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# The Mark of the Beast: a bone assemblage assessment from the North of the Iberian Peninsula (MIS 3)

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ABSTRACT

The cave of Abauntz (Navarra, Spain) has had a consistent record of human presence since 50,000 years ago. In this paper, we present the results of the taphonomy and taxonomy analyses made on an assemblage composed of over 3,000 bones found in the unit h of the cave of Abauntz, the earliest level in the cave's stratigraphy with human presence and dated in the MIS 3. Taxonomy assessment described 14 mammal taxa, identified 2,426 remains, and quantified 33 individuals, showing a greater abundance of cave bears (*Ursus spelaeus*) over any other taxa. The Taphonomic study assessed the skeletal survival ratio, the assemblage spatial distribution, the skeletal elements' breakage pattern, and the toothmarks on the remains. Altogether, the combined results of the analyses allowed inferring that carnivores were the main accumulator agents over human activity. An occupation pattern of the cave is proposed here, with *Ursus spelaeus* using the cavity during winter as a shelter for hibernation. In contrast, carnivores used it in other seasons mainly for feeding. At some point during MIS 3, neanderthals used it briefly, leaving behind a lithic tools' assemblage. The results were compared to the faunal assemblages described in younger levels inside the cave, showing a severe decrease in the carnivore's variety and abundance.

## 1. 1. Introduction

Abauntz is a cave located in the northwest of the Ebro's Basin, in a strategic position, becoming a linking point between the Ebro valley and the Cantabrian Coast and the transpirenean lands (Fig. 1). The excavation campaigns and fieldwork took place inside the cave in two stages, from 1976 to 1979 under Pilar Utrilla's direction and then with Carlos Mazo as co-director (in 1988, 1991 and from 1994 to 1996) (Utrilla et al., 2015). Altogether, these campaigns have assessed one of the most completed archaeological and palaeontological sequences in the Ebro's Basin. Besides the human presence, there are relevant and biodiverse faunal assemblages in the different levels or units (as we use this term for archaeo-stratigraphic layer in the present work) of Abauntz: after the first assessment that compiled all faunal remains discovered until 1979 (Mariezkurrena and Altuna, 1982) other studies succeeded in comprising the postpaleolithic (Blasco, 1995–1996) and paleolithic levels (Altuna and Mariezkurrena, 1996; Altuna et al., 2001–2002; Mazo et al., 2012).

During the 1994 excavation campaign, the unit h was discovered

(Mazo and Utrilla, 1996), the earliest archaeological level found so far, dated around MIS 3 (Mazo et al., 2012). In it were found more than 3,000 fossils of faunal bone remains along a lithic assemblage composed of 42 tools (Mazo et al., 2012). Mazo et al. published in 2012 an exhaustive study about the unit h focusing on the archaeological features. This first assessment of the faunal bone assemblage pointed out its main traits: the remarkable abundance of cave bear (*Ursus spelaeus*) remains and the notorious toothmarks on some bones, disregarding the species. The scope of this paper is to present the results of the exhaustive analyses made on the whole faunal assemblage found in the unit h of Abauntz, focusing on the palaeontological aspects regarding the taphonomy and osteology of the identified taxa, the possible relation to the lithic tools assemblage and, therefore the origins of the faunal bone assemblage accumulation.

### 1.1. Location and geology of Abauntz

Abauntz is in the North of the Iberian Peninsula, at the Northwest of the Ebro basin. Abauntz is close to the Belate Pass, a link between the

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Ebro basin, the Cantabrian coast, and the plains of Southwestern France. Its entrance, at 650 m a.s.l., opens on the side of Mount Arizerte, in front of Mount San Gregorio, and the Zaldazaín stream flows 30 m below (Fig. 1). Its UTM coordinates are 43.013983, −1.641383. Its geographic location in a natural pass combines with the access to the environments of the mountains and the valley and, therefore, to its resources (Mazo et al., 2012).

The geology of Abauntz is composed of Early Cretaceous reef limestones affected by the karstic process, the activity of the Zaldazain stream and two diaclastic systems. The first system develops Southeast to Northwest orientation, creating the main chamber (56 m length) of the cavity, whilst the second system runs perpendicular to it and creates two galleries; one of them is the access to the cave, and the other is at the bottom, and it is uncharted. These processes created the characteristic shape of the cave (Fig. 2) and can be observed in well-differentiated areas. The entrance is short, with a low ceiling and an abrupt slope down to the Hall 1, possibly helping the flooding of the cave at some points in its past. The Hall 1 is at a lower altitude than the entrance, and while it is broader than the previous access, its main development is vertical. Beyond the Hall 1, the cavity turns 90 degrees to the Southeast and throughout a transitional corridor access to the Hall 2. This is the largest area of the cave, and its floor slopes down to the interior, reaching its lowest level between the bands 35 and 37. Beyond this point, the floor level rises deep to the cave's interior while the ceiling descends, creating a corridor to access the last Hall. Beyond the last Hall, rocks fallen from the walls and the ceiling of the cave block any access. Because of its curious shape, it is possible that daylight only reached the Hall 1.

### 1.2. Stratigraphy of Abauntz and dating of the unit h

The stratigraphy regarding the archaeological record comprises the following, level a (Late Roman Empire), levels b1 and b2 (Calcolithic), level b4 (Neolithic), level d (Azilian), level 2r (Upper Magdalenian), level e (Middle Magdalenian), level f (Solutrean) and unit h (Mousterian) (Utrilla et al., 2015). Fieldwork assessed recent alterations in its strata and some old anthropic interventions, such as pits during the Roman Age, the Chalcolithic burials, and some with faunal origins, like the unit h. To these changes, the action of the water must be added, either by flooding or leaking from the ceiling of the cave. As it was

previously mentioned, fieldwork took place in two stages, from 1976 to 1979 under Dr Utrilla's direction and, in 1988, 1991 and from 1993 to 1996, with Dr Mazo as co-director. The first stage focused on the Hall 1 (Utrilla, 1982), while the second advanced to the inner areas (Utrilla et al., 2014). Altogether, they established the stratigraphy of Abauntz (Table 1), assessing an intense and varied purpose of human activity in most of the levels dated (Utrilla et al., 2015). During the 1994 excavation campaign, because of a sondage made in the band 35 2 m below the level f (Solutrean), a new level with archaeological relevance was found, the unit h (Mazo and Utrilla, 1996). Some other levels were described in the sondage, but no archaeological/palaeontological features were in them. The unit h development ended in band 35, so the ulterior fieldwork campaigns, until 1996, advanced towards the entrance of the Hall 2, reaching bands 23 and 25. It must be pointed out that the unit h was not fully excavated in all the cave extension, from bands 25 to 35 and D to F comprising around 8 m$^2$, but lithic tools and substantially numerous faunal remains were discovered (Mazo et al., 2012). The unit h was described as well-defined and isolated from upper and lower levels. In its upper boundary, the soil composition of the unit h is defined by medium to large limestones with fine, brown coarse sandy clay. The limestones probably came from the ceiling and walls of the cave. In its base, the unit h lays on a new level of grey silt lacking any stones or archaeology/palaeontology, the level i. Between bands 29 and 31, the unit h reaches 50 cm of depth. In band 25 were found some gravel pockets, well defined and limited, with uncertain origins, possibly related to water flooding, but which added more complexity to the unit h (Mazo et al., 2012). Because of that complexity, we use the term 'unit' instead of 'level'. This complexity suggested an extended period of sedimentary formation in which variations in its composition obeyed the different conditions that affected the process. In that sense, what gives the stratigraphic unity criteria to the unit h are the faunal remains.

