibule of El Mirón cave has a particularly rich and intact Lower Magdalenian occupation horizon, Levels 15–17. The excavations in the outer vestibule “Cabin” area of the site revealed excellent bone preservation. Artefacts and faunal remains were individually recorded and sediments water-screened to yield a large sample of archaeological finds and spatial data. Zooarchaeological analysis provided the taxonomic, anatomic and taphonomic determination of the faunal individual finds. Smaller animal remains were categorized and counted; special attention was given to the identification of anthropogenic modifications such as burnt bones or bone flakes. These small refuse items are considered to be useful, *in situ* indicators of localized activities. The spatial distribution analysis of this dense and complex palimpsest of El Mirón Lower Cantabrian Magdalenian layers required GIS based methods including density analysis, heatmaps and cluster analysis. Based on the spatial distribution of Level 15 and 16 faunal remains, different activity areas were identified comprising hearth, working and dropping zones. These results imply the deliberately segregated use of space within the Lower Cantabrian Magdalenian site area, in which bone-processing activities played a central role.

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## Introduction

There is a broad interest in the study of human activities through the reconstruction of behaviour patterns, variability and adaptation

to changing environments and climatic conditions among Palaeolithic hunter-gatherers (Binford, 1978; Nakazawa et al., 2009). Analysis of specific activities can be used to understand

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Palaeolithic human behaviour. It is widely recognized that zooarchaeological remains provide the means to reconstruct Palaeolithic behaviour (Bartram et al., 1991) and campsite structures (O'Connell et al., 1991). Activities of interest for the exploration of campsite organisation include butchering, bone marrow extraction, grease rendering or bones used as fuel. Based on ethnographical studies, distributions of tiny bone fragments in camps may reflect the location of activities generating bone refuse (processing, consumption, and discard). The intensity of secondary disposal activities and taphonomic factors (trampling, post occupational carnivore/scavenger activities) can also give insights into subsequent actions (Bartram et al., 1991, 137).

Spatial distribution analysis is based on the three-dimensional relationships of archaeological remains (Schiffer, 1996). Scrutiny of object distributions within human occupation layers is a useful tool for reconstructing intra-site spatial organisation and use (Clarke, 1977). By using these methods archaeologists are able to reconstruct activity areas (Ferring, 1984, 117). These are generally exemplified by hearth-centered models, where different types of activities are spatially distinguishable (Alperson-Afil et al., 2009; Audouze and Enloe, 1997; Fladerer et al., 2002; Goren-Inbar and Alperson-Afil, 2010; Leroi-Gourhan and Brézillon, 1966; Nakazawa et al. 2009). According to Binford (1978) three main areas of bone distribution around a hearth are identifiable: a drop zone, a seating area and a toss zone. More recently these basic categories have been widened to incorporate cooking, production, curation, walking or sleeping areas and multiple hearths, increasing the evidence for functional patterning of intra-site spatial use in the Palaeolithic (see also Henry, 2012).

According to plant-animal subsistence ratios among worldwide modern hunter-gatherers (Cordain et al., 2000), diets include more than 50% animal-based foods (more in cold and high-latitude settings such as Oldest Dryas northern Spain) and therefore the exploitation of faunal remains is

presumably a frequent activity. Although plant foods can play a role in the diet, under glacial conditions the basis of subsistence was mainly fat and meat. A broad spectrum of activities based on animal remains and their subsequent spatial distribution can be used to define activity zones such as roasting, meat-, marrow- and grease-processing or discard (Henry, 2012). Distinct accumulating agents (humans versus raptors and terrestrial carnivores), anthropogenic modifications and preservation conditions can all be identified with the help of zooarchaeological investigations (Lyman, 1994; Reitz and Wing, 2008; Straus, 1982; Villa et al., 2004).

Stratigraphically distinguishing between single occupational events and activities is difficult or impossible. It is generally assumed that anthropogenic layers, such as archaeological levels within thick cave deposits, consist of recurring occupations and activities, commonly known as palimpsests, that are conditioned by the physical features of each cave such as walls, entrance and terrace, blocks, ceiling height, sunlit vs. dark areas (Bailey, 2007; Henry, 2012; Schiffer, 1996; Straus, 2008, 1979). The term palimpsest refers to the superimposition of successive activities or traces of multiple, overlapping activities revealing time-averaged assemblages (Henry, 2012). In the absence of evident structures which segregate space in a tangible way, zooarchaeological studies may provide insights into spatial organisation and site formation processes such as "invisible hearths" features (Goren-Inbar and Alperson-Afil, 2010; O'Connell et al., 1991). Particularly, good bone preservation can indicate little post-depositional disturbance from natural agencies and make it possible to investigate the evidence of living floors.

The identification of Palaeolithic living floors relies on the notion that small refuse items are prone to remain in place to a greater extent than large ones. Small bone fractions (generally < 2–3 cm) suffer less transportation and are therefore suitable markers of activity zones or living floors

(Malinsky-Buller et al., 2011). Additionally they can represent primary refuse as they are less likely to be displaced during surface cleaning (Schiffer, 1996). Therefore small refuse items such as manufacturing debris of antler, bone or stone found in association with finished tools can be helpful in identifying activity zones.