The lithic assemblage was scarce in number, but the presence of eleven cleavers and two handaxes stood out, and, because of it and the typology of the tools, the assemblage was described as Mousterian of Acheulian Tradition (MTA) (Mazo et al., 2012). Mazo et al., 2012, described those finds and used them to re-assess the question regarding the possible existence of the Vasconian facies in the Mousterian industry. Regarding the raw material, only 13 tools were made on flint, the most advanced typologically, like two scrapers and a cordate handaxe. The spatial distribution of the flint tools showed more abundance of the



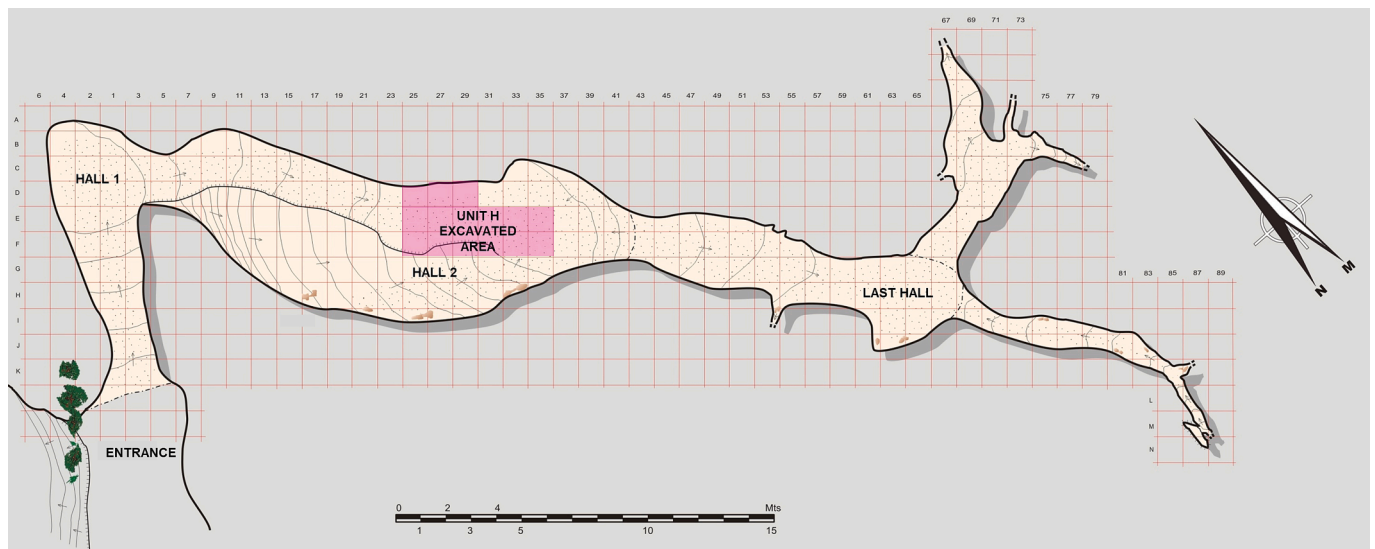**Fig. 1.** Location of the cave of Abauntz (Navarra, Spain).

**Fig. 2.** Planimetry of Abauntz (Navarra, Spain). Highlighted in pink the area excavated affecting to the unit h. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

**Table 1**
Archaeological levels of Abauntz dated, by culture and chronology according to the dating methodology applied.

| Level/ Unit | Culture/Period | Dating | Method |
|---|---|---|---|
| A | Late Roman Empire | 408 d.C. | |
| b1 | Calcolithic | 3.900 ± 35 (GrA-37323; 4.341 ± 57 cal BP)- 4.370 ± 70 (CSIC 785; 5.012 ± 124 cal BP) | AMS |
| b4 | Neolithic | 5.390 ± 120 (I-11309; 6.158 ± 129 cal BP) | AMS |
| D | Azilian | 9.530 ± 300 (Ly-1964; 10.858 ± 405 cal BP) | AMS |
| e1/2r | Upper Magdalenian | 11.760 ± 90 (OxA-5116; 13.643 ± 151 cal BP) | AMS |
| E | Middle Magdalenian | 13.500 ± 160 (OxA-5983; 16.413 ± 423 cal BP) | AMS |
| F | Solutrean | 21.600 ± 200 (GrN-21011; 25.809 ± 524 cal BP) | AMS |
| H | Mousterian | >45.000 (GrA-16960) 27.460 ± 4.000 47.000 ± 7.000 | AMS ESR AAR |

Carbon dating calibrated by CalPal online v.1.5. Only the earliest dates obtained for every level are showed, but in level b1 (Calcolithic) where are the earliest and latest obtained. Modified from Utrilla et al. (2015).

retouched ones at the bottom of the cavity, but given their scarcity quantity, any further assumption was inconclusive (Mazo et al., 2012). The cleavers and the oval handaxe were made of limestone and volcanic stones, like basalt and quartzite. Also, there were seven spokeshaves, four denticulates, and a piercer made of non-flint stone. The spatial distribution of these tools did not show a clear pattern besides a major accumulation of limestone tools closer to the entrance, whilst the ones made on basalt were to the bottom (Mazo et al., 2012). The dominance of the cleavers and handaxes in the assemblage, unique in the Ebro's Basin Middle Paleolithic, combined with the choice of the non-flint raw materials to elaborate them has been interpreted as a link to near archaeological sites such as Olha or Isturiz (France) as well as to farther away sites such as Castillo, Morín, Pendo (Cantabria, Spain) and even those located on the Najerilla River (La Rioja, Spain) (Mazo et al., 2012; Utrilla et al., 2015).

The geographic and chronologic distribution of the Mousterian industry coincides with the Neanderthal distribution; therefore, it has been interpreted as a direct relationship between them (Pettit and White, 2012). Mousterian is a Middle Paleolithic industry, more complex and heterogeneous than was previously considered, with internal variations probably developed as a response to environmental, economic, and cultural factors (Deschamps, 2014). The Early to Middle Paleolithic transition was established around MIS 10/8 in the Ebro Basin (Mazo and Alcolea, 2019). In this area, there is a time gap till MIS 6/5, where the level h of Moros de Gabasa (Montes and Utrilla, 2014) is located. Most of the human occupation during the Middle Paleolithic for the Ebro's Basin had placed around MIS 3, specifically between 50 and 40 kyr ago (Mazo and Alcolea, 2019) when this industry vanished from the Ebro Basin archaeological record.

Besides the description of the lithic assemblage to the MTA, the unit h was dated through three different methodologies. One deer metatarsal bone from the unit h faunal bone assemblage was dated using radiocarbon AMS, giving an inconclusive dating of >45,000 (GrA-16960). Six samples from deer teeth were analysed using Electron Spin Resonance (ESR) from the same bone assemblage. The results ranged from 22,280 ± 3,890 to 33,630 ± 5,600 years, with an average date of 27,460 ± 4,000 years. It must be pointed out that the samples obtained deeper in the stratigraphic unit had more recent dating than the others. This discrepancy was interpreted as a possible alteration of the soil, as we previously mentioned, or during the extraction and processing of the samples. Finally, four teeth of *Ursus spelaeus* were sampled for dentine extraction and were analysed through amino acid racemisation (AAR). The sample dating results were 42, 44, 55, and 100 kyr, averaging 60 ± 27 kyr. After rejecting the dating of 100 kyr, which sample had substantially lower amino acid values, the average dating was 47 ± 7 kyr. Mazo et al. (2012) considered this discrepancy between the dating obtained related to alteration/s of the soil with possible anthropic, animal, or other natural origins. Given the adscription of the lithic assemblage to MTA and the dating obtained through diverse analyses, it was established that the chronology for the unit h was MIS 3 (59,000–24,000 BP) (Mazo et al., 2012).