This paper asserts that reconstructions of activity zones within campsites for diachronic behaviour studies are more precise and complete when they incorporate small bone fractions as indicators of primary refuse areas. Density analyses are used to create plots of spatial distributions to investigate dense archaeological layers and enable the interpretation of activity zones.

The Lower Cantabrian Magdalenian (LCM) occupations found throughout the northern Atlantic region of Spain provide examples of such dense archaeological layers. This cultural period, spanning 16–14.5kya, is characterised by a specific suite of material culture remains. Stone tools include bladelet cores and nucleiform endscrapers as well as a variety of backed elements (especially bladelets, but also geometric microliths). Due to the favourable preservation conditions in Northern Spain, organic remains are commonly found, including antler sagaies with varied (but especially quadrangular) cross-sections and bases (mainly single-bevel), needles, perforated shells, and regionally and temporally diagnostic red deer scapulae with red deer hind engraved images whose outlines are filled with striations (González-Morales et al., 2006; Straus and González-Morales, 2012a). Many LCM levels have one overarching aspect in common, which is the extraordinary density of occupation layers, very rich in organic materials, hearth remnants, artefacts, etc., as found at Altamira, El Castillo, El Juyo, Rascaño, Santimamiñe and El Mirón cave (Outer Vestibule levels 15, 16 and 17, Mid-Vestibule Level 312, Inner Vestibule levels 109–116, and Vestibule Rear levels 504–505) (González Echegaray and Freeman, 1992; González-Morales and Straus, 2014; Straus, 1992). These extraordinarily

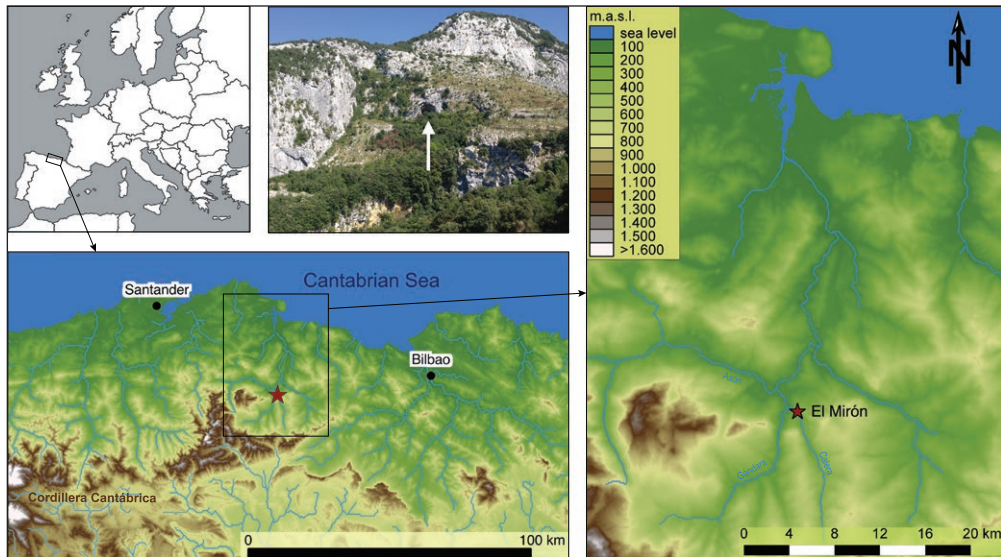
thick, dense artefact, manuport and bone accumulations make it difficult to differentiate individual living floors during excavation, and therefore they are usually treated as units and referred to as a palimpsest. General changes in duration and/or frequency of site occupations following the Last Glacial Maximum (LGM) are indicated by these distinctive, thick LCM archaeological deposits. It is assumed that the history of occupation of these sites reveals varied aspects of Upper Palaeolithic lifeways, while their dense, detailed record provides considerable, albeit difficult to untangle and decipher, evidence of specific activities.

This paper seeks to propose intrasite spatial analyses for the purpose of identifying LCM hunter-gatherer activities in El Mirón cave based on faunal remains. Combined analytical studies of zooarchaeological methods and spatial distribution analysis using Geographical Information Systems (GIS) enabled the first author to achieve these goals. Zooarchaeological and taphonomic studies inferred the existence of very good preservation conditions. The identification of activity zones such as hearth, bone processing areas and dumping zones were condensed into systematic plots. The spatial relationship of animal remains inside the rich LCM layer reveals some aspects of Palaeolithic behaviour, reconstructed using the distributions of zooarchaeological data.