## 2. Materials & Methodology

### 2.1. Palaeontology: quantification

The bone assemblage studied was composed by 3,146 remains and fragments, and they were moved in the University of Zaragoza in 2015

for its study. The fossil faunal bone assemblage found in the unit h inside the cave of Abauntz is currently deposited in the Museum of Pamplona (Navarra, Spain). An exhaustive inventory of the identified remains, and the tables with anatomical elements identified and quantified data for each taxon are provided as Supplementary Online Material.

Quantification of remains was achieved under the procedures indicated by different authors (Brain, 1981; Lyman, 2008), adapting them to our assemblage. The number of remains (NR) has been defined as the total number of fragments, bones and teeth, disregarding its conservation status and assigned to a taxon. In this study, a specimen (SP) is composed of one or more remains (NR) which clearly show traits to have been one skeletal element previously; all of them form the number of individual specimens (NISP). Isolated teeth have been considered in this category but not those attached to dentary or maxilla bones. The NISP has allowed us to calculate the minimum number of elements (MNE) and the minimum number of individuals (MNI) through them. In the MNE account, non-identified taxa remains were excluded. Teeth have been considered qualitatively but not quantitatively. The minimal number of animal units (MAU) was calculated using the MNE divided by the number of the skeletal element/s in an undisturbed skeleton (Reitz and Wing, 2008). %MAU was obtained by dividing the MAU of each skeletal element by the largest MAU in the taxa and multiplying by 100 (Reitz and Wing, 2008).

*2.2. Palaeontology: Taxonomy and anatomical identification*

The taxonomic identification was carried out using a general atlas (Schmid, 1972; Pales and García, 1981) for the following taxa: *Bos/Bison, Canis lupus, Capra pyrenaica, Cervus elaphus, Crocuta* sp., *Equus* sp., *Lepus capensis, Meles meles, Panthera pardus* and *Vulpes vulpes*. Specific works were used for *U. spelaeus* remains (Torres, 1988; Grandal-d'Anglade, 1993). Moreover, paleontological collections located at the University of Zaragoza and the mammalogy collection of The Academy of Natural Sciences of Drexel University of Philadelphia were consulted to assess the previously mentioned taxa and to identify the following taxa: *Coelodonta* cf. *antiquitatis, Cuon alpinus* and *Rupicapra rupicapra.*

Our study established three groups of fossil mammal remains, cave bears (*U. spelaeus*), carnivores and herbivores. We have considered this division appropriate due to the nature of the *U. spelaeus* and their remains. Firstly, the astonishing number of remains from this species makes them worthy of different consideration. A second reason to split them from other Carnivora taxa is related to the activities inside the cave. While some predators could use the cavity as a short-term shelter or for feeding purposes, *U. spelaeus* occupied it for hibernation (Grandal-d'Anglade et al., 2018). Besides, the dietary habits of *U. spelaeus* probably differed significantly from those practised by most of the Carnivora taxa (Baca et al., 2016; Bocherens, 2019; Pérez-Ramos et al., 2020).

*2.3. Palaeontology: Age classes*

An exact chronological age determination for an archaeological specimen is unlikely, but epiphyseal fusion, tooth eruption, tooth wear, and growth increments are primary data to establish an estimation (Reitz and Wing, 2008). As most of the taxa in the assemblage were represented just by one or a few individuals, it was challenging to establish relative age estimation. Thus, epiphyseal fusion and tooth eruption were the main drivers in its discrimination to assess the maturity of the individuals (Reitz and Wing, 2008).

In the case of *U. spelaeus*, by virtue of its abundance, the age estimation was made through different approaches to infer a more accurate picture of the age classes.

For the postcranial skeleton, particular focus was put on the size of the bones and the degree of epiphyseal fusion (Marks and Erickson, 1966; Weinstock, 2000, 2009). In such fashion, three groups were observed: juveniles (including infantile), described through their smaller size with un-fused epiphyses and thin cortical surface; subadults,

to bigger size bones (frequently similar in size to adults) with thick cortical surface and with un-fused epiphyses; and adults, to bigger bones with thick cortical surface and fused epiphyses. Also, we added new-borns through the morphometry and the porous surface of the tiny bones.

For the dentition, we used the dental eruption criteria and the disposition of the molar teeth (Ehrenberg, 1931; Dittrich, 1960; Rausch, 1961; Torres, 1988). We have applied the criteria established by Stiner (1994, 1998) for cave bears dental wear. This system is based on describing the teeth enamel worn on occlusal view and assigns them to one of the nine cohorts. These cohorts depend on the wear degree and can be resumed in three stages: I (juveniles), II (adults) and III (elders). Stage I includes decidual teeth and permanent teeth with absence or little wear on it (cohorts 1 to 3); stage II includes permanent teeth with moderate to abundant wear (cohorts 4 to 6); and stage III has permanent teeth with exposed dentine, which frequently lack of enamel and sometimes the radicular channels can be observed (cohorts 7 to 9). This approach considers the dental eruption cycle, which can occur when the same individual shows different dental wear in their teeth. The system only allows guessing relative ages inside the same assemblage; in any case, not absolute ages, but patterns can be observed. Due to the wear shown by most dentitions, a remarkable number of teeth couldn't be identified, leading us to test our results against the expected number of dentitions considering the species MNI. The *U. spelaeus* dental formula (Torres, 1988) is $I_3^3 C_1^1 Pm_1^1 M_3^2 \times 2 = 30$.

To analyse the mortality profile of a bone assemblage or population, two models are frequently used: attritional or catastrophic (Klein and Cruz-Uribe, 1984; Kurtén, 1953). Both are theoretical and help understand the possible causes of death. The catastrophic model is represented by a stepped profile in which the number of individuals decreases while the age increases. This model represents an established population suddenly death by any means, natural or anthropic (Cruz-Uribe, 1991). On the contrary, the attritional model is a complement of the previous. In this model, juveniles and seniles are more common than adults and represent an established population in which death is produced by hunters picking the weakest members of the population. Usually, it is represented by a U-shaped profile (Cruz-Uribe, 1991).

*2.4. Palaeontology: Ursus spelaeus sexual dimorphism*

Sexual dimorphism is a trait shared by the Ursidae family manifested through males being bigger than females, but in degrees depending on the species (Stirling, 1993). In *U. spelaeus*, sexual dimorphism seems to be a very extensive process (Kurtén, 1955; Grandal-d'Anglade, 2001; Baryshnikov, 2007), reaching the extreme of in the canine size (Koby, 1949). According to these authors, the sexual distribution of a cave bear (*U. spelaeus*) population can be established by discriminating the bone assemblage through a bivariate analysis of their metrics. Thus, we have considered the differences in the measurements obtained and available on diverse adult skeletal elements, as well as their description, to infer the sexual distribution of the *U. spelaeus* population of Abauntz. Thus, we have compared canines (transversal vs longitudinal diameter), humerus (diaphysis transversal diameter vs distal epiphysis transversal diameter), ulna (total length vs diaphysis anteroposterior diameter), radius (proximal epiphysis transversal vs anteroposterior diameters and distal epiphysis transversal vs anteroposterior diameters), carpal bones (tranversal vs anteroposterior diameters), metacarpal bones (total length vs diaphysis transversal diameter), femur (distal epiphysis anteroposterior vs transversal diameters), tibia (distal epiphysis transversal diameter vs diaphysis transversal diameter), tarsal bones (tranversal vs anteroposterior diameters) and metatarsal bones (total length vs diaphysis transversal diameter).