## **Material and Methods**

### ***Lower Cantabrian Magdalenian Deposits In El Mirón Cave***

El Mirón is a west-facing cave located in the upper Rio Asón valley on the northern edge of the Cantabrian Cordillera, some 20 km upstream from the modern Atlantic shoreline, surrounded by 1000-meter high mountains and dominating the confluence of two tributaries with the Asón (**Fig. 1**). The cave has been excavated since 1996 under the direction of L.G. Straus and M.R. González-Morales. The site is well dated with 84 radiocarbon dates ranging from the late Middle Palaeolithic to the early Bronze Age (Straus



**Figure 1:** The site of El Mirón is located at the northwest slope of Monte Pando (Ramales de la Victoria) in Cantabria, Northern Spain; at the confluence of the rivers Caldera, Gandára and Asón surrounded by 1000m high mountains in the first main chain of the Cantabrian Cordillera.

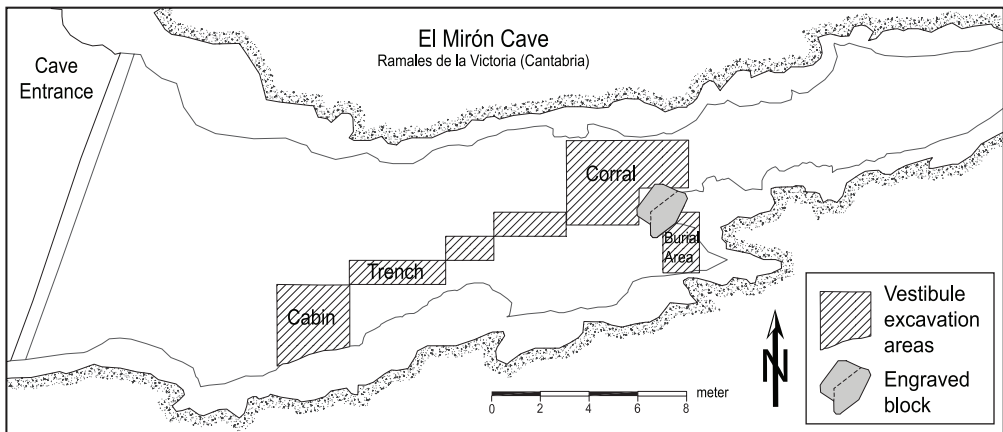
and González-Morales, 2012b, 2010, 2007a; Straus and González-Morales, 2003).

Two main excavation areas are located in the outer and rear sectors of the cave vestibule (Cabin and Corral areas respectively), which are connected by a  $9 \times 1$ -meter Mid-Vestibule Trench (**Fig. 2**). Between 2001 and 2013 additional Lower Magdalenian layers were excavated in the smaller “Burial Area” behind a large engraved block, where a primary human burial covered by sediments with specular hematite crystals and abundant red ochre was uncovered (Geiling and Marín-Arroyo, 2015; Straus et al., 2011; Straus and González-Morales, 2015). For this case study, only Levels 15 and 16 were chosen, which correspond to the uppermost part of the 80 cm-thick LCM deposit in the  $9\text{--}10\text{ m}^2$  Cabin area of El Mirón cave (Straus and González-Morales, 2007b). The Magdalenian sequence in the Cabin area is dated on the overlying Middle Magdalenian level 14:  $14.600 \pm 190$  (GX-32383), the LCM level 15:  $15.010 \pm 260$  (GX-23392);  $15.220 \pm 300$  (GX-23393) and level 16:  $15.180 \pm 100$  (GX-23415) and the upper part of the underlying LCM

level 17:  $15.470 \pm 240$  (GX-24466) and  $15.700 \pm 190$  (GX-25853) radiocarbon years before present (Straus and González-Morales, 2012a). The zooarchaeological material from these layers shows the continuous hunting of both *Cervus elaphus* and *Capra pyrenaica*.

### Field Methods

During excavation at El Mirón cave, standard methods of Palaeolithic excavations were applied. These methods include: three-dimensional individual recording of lithics larger than 1 cm, bones longer than 5 cm, as well as of smaller, but field-identifiable specimens (e.g., teeth, phalanges) with a total station theodolite. The excavations were conducted in subsquares ( $50 \times 50$  cm) by spits (app. 1–3 cm thick), the sediments were then water-screened through fine mesh to collect the smaller finds or “non-identifiable” bones in so called “General Bags” (GB). Spits are arbitrary subdivisions of natural levels. Nine depth measurements were taken for top and bottom heights of each spit’s meter square centre, edge center and corner. Based on these, upper (Level 15), middle (Level 16.1)



**Figure 2:** The two main excavation areas, Cabin and Corral, are connected with a trench and, behind the engraved block, a human burial was excavated. The material from this study originates from the Cabin area. Lower Cantabrian Magdalenian deposits were found in all other excavation areas (plan modified, original outlines made by GIM GEOMATICS company).

and lower samples (Level 16.2) were articulated (L.M. Fontes *pers. comm.*).

### Laboratory Methods

This study will focus on individually plotted macromammal finds and remains from the GBs. Faunal elements were classified taxonomically and anatomically. GB items were included to increase the usable taxonomic, anatomic and taphonomic information. All identified faunal remains were used to calculate the Minimum Number of Individuals (MNI). GB find categories were bone or teeth fragments smaller than 5 cm, burnt bones, bone flakes, young spongy bones or digested bones. The final numbers of teeth and bones specimen vary widely between individual and GB data per square (see Table in **Fig. 3**).