## 2.5. Taphonomy

Several variables are directly related to determining how bones have been accumulated and/or dispersed. Scattering and accumulation are taphonomical processes that have mirror effects on the skeletal composition and are challenging to conceptually distinguish (Lyman, 1994). Dispersal, as synonymous with scattering, indicates a relationship to where the carcass was originally placed in contrast to accumulation, which implies mobilization to a final location (Lyman, 1994). Accumulation can be considered passive or active, depending on the action of taphonomical factors other than the behaviour of the animals whose remains are studied. As such, they are considered agents as humans, carnivores or water flows, which can affect the bones differently (i.e. abrasions, toothmarks, trampling), creating diverse outcomes (i.e. breakage pattern, spatial distribution, skeletal survival ratio) (Lyman, 1994).

### 2.5.1. Skeletal survival ratio

The skeletal survival ratio has been calculated using the following formula: $MNE \div (no\ of\ bones \times MNI)$. Where the number of bones means the quantity of a determined bone in the skeleton of an individual. The ratio of epiphyses and diaphysis and the proportion between them has been calculated using the NISP described of long bones, assigning a value from 0 to 1 depending on their survival stage. The presence of the epiphysis is valued as 1 or 0 whether in the diaphysis depends on the length preserved. Therefore, if the length is equal to or less than ¼ of the original length counts as 0.25; 0.5, between ¼ to ½ of the original length; 0.75, between ½ to ¾ of the original length; and 1, over ¾ of the original length. We are aware that it could lead to a slight overrepresentation of the diaphysis compared to the epiphyses but this is a statistical approach and it is more accurate than a binary assignation.

### 2.5.2. Spatial distribution

The spatial distribution has been developed using the topographies made by the Speleological Centre of Aragon (CEA, in Spanish), the excavation's spatial organization established by the excavation directors and the inventory numbers of NISP. Exceptions were made to the *U. spelaeus* skulls and isolated teeth to avoid overrepresentation, but the first were represented in the MNE. Due to the lack of further details on the exact location of the remains as they were found, the spatial distribution on the plan was broadly established considering the inventory number assigned to them. The inventory number contained the row and rank of the topography where remains were located. Not knowing the exact orientation of the remains prevented deeper insights into their spatial distribution and dispersion (e.g. rose diagrams, stereographic projections).

### 2.5.3. Breakage pattern

Through the breakage pattern and the toothmarks studies, the main accumulator agents which caused the bone assemblage can be inferred. The breakage pattern study has been performed using the analysing procedures established by Villa and Mahieu (1991) and followed by other authors such as Rabal-Garcés et al., 2012. The study focuses on the long bones' fractures (stylopodials and zeugopodials, adding metapodials for ungulates) and the type of the angle (oblique, straight or mixed), the delineation (transversal, curved or intermediate; we also add longitudinal here) and the edge (smooth or irregular) of the fractures described (Fig. 3). Also, the degree of the shaft preservation has been considered in terms of length (L1, equal to or less than ¼ of the original length; L2, between ¼ to ½ of the original length; L3, between ½ to ¾ of the original length; L4, over ¾ of the original length) and circumference (C1 < original half; C2 > original half; C3 = complete). The results obtained must be considered as a statistical trend. Some biostratinomic factors, besides anthropic and carnivore actions, like water flows, were considered and assessed (Lyman, 1994).
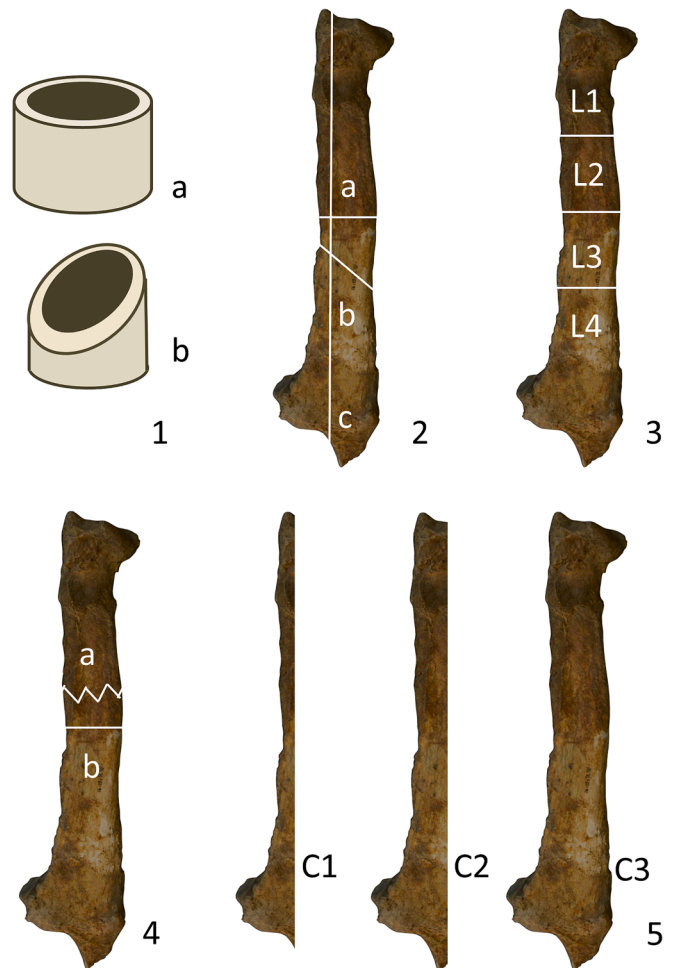


**Fig. 3.** Typology of the fractures described. 1: fracture angle (a, straight; b, oblique); 2: fracture delineation (a, transversal; b, curved; c, longitudinal); 3: length of the shaft preserved; 4: fracture edge (a, irregular; b, smooth); 5: circumference of the shaft preserved.

### 2.5.4. Toothmarks

Other kinds of marks were found on the bones' surface. Those marks were usually the result of carnivores' activity on them, and the agent causing them can be guessed through the study of their morphometry. Each agent produces different marks, varying in size and quantity as well as in morphology, which has been studied and established by different authors (Haynes, 1983; Binford, 1981; Lyman, 1994; Andrews and Fernández-Jalvo, 1997; Domínguez-Rodrigo and Piqueras, 2003; Pobiner, 2008). We can describe them as pits, punctures, pitting, scores, scoring, notches, crenulated edges, furrowing, scooping out, and acid etching (Figs. 4 and 5). Thus, the mark's size, type, and location must be considered to diagnose the agent accurately. Our study uses the methodology established by Selvaggio and Wilder (2001), reviewed and extended by other authors whose results have also been used for comparative purposes (Andrés et al., 2012; Delaney-Rivera et al., 2009; Domínguez-Rodrigo and Piqueras, 2003; Pickering et al., 2004; Rabal-Garcés et al., 2012; Rodríguez-Hidalgo et al., 2013; Sala and Arsuaga, 2013; Saladié et al., 2011). Although we have considered all types of marks and bones affected, we give diagnostic preference to pits and punctures on long bones. Pits and punctures are generally described as oval or circular marks caused by the teeth' cusps pressuring the bone surface, disregarding if they get through the cortical surface or not, and they show the best correlation between their size and the size of the tooth that caused them (Pinto-Llona et al., 2005). These can be measured through two axes, one major or length and the other minor or
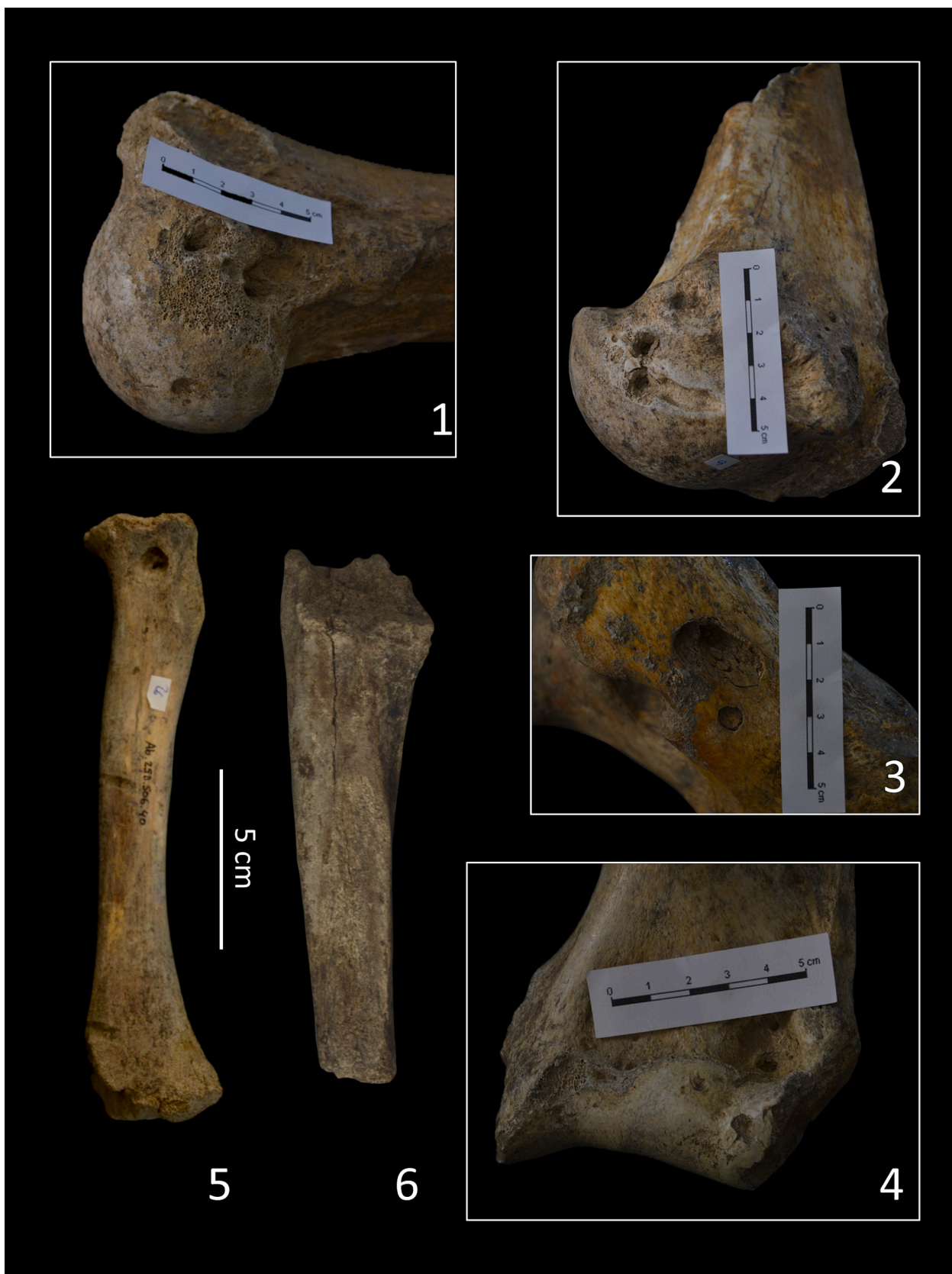
**Fig. 4.** *Ursus spelaeus* long bones affected by carnivore toothmarks. 1, (Ab 33E.519.77) right humerus with pits, punctures and furrowing on the proximal epiphysis lateral side; 2, (Ab 33E.519.77) right humerus with pits, punctures and scores on the proximal epiphysis medial side; 3, (Ab 25D.516.30) right femur with pits and punctures on the proximal epiphysis lateral side; 4, (Ab 27D.492.1) left humerus with pits, punctures and furrowing on the trochlea (lateral epicondyle area); 5, (Ab 25D.506.40) left radius with puncture, scores and furrowing; 6, (Ab 25D.502.39) right ulna with crenulated edges on the proximal edge.

**Fig. 5.** *Ursus spelaeus* bones affected by carnivore toothmarks. 1, (Ab 33E.521.86) rib with puncture, notches and crenulated edges; 2, (Ab 25D.517.16) rib with punctures and furrowing; 3, (Ab 27F.500.16) left astragalus with pits, punctures and furrowing; 4, (Ab 25E.501.89) left scapula achromion spine with puncture; 5, (Ab 25E.499.37) thoracic vertebra with puncture on the cranial facies of the body; 6, thoracic vertebra (Ab 25E.499.37) with puncture and furrowing on the caudal facies of the body.

width (Selvaggio and Wilder, 2001). The width shows a greater confidence degree between the value of this factor and the size of the agent causing it compared to the length (Pobiner, 2008). Besides it, marks located on cancellous bone areas or epiphyses also show a better correlation between the marks and the agent than those located on the cortical bone (diaphysis) or thin cortical bone (metaphysis) (Delaney-Rivera et al., 2009). We also have split the remains affected by toothmarks into categories based on the average body mass of the taxa (Bunn, 1986) (Table 2).

*2.5.4.1. Toothmarks affecting to Ursus spelaeus.* The remarkable number of *U. spelaeus* remains in the bone assemblage requires a specific approach for the toothmarks affecting them. The procedure established by Pinto-Llona et al. (2005) has been applied in other studies too (Rabal-Garcés et al., 2012), focusing on long bones and creating categories depending on the type of the marks and their location: A, pits and punctures on diaphysis but excluding fractured edges; B, scores on diaphysis: C, pits and punctures on epiphysis; D, notches on spiral fractures; E, notches on transverse fractures; F, notches on longitudinal fractures; G, molar toothmarks (multi cusps); H, pits and punctures on skeletal elements other than long bones; and I, scores on epiphysis. We did not use two categories (G and H, according to Pinto-Llona et al., 2005) due to the lack of a representative sample. Also, the width of the toothmarks is considered in different size categories: I, ≤2,5 mm; II, >2,5–5 mm; III, >5–7 mm; IV, >7–9 mm; V, >9–11 mm; VI,>11 mm. Besides it, this system regards if the bones affected belong to adults or juveniles. The value of these analyses is merely statistical; therefore, the agent should be inferred based on the general trends observed better than over isolated toothmarks. All measurements have been taken with a calliper and are expressed in millimetres (mm).