The taxonomically and anatomically identified GB items were assigned to subsquares and do not have coordinates. In order to make them available for distribution analysis a program tool was used to plot identified GB finds; GB items received coordinates based on an excel-function (Gilead, 2002). The following function was used:  $RANDBETWEEN(0;50)/100$  to give random numbers according to the two-dimensional subsquare extensions between 0 and 0,50m

in each direction, for X and Y coordinates respectively. Gathered identified GB data creates more reference points for distribution analysis and also increases the density of point clouds. The higher concentrated single data points inside a defined unit are, the less informative simple scatter plots become (Oron and Goren-Inbar, 2014).

Heatmaps were created to represent artefact densities. Heatmaps show areas of high and low point density visually distinguished by colour coding. For individual data sets counts the procedure points features (representing artefacts) inside a specified area; this study used analytical radiuses of 0,2m around each point. The outcome of a kernel density analysis is a surface of raster cells, illustrating the sum of overlapping radiuses around each point. Here, a small cell size of 0,01m was chosen to create smooth density maps. The highest values within the plots correspond to 1 and the lowest values correspond to 0, represented by colour codes, red to blue respectively (Baxter et al., 1997; Silverman, 1986).

Areas with different densities can be summarized in clusters (Baxter et al., 1997; Silverman, 1986; Whallon, 1984). To identify clusters during analysis two threshold values

Square	Individual data			General Bag data						TOTAL
	Bones	Teeth	SUM	Bones	Teeth	BB	F	YOU	SUM	
H1	20	6	26	187	14	6	0	3	210	236
H2	216	54	270	4.461	686	60	35	23	5.265	5.535
H3	432	104	536	5.512	665	44	67	46	6.334	6.870
H4	383	112	495	5.149	374	99	89	59	5.770	6.265
I2	76	28	104	1.618	168	56	40	17	1.899	2.003
I3	107	61	168	3.237	493	110	96	38	3.974	4.142
I4	179	46	225	8.687	558	372	60	50	9.727	9.952
J2	130	24	154	1.074	68	95	76	17	1.330	1.484
J3	364	66	430	5.265	205	337	148	27	5.982	6.412
J4	93	13	106	8.874	284	872	42	24	10.096	10.202
<b>Total</b>	<b>2.000</b>	<b>514</b>	<b>2.514</b>	<b>44.064</b>	<b>3.515</b>	<b>2.051</b>	<b>653</b>	<b>304</b>	<b>50.587</b>	<b>53.101</b>

**Figure 3:** Table. Overview of the counts from the individual finds (>5cm) and GB data (<5 cm) by squares for Level 15 and 16. BB = burnt bones, F = bone flakes and YOU = porous bones from very young animals (red represents the highest numbers, blue the lowest).

were defined: one 50 % boundary to delimitate low from high densities, plus an additional 95% boundary to identify hot spots with high concentrations. These clusters are considered to be a sample from the gathered raw data and provide useful insights in distribution patterns (Blankholm, 1991; Whallon, 1984).

The smaller faunal remains (less than 2–5 cm) found within GB are generally not identified in terms of taxonomic classification and were instead counted per subsquare. GBs also contained teeth enamel fragments or small bone fractions. Other categories follow specific types of anthropological modifications like burnt bones for hearth activities or bone flakes originating from percussion through intentional bone cavity opening related to actions for bone marrow and grease extraction (Costamagno et al., 2013; Manne et al., 2006; Outram, 1998). The small fraction categories are of particular interest in identifying Palaeolithic activity zones, and heatmaps were created for each sublevel by subsquare. The colour code used for the subsquares ranges also from blue to red, from low to high density respectively.

Density and cluster analysis are methods used to simplify high concentrated data points (Blankholm, 1991; Hodder and Orton, 1976), but also to find patterns and allow comparisons between levels. The term density used here refers to “relative density” by comparing quantities of objects per unit area or surface measured in square meters. Consequently density is a relative term, while it refers to the overall data found within a given unit.

## Results

The taxonomical identification of animal remains from level 15 and 16 revealed that most of the identified taxa (NISP = 1.854) could be attributed to *Cervus elaphus* (MNI = 2; NISP = 680; 36,7%) and *Capra pyrenaica* (MNI = 10; NISP = 1.100; 59,3%). The succeeding spatial distribution analysis of individual items will concentrate on these two species, while taphonomic studies revealed an anthropogenic character of accumulation (Geiling, 2014). The majority of the GB content was identified as small bone and teeth fragments (n = 50.658). Burnt bones (n = 2.051) were also represented. Additional

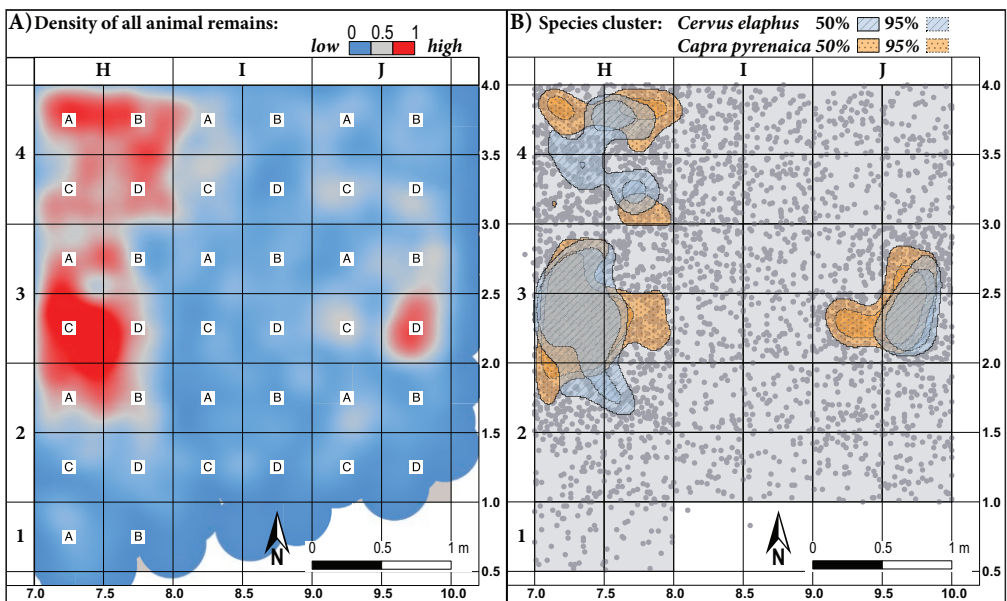
categories are bone flakes (n = 653) indicating intentional bone processing activities (possibly marrow and grease extraction), and porous bones from young individuals (n = 304), which indicate the favourable preservation conditions of these archaeological layers.

The general spatial distribution of all individual faunal remains shows dense archaeological accumulations in two areas: one across squares H2, H3 and H4 and another one in square J3 (Fig. 4-A). The spatial distribution of the two main game species (Fig. 4-B), *Cervus elaphus* and *Capra pyrenaica*, show similar concentration across the Cabin area. The close clusters of 50%- and 95%-density borders indicate a rapid increase in point intensities in the same areas of higher general densities. The spatial cluster of high-density areas for each species overlap by more than 50%. The similarity in find provenance indicates that there is no species-specific area for processing or

dumping faunal material; in other words, the bones of both species were processed and discarded in the same areas across the site.

McKellar's Principle, which states that small refuse items are commonly discarded in the same area in which they were produced, rather than disposed of somewhere else, was used to analyse the GB data. By this principle larger items are more prone to transport, while small *in situ* refuse, tends to penetrate into the sediment through trampling (McKellar, 1983; Schiffer, 1983). This allows archaeologists to reconstruct living floors.

Burnt bones (<2 cm) are smaller than unburned residues (Costamagno et al., 2006; Stiner et al., 1995) and generally remain in place; burnt bones may help to localize hearths, especially if structural elements missing (Alperson-Afil et al., 2009; Goren-Inbar and Alperson-Afil, 2010). The spatial distribution of burnt bones from GBs is used to identify hearths in the LCM levels. Burnt



**Figure 4:** The spatial distribution pattern of faunal remains shows: A) generally high densities corresponding to hotspots in meter- squares H3, H4 and J3; B) that the spatial distribution clusters of high densities of the two main game species, *Cervus elaphus* and *Capra pyrenaica*, largely overlap and indicate similar processing or discarding activities (Grey points mark individual faunal finds).

bones found at El Mirón LCM layers corresponds to the “Color Code 3” (Stiner et al., 1995, p. 226), which mean they are fully carbonized. Burnt bone concentrations within the three sublevels analysed here cluster differently, while showing some degree of spatial overlap. High concentrations of burned bones are found in the lower sublevel 16.2 in subsquares J4-D, J3-B,D; in the middle sublevel 16.1 in subsquare I4-B and subsquares J4-B,C,D; and finally in the upper sublevel 15 in I4-B,C and J4-D (Fig. 5).

The spatial distribution of individually plotted larger bones with impact marks and small bone chips from GB show different concentration (marked in red; Fig. 6) indicating varied density areas. In the lower sublevel, 16.2 bones with impact marks concentrate in subsquare J3-D, while more loosely dispersed throughout the remaining excavated squares. In sublevel 16.1, bones with impact cluster within squares J3 and H4 as well as subsquare H3-C. In sublevel 15, bones with impacts marks were found in