## 3. Results

### 3.1. Palaeontology: quantification

In the unit h bone assemblage was identified 2,426 NR, 1,801 NISP and 1,117 MNE. The estimated total amount of MNI is 33 (Table 3). According to the NR and skeletal areas of the whole assemblage, cranial elements were depicted in skulls (258), mandibles (52) and teeth (329), the last including isolated pieces as well as those attached to the dentary and maxilla bones. The axial skeletal elements were the most abundant, ribs (478) and vertebrae (354), followed by the appendicular elements: scapulae (44) and pelvis (42), humerus (38) and femur (33), ulnae (37) and tibiae (43), radius (32) and fibulae (16), carpal (37) and tarsal (59) bones, metapodials (140) and phalanxes (295). Other bones were represented such as hyoid bones (36), patellas (9), sesamoids (54), baculii

**Table 2**
Taxa described in the unit h according to the Bunn (1986) bodymass classification.

| Type | Bodymass range (kg) | Taxa and estimated age | MNI |
|---|---|---|---|
| 1 | <22,67 | newborn *Ursus spelaeus* | 2 |
| | | adult *Vulpes vulpes* | 4 |
| | | adult *Cuon alpinus* | 1 |
| | | adult *Meles meles* | 1 |
| | | adult *Martes* sp. | 1 |
| | | adult *Lepus capensis* | 1 |
| 2 | 22,67–113,39 | adult *Canis lupus* | 1 |
| | | adult *Panthera pardus* | 2 |
| | | adult *Crocuta* sp. | 1 |
| | | adult Caprinae | 2 |
| | | juvenile *Ursus spelaeus* | 3 |
| 3A | 113,39–204,11 | adult *Cervus elaphus* | 3 |
| 3B | 204,11–340,19 | adult *Ursus spelaeus* | 8 |
| 4 | 340,19–907,18 | adult *Bos/Bison* | 1 |
| | | adult *Equus* sp. | 1 |
| 5 | >907,18 | adult *Coelodonta antiquitatis* | 1 |

**Table 3**
Identified taxa of the unit h bone assemblage.

| Taxa | NR | NISP | MNE | MNI |
|---|---|---|---|---|
| *Ursus spelaeus* | 2053 | 1506 | 941 | 13 |
| Carnivores | 251 | 195 | 109 | 11 |
| *Canis lupus* | 26 | 23 | 17 | 1 |
| *Vulpes vulpes* | 85 | 63 | 44 | 4 |
| *Cuon alpinus* | 14 | 2 | 2 | 1 |
| *Panthera pardus* | 69 | 54 | 40 | 2 |
| *Crocuta* sp. | 5 | 5 | 4 | 1 |
| *Meles meles* | 1 | 1 | 1 | 1 |
| *Martes* sp. | 1 | 1 | 1 | 1 |
| No ID Carnivore | 50 | 46 | | |
| Herbivores | 122 | 100 | 67 | 9 |
| Caprinae | 49 | 37 | 24 | 2 |
| *Cervus elaphus* | 49 | 39 | 33 | 3 |
| *Bos/Bison* | 9 | 9 | 6 | 1 |
| *Coelodonta antiquitatis* | 1 | 1 | 1 | 1 |
| *Equus* sp. | 1 | 1 | 1 | 1 |
| *Lepus capensis* | 2 | 2 | 2 | 1 |
| No ID Herbivore | 11 | 11 | | |
| TOTAL | 2426 | 1801 | 1117 | 33 |

Non-identified taxa specimens haven't been taken account on MNE.

(9).

### 3.2. Palaeontology: taxonomy, anatomical identification, age classes and Ursus spelaeus sexual dimorphism

According to the NR, *U. spelaeus* (2053 NR, 84.62 %) was the most abundant species, followed by the other Carnivora taxa (251 NR, 10.35 %) and then, the herbivore mammals (122 NR, 5.03 %). That trend barely changes regarding NISP and MNE: *U. spelaeus* 1506 NISP (83.62 %), 941 MNE (84.24 %); other Carnivora taxa 195 NISP (10.83 %), 109 MNE (9.76 %); herbivores 100 NISP (5.55 %), 67 MNE (6 %). Regarding the MNI, the estimation was 33 distributed in the assemblage as follows: *U. spelaeus* 13, other Carnivora taxa 11 and herbivores 9 (Fig. 6).

#### 3.2.1. Ursus spelaeus
The distribution of the *U. spelaeus* anatomical areas according to the NISP was: cranial and dentition 15.6 %, axial 41.5 %, appendicular 42.5 % and other (baculii) 0.4 % (Suppl. mat. Table 2). The laterality of the NISP forelimb distribution was right side 41.36 % vs left side 58.64 %, while for the NISP hindlimb is right side 53.25 % vs left side 46.75 %.

*3.2.1.1. Ursus spelaeus age classes.* To understand the mortality profile of the *U. spelaeus* population in Abauntz, two approaches have been used, as stated in Section 2.3. The postcranial skeleton allows splitting adults from juveniles, but the dental wear allows observing different degrees inside the adults of the same assemblage. According to the general description of the skeleton, we have tallied a MNI of 13 for
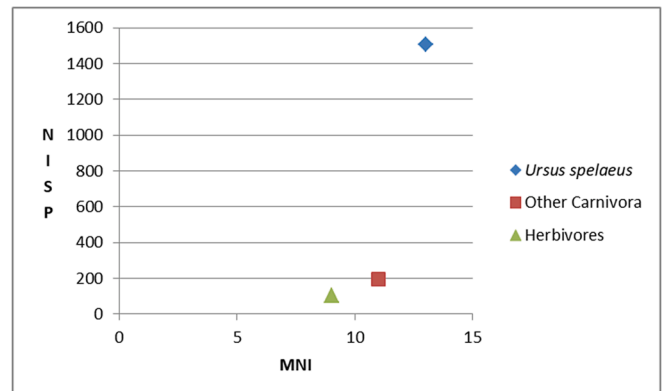


**Fig. 6.** NISP vs MNI comparison by main groups in the unit h bone assemblage.

*U. spelaeus* (Suppl. mat. Table 2). Inside this species, we observed seven adults, one subadult (because of the un-fused epiphyses), and five juveniles/infantile (including two perinatal), so the adults dominated the sample (Fig. 7).

The teeth-worn analyses showed a U-shape profile (Fig. 8), but in this case, we can also observe degrees inside the stages. Each dental piece analysed tends to accumulate the results in the edges of the classification (Fig. 9), with some showing a more biased tendency, like P4 and M1. Generally, the most frequent stage is III with 41.30 %, closely followed by the stage I (39.13 %). Stage II comprehends adults and prime adults and only represented 19.57 %. However, considering only the cohorts, the most common is cohort 3 (27.17 %). This is especially remarkable if we consider that the other two cohorts inside stage I only represented 11.95 % of the total. Thus, we can establish that the cave bear population of Abauntz has an attritional mortality profile, with youngling and senile individuals dominating the sample.

*3.2.1.2. Ursus spelaeus sexual dimorphism.* We have compared different measurements of our population, observed the aggrupation formed and compared the results (Table 4). Regarding the postcranial skeleton, a remarkable male dominance was observed. This percentage ranges from 60 % in metatarsal bones to above 77 % in carpal bones. The canines were very similar morphologically, with the upper canines being bigger than the lower ones (Torres, 1988). In our assemblage, we had nine canines associated with their alveolus (five to the maxillas and four to the hemimandibles). Thus, we compared the transversal and anteroposterior diameters and plotted them in a bivariate diagram, obtaining two groups (Fig. 10). These groups showed a well-known pattern: top right, males; bottom left, females. In both cases, the maxillar canines are bigger than the mandible ones, but there was an exception. One of the male canines is in an awkward position due to having suffered an extensive erosion process; fortunately, it was attached to a skull with apparent male features. Having established those two groups, we plotted the remaining *U. spelaeus* canines, which were identified but isolated (Fig. 11). The groups were clearly split, allowing us to infer that, in our case, the male mandible canines were bigger than the female maxillar canines. The results observed established that 61 % of canines belong to males vs 39 % to females. These percentages were slightly lower for male dominance than those obtained in postcranial bones, but it was still a sounding dominance, even being conservative. The bivariate analysis supported the insights obtained through the anatomical study of the *U. spelaeus* remains (Suppl. mat. Table 2) and made them consistent. Of the seven skulls described, only one showed clear female traits. Also, six baculii were described, which is remarkable given the MNI of 13 for *U. spelaeus*.