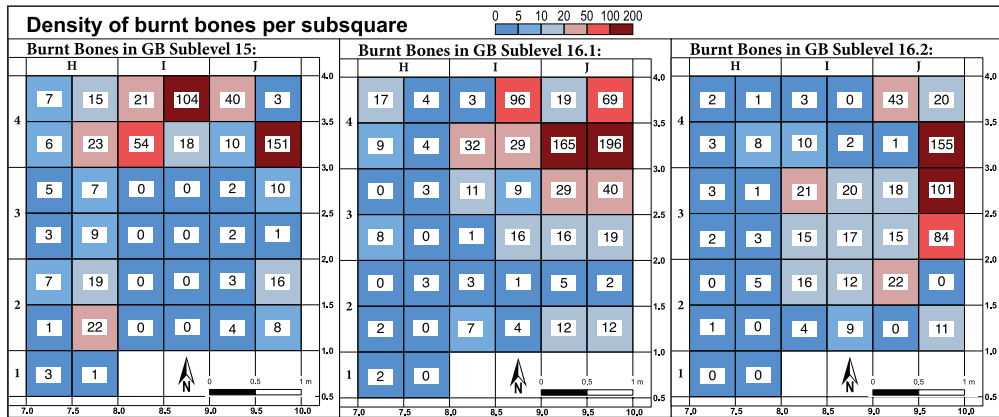


Figure 5: The small refuse burnt bone distribution varies between sublevels 15, 16.1 and 16.2. Amounts of burnt bone remains constant in the northeastern edge of the excavation areas (square J4), which may be associated with a hearth.

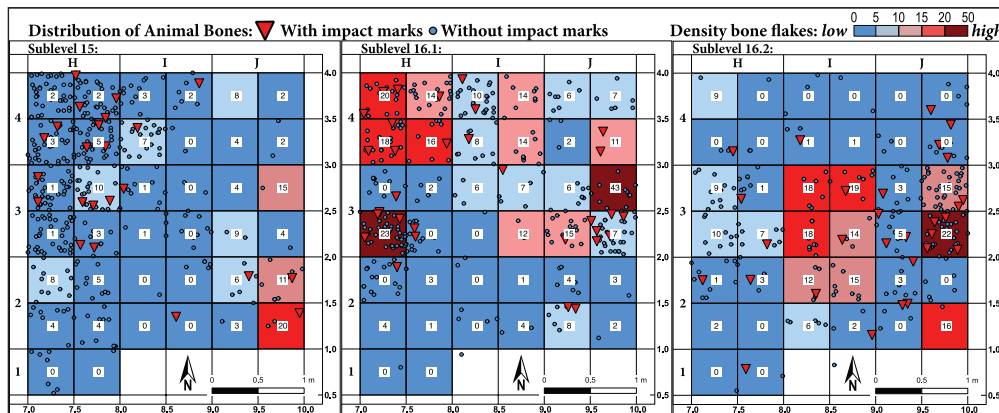


Figure 6: The two components, impact marks on bones and bone flakes or chips, are combined to achieve the distribution of bone working areas contributing to marrow extracting or grease rendering activities. Individual faunal remains with impact marks are plotted individually. Based on the counts of bone flakes the subsquares were colour coded according to low and high densities, from blue to red respectively.



squares H3 and H4 as well as in the south-eastern edge of the excavation area (square J2). Bone flakes and chips from GB show a different spatial patterning. In Sublevel 16.2, these find categories clustered within subsquares J3-D, J2-D and square I3. The superimposed sublevel 16.1 shows high amounts of bone chips in subsquares J3-B, H4-A, -C, -D and H3-C, while within sublevel 15 chips concentrate in subsquare J2-D. Within the sublevels analysed here the bone flakes concentrations and bones with impact-marks coincide in some areas. In sublevels 16.2 and 16.1 these categories overlap in square J3; within sublevel 16.1, additional overlap was identified in squares H3 and H4. In sublevel 15, no overlap was detected.

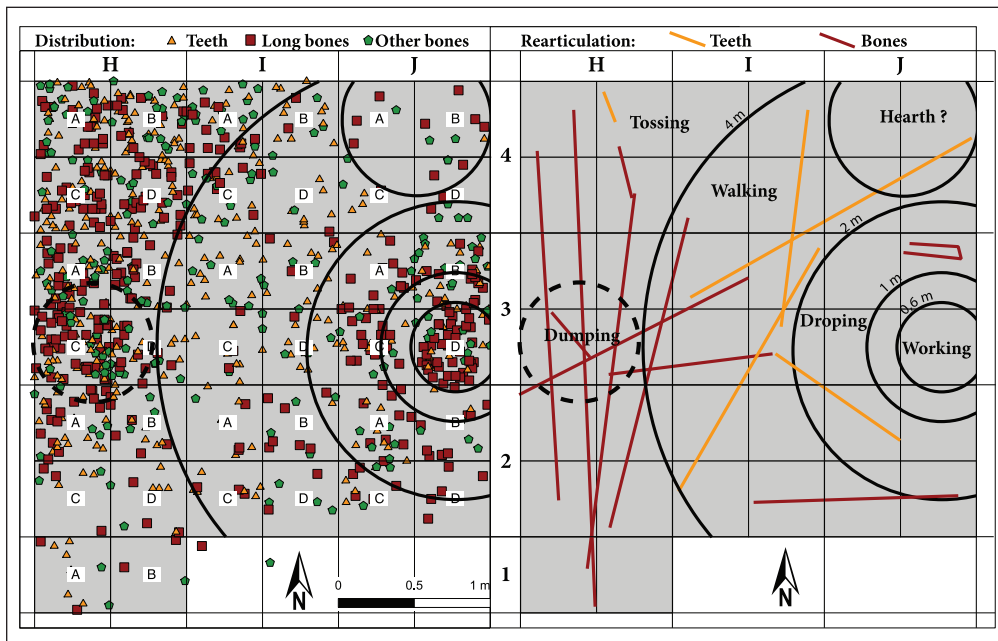
## Discussion

The zooarchaeological and taphonomic studies of dense bone accumulations within El Mirón cave revealed excellent conservation conditions. Particularly, good bone preservation indicates little post-depositional disturbance. The existence of young animal remains (very porous, spongy, tiny bones) demonstrate quite limited non-cultural formation processes. During excavations no significant sediment movement, pressure or wash-outs were observed, phenomena which would have suggested a disturbance of original archaeological layers (González-Morales and Straus, 1996–2011; Straus and González-Morales, 2012b). These results demonstrate the existence of an intact archaeological stratigraphy and LCM strata in El Mirón that are very suitable for investigating the spatial distribution pattern of finds, from which evidence of activity areas can be inferred. Additionally, cultural formation processes can be used to enhance interpretations of human behaviour. Due to the problems archaeologists face when attempting analysis of very thick cave deposits (the palimpsest problem), spatial distribution analysis can simplify the data, enabling one to recognize spatial patterns among archaeological find categories that are not visible with the naked eye. Consequently, in the following sections

we will discuss our first insights into the activity areas of two LCM layers in El Mirón cave, based on spatial distribution analysis of faunal remains.

This paper analysed general point patterns using kernel density and created heat-maps to show clustering of individual finds. The faunal distributions in levels 15 and 16 inside the Cabin area are not homogeneous (**Fig. 4**), according to 'first-order' characteristics (Bevan et al., 2013). The excavation area represents a spatial heterogeneity, because the southern excavation border is the cave wall. Due to accumulation principles, items do cluster along vertical borders (Harris 1989). This might be the reason for accumulation clusters along the southern squares, but does not explain varied point intensities in other areas. Low point intensities next to hot spots are visible along the western and eastern excavation borders. They were presumably created due to 'edge effects' of point distribution while using kernel density analysis (Orton, 2004). In any event, these patterns do not affect the question addressed here concerning general bone distribution by ungulate species. Our results explored whether the two most hunted animal species, red deer and ibex, overlapped in their spatial distribution patterns (**Fig. 4**). Their almost complete coincidence implies that both species (with similar anatomies but moderately different average sizes) were butchered, exploited and discarded in the same way and therefore suggests a uniformity of accumulation processes. We have shown that non-cultural formation/destruction processes were very limited relative to cultural ones, leading to confidence in the following discussion about activity areas within Levels 15 and 16 of the El Mirón Outer Vestibule excavation area, with the obvious caveat that this 9.25 m<sup>2</sup> area represents a very small portion of the whole ca. 300 m<sup>2</sup> habitable surface of the vestibule.

Activity zones can be distinguished within the sublevels of the LCM palimpsest horizon in El Mirón cave (**Fig. 7**), in particular hearth, working and dumping areas can be seen.



**Figure 7:** There exists a spatial sorting of the bone types: long bones fragments cluster in two areas as opposed to smaller bones (short or irregular) and teeth. The spatial interpretation of activity zones inside the LCM camp in El Mirón cave refers to bone working, dropping, walking, tossing and dumping zones. A hearth was presumably located around square J4. A bone processing area around square J3 appears to have played a central role in the organization of reconstructed activities.

The spatial data of the faunal remains permits archaeologists to identify activity areas, comparable to ethnographic examples of disposal modes in bone assemblages (Bartram et al., 1991; Binford, 1978).

The distribution of small burnt bones concentrates around square J4. The spatial patterning of burned remains may indicate the location of a hearth in the northeast of the excavation area. In addition to the burnt material, ashy dark, organic rich sediments were excavated in this square of the site (González-Morales, Straus and Student Excavators unpub Field notes). The bones were possibly used to fuel the fires at the site. Spongy, cancellous bones are better fuel, while dense long bone shaft fragments are unsuitable as fuel, given that they do not burn reliably (Bosch et al., 2012; Costamagno et al., 2006; Morin, 2010; Théry-Pariset, 2002; Théry-Pariset et al., 2005; Villa et al.,

2004). Whether the burnt bone fragments at El Mirón Level 15 and 16 were simply disposed of into the fires or served as a secondary fuel source (wood was relatively scarce during Oldest Dryas in this region) remains open for discussion.