### 3.2.2. Other Carnivora taxa

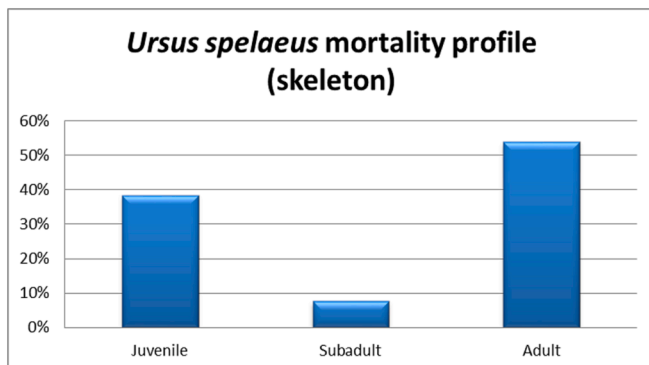Carnivora was the most abundant taxonomic Order in the unit h.



**Fig. 7.** Mortality profile of the *Ursus spelaeus* population according to the description of the postcranial skeleton.
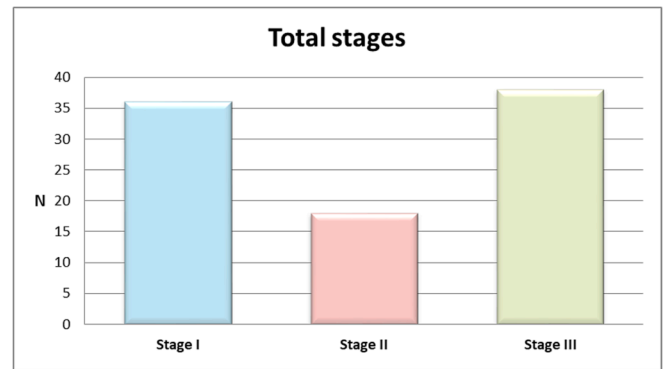


**Fig. 8.** Classification of the age distribution of the Abauntz *Ursus spelaeus* population based on the stages established through dental wear.

Even if we exclude *U. spelaeus*, the remains of this Order exceed herbivores by a large amount. Although their numbers were lesser than cave bears (*U. spelaeus*), all the anatomical elements were represented except in species with scarce presence in Abauntz (*Crocuta* sp., *Meles meles* and *Martes* sp.) (Suppl. mat. Tables 3–6).

*3.2.2.1. Canidae.* Canidae was the most abundant group in unit h besides ursids. Altogether, it was identified 125 NR, 88 NISP and 63 MNI is estimated in 4 to *Vulpes vulpes* (Suppl. mat. Table 3) and 1 to *Canis lupus* and *Cuon alpinus* (Suppl. mat. Table 4). The anatomical regions were distributed according to the NISP as follows: *Vulpes vulpes*, cranial and dentition 41.78 %, axial skeleton 18.82 %, appendicular 40 %; *Canis lupus*, cranial and dentition 8.70 %, axial skeleton 39.13 %, appendicular 52.17 %; *Cuon alpinus,* cranial and dentition 100 %. There was a *Cuon alpinus* skull and a left hemimandible described through the occipital shape and the six teeth in the teeth row (Chacon, 2000). No postcranial bones have been described for this species; however, there were unidentified Carnivora remains (50 NR), and some of them, phalanges and metapodial bones in diverse preservation status were identified as Canidae which could belong to these genera.

*3.2.2.2. Panthera pardus.* This was the sole member of the Felidae family in the unit h assemblage, but its remains were relatively abundant (Suppl. mat. Table 5). According to the NISP, the anatomical regions were cranial and dentition 27.78 %, axial 46.30 % and appendicular 25.92 %. There were two adult individuals, at least, which showed remarkable differences in their skull size.

*3.2.2.3. Crocuta sp..* Only five specimens (SP) were described as belonging to the *Crocuta* genus, mainly limb bones and a tooth (Suppl. mat. Table 6). However, at least 27 coprolites were identified in the genus due to their morphology (Horwitz and Goldberg, 1989).

*3.2.2.4. Mustelidae.* Two taxa were described: *Meles meles* and *Martes* sp. Both were represented by one remain each, a right scapula (*Meles*) and a left ulna (*Martes*) (Suppl. mat. Table 6).

### 3.2.3. Herbivores

The taxa observed in this group were all ungulates except for a lagomorph (Suppl. mat. Tables 7–9).

*3.2.3.1. Artiodactyla.* This was the most abundant group of herbivores in Abauntz. They were represented through at least four species and tallied 85 NISP of 100 NISP for the herbivores. The most common species in this order was *Cervus elaphus* (Suppl. mat. Table 7), closely followed by the Caprinae subfamily members, *Capra pyrenaica* and *Rupicapra rupicapra*, and finally, *Bos/Bison* (Suppl. mat. Table 8). The anatomical regions are distributed according to the NISP as follows:
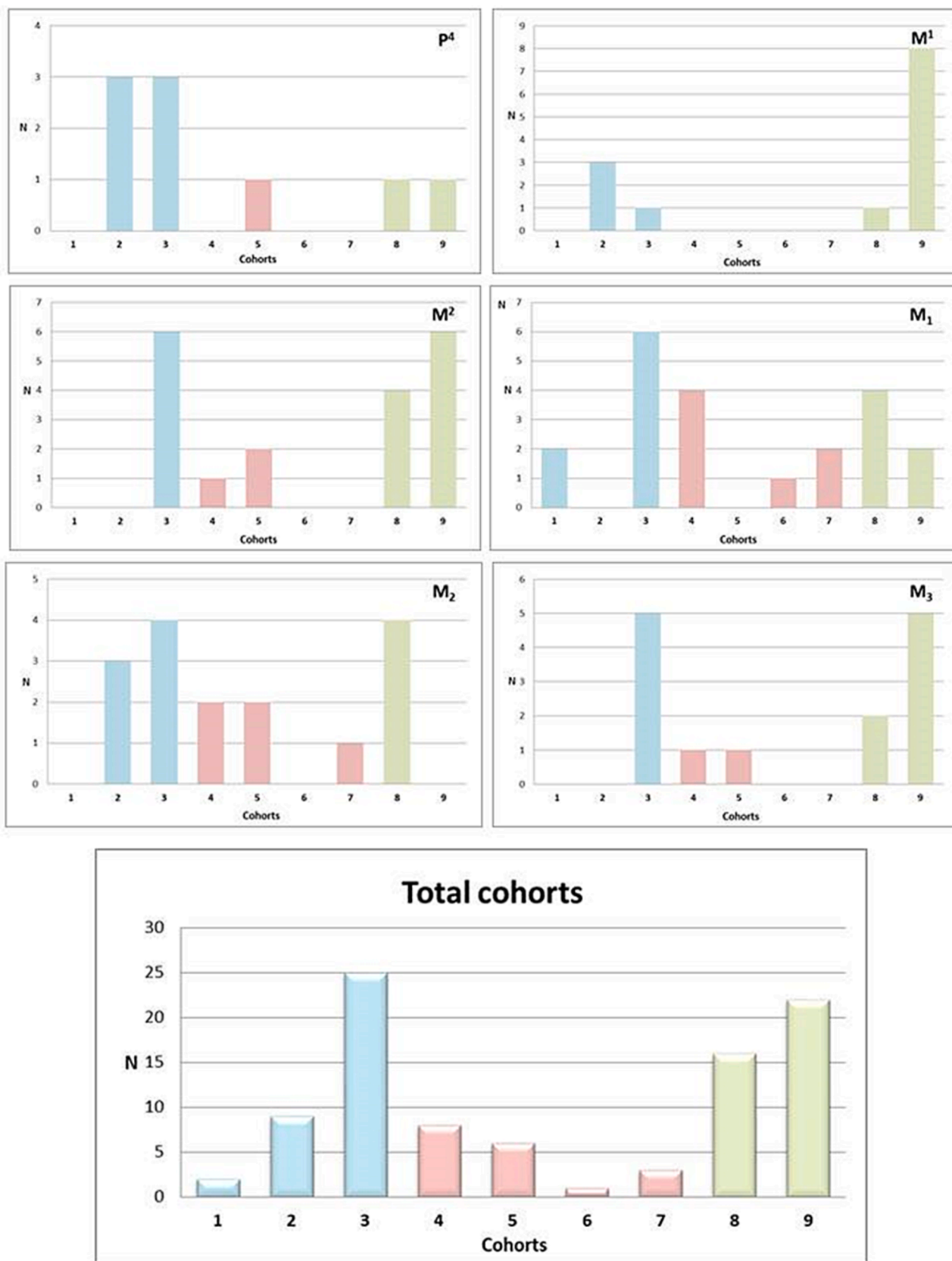
**Fig. 9.** Classification of the age distribution of the Abauntz *Ursus spelaeus* population based on the cohorts established through dental wear. P4: upper fourth premolar, M1: upper first molar, M2: upper second molar, M1: lower first molar, M2: lower second molar, M3: lower third molar.