Intentional bone cracking activity areas have been identified in square J3, in both sublevels 16.2 and 16.1. Bones were deliberately fragmented, probably in the course of marrow extraction and preparation for grease rendering activities (Janzen et al., 2014). Three criteria are necessary for the identification of bone grease rendering at prehistoric sites: stone anvils to break bones prior to cooking, fire-cracked rocks indicative of stone boiling and highly fragmented spongy bones (Binford, 1978; Stiner, 2003). Stone-boiling technology has been found in the El Mirón LCM deposits, which indicates cooking activities in the same area and time

period (Nakazawa et al., 2009). Despite the fact that the quartzic sandstone cobbles were probably used as percussion stone or anvils before being heated, no other specific stone anvils for the purpose of bone cracking were identified (Straus and González-Morales, 2007b; Straus and González-Morales, 2012a). A drop zone (around 1m in radius), located on the peripheries of the working zone in square J3 was determined, based on larger bone leftovers with impact marks. The working area was possibly a central locus of bone processing activity close to the fireplace and the dropping zone.

Along the surroundings of the bone-processing zone, within a two meter radius, the high density of long bone items decreases and mostly teeth and other bone types such as short or irregular bones are represented. The area may be interpreted as a walking corridor as it contains fewer long bone fragments (squares I2, I3 and I4). Further away (at more than a 2 m radius) from the working zone, a dense accumulation of faunal material with anthropogenic modifications is interpreted as a toss zone (squares H2, H3 and H4).

In subsquare H3-A across sublevel 16.1 another small cluster of small bone refuse fragments, burnt bones and bones with impact marks was found. Given the overall thickness (1–2 cm; one spit) and dense accumulation, this area could be interpreted as a dumping zone (O'Connell et al., 1991; Schiffer, 1996). Ethnographical comparisons have shown that hearths and adjacent areas were cleaned only when primary refuse densities reached unpleasant levels. After removing the larger pieces, only the smaller fragments remain in place (Schiffer, 1996). Cleaning processes might be necessary during long or frequent occupations, as is implied for the LCM El Mirón residential hub campsite.

The distribution of activities zones within the LCM layers of El Mirón is supported by refittings of the faunal material. The number of bone refits increase within the toss or drop zones, while teeth are commonly

rearticulated within the walking zone. Additionally, narrowing down excavation spits to check for bone refits might help the identification of activity areas within such thick archaeological cave deposits. We are aware that present bone refits are the only way with which to prove the existence of living floors in LCM layers of El Mirón, since the associated lithic artefact assemblages have not yet been studied from this perspective.

The occupations in Level 15 and 16 in El Mirón cave represent the uppermost layers and therefore the end of the LCM occupation in the excavated Cabin area. The identification of specific activities and aspects of campsite organisation reveals insights into the behaviour of LCM hunter-gatherers. The LCM cultural period initiated quickly changing technologies, settlement patterns, subsistence strategies, and artistic activities (Straus 1992). Whether the El Mirón accumulations are the results of one long or (more likely) several relatively short, but repeated, occupations remains an open question but they represent a change in resource usage in the cave relative to the Solutrean levels therein. While red deer and ibex meat were definitely common components of the LCM diet (see also Marín-Arroyo and Geiling, 2015), additional regular extractions of bone marrow and grease imply a more intensive exploitation of these animals. The reconstructed activities also indicate a continuous/repeated use of these working areas, while spaces were maintained/reused. Examples include the bone working zone overlapping with cobbles presumably used several times to open bone marrow cavities, and the evidence for dumping events indicating cleaning procedures on site and hence some degree of longevity and/or repetition of use of this space. The thickest and densest LCM layer is the underlying Level 17, which is currently being studied by the first author (fauna) and by L.M. Fontes (lithic artefacts). The abrupt end of these occupations after Level 15 might reflect the abandonment of the cave by LCM hunter-gatherer groups. In contrast, despite higher sedimentation rates,

the overlying stratigraphic layer (Level 14) in the El Mirón Outer Vestibule representing Middle Magdalenian occupations, displays very low archaeological and faunal densities compared to those described here (Marín-Arroyo, 2010; Straus and González Morales 2012a).

### Conclusions

The use of GIS analysis on faunal remains in Palaeolithic occupation horizons can yield positive results when dealing with large amounts of quantifiable data. The creation of plots is the first step, while additional statistical analysis can be added. Density cluster and heatmaps not only enhance archaeological interpretation, but also produce results that can be compared across archaeological and ethnographical sites. This useful tool is of particular interest in analysing dense occupational layers such as the LCM deposits in the Cantabrian region. In sum, through the additional inclusion of GB data, it was possible to reconstruct activities in the LCM levels 15 and 16 in El Mirón cave. This case study has shown that a range of spatial data can be synthesized by combining different faunal categories from Individual and GB data. These interpretations of intense LCM occupations are made possible by spatial distribution plots showing different anthropogenic activities.

Activity areas identified at El Mirón are a grease-rendering working zone for bone processing, a drop zone, a walking zone, hearths, a dumping area and a toss zone. The bone-processing zone had a central role in the spatial organization of this area of the site. This specific activity produces a large quantity of bone debris, which in turn is visible in the high-density LCM layers found across Northern Spain and makes it archaeologically tangible. Whether these thick deposits represent specific cultural activities of the LCM remains to be seen and will be the subject of future research.

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### Competing Interests

The authors declare that they have no competing interests.

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