**Table 4**
Sexual distribution according to different skeletal elements in the *Ursus spelaeus* population of Abauntz.

| Skeletal element | N | ♂ | | ♀ | |
|---|---|---|---|---|---|
| | | N | % | N | % |
| Canine | 18 | 11 | 61 % | 7 | 39 % |
| Humerus | 8 | 6 | 75 % | 2 | 25 % |
| Ulna | 8 | 6 | 75 % | 2 | 25 % |
| Radius | 7 | 5 | 71,43 % | 2 | 28,57 % |
| Carpal | 31 | 24 | 77,42 % | 7 | 22,58 % |
| Metacarpal | 36 | 24 | 66,67 % | 12 | 33,33 % |
| Femur | 4 | 3 | 75 % | 1 | 25 % |
| Tibia | 4 | 3 | 75 % | 1 | 25 % |
| Tarsal | 39 | 26 | 66,67 % | 13 | 33,33 % |
| Metatarsal | 25 | 15 | 60 % | 10 | 40 % |
| Total | 180 | 123 | 68,33 % | 57 | 31,67 % |

*Cervus elaphus*, cranial and dentition 7.69 % and appendicular 92.31 %; Caprinae, cranial and dentition 27.03 % and apendicular 72.97 %; *Bos/ Bison*, cranial and dentition 22.22 % and appendicular 77.78 %.

*3.2.3.2. Perissodactyla.* There were only two species from the Perissodactyla order in Abauntz: *Equus* sp. and *Coelodonta* cf. *antiquitatis* (Suppl. mat. Table 9). Their remains were scarce but so well preserved that they allowed their identification at the genus level. The *Equus* sp.

remain is a distal phalanx, while the *Coelodonta* cf. *antiquitatis* is the distal epiphysis of a left radius.

*3.2.3.3. Lagomorpha.* Two remains of *Lepus capensis* were described: part of a left humerus and a metatarsus (Suppl. mat. Table 9).

### 3.3. Taphonomy: Skeletal survival ratio

The analysis of the skeletal survival ratio applied to the three main groups of mammals (bears, other Carnivora taxa and herbivores) showed two different patterns (Fig. 12). *U. spelaeus* had all the skeletal elements represented, the most common element being the ulna. Other Carnivora taxa lack various skeletal elements, but the three skeletal regions were present: cranial, axial and appendicular. This was directly related to the abundance of their remains in the assemblage. Therefore, the most abundant taxa, like *Vulpes vulpes*, represented the skeletal elements more completely. On the contrary, the herbivores showed a different trend with the total absence of axial elements. In this case, the abundance of the taxa remains didn't affect the skeletal regions, just the number of the elements. We also compared the ratio between axial and appendicular NISP (Table 5). Besides the remarkable absence of axial elements in herbivores, the variation in the abundance of axial remains must be noticed. In the case of *U. spelaeus*, these are more abundant than the appendicular elements, while in carnivores, it is the opposite. The
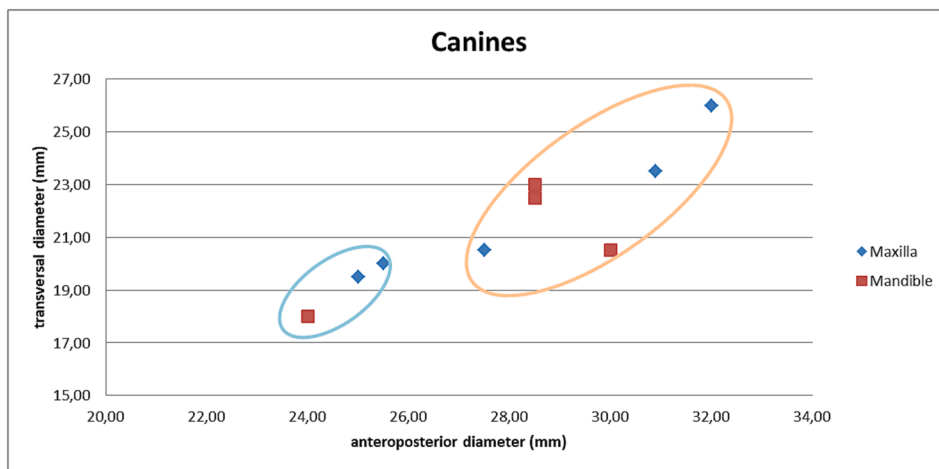


**Fig. 10.** Bivariate analysis (anteroposterior vs transversal diameter) on described *Ursus spelaeus* canines from unit h of the cave of Abauntz. Diamonds are identified upper canines and squares are identified lower canines. Ellipses circle male (top right) and female (bottom left) agroupations.
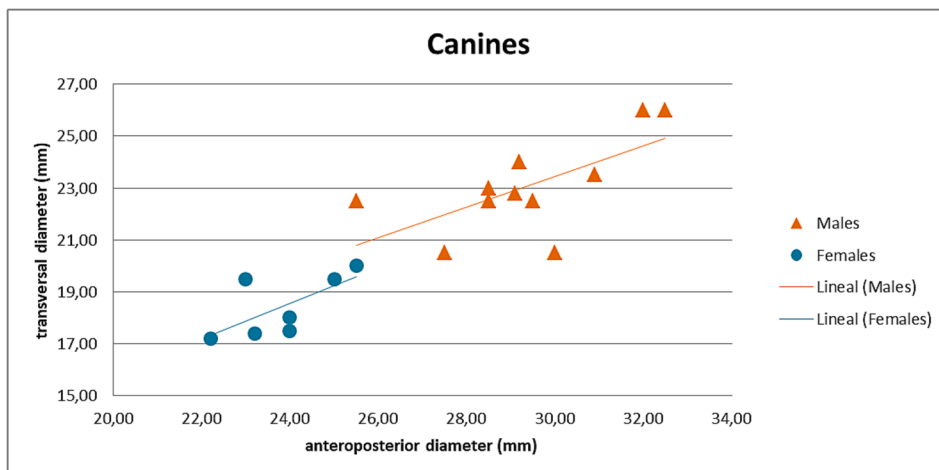


**Fig. 11.** Bivariate analysis on identified cave bear canines from unit h of the cave of Abauntz. Triangles are male canines and circles are female canines.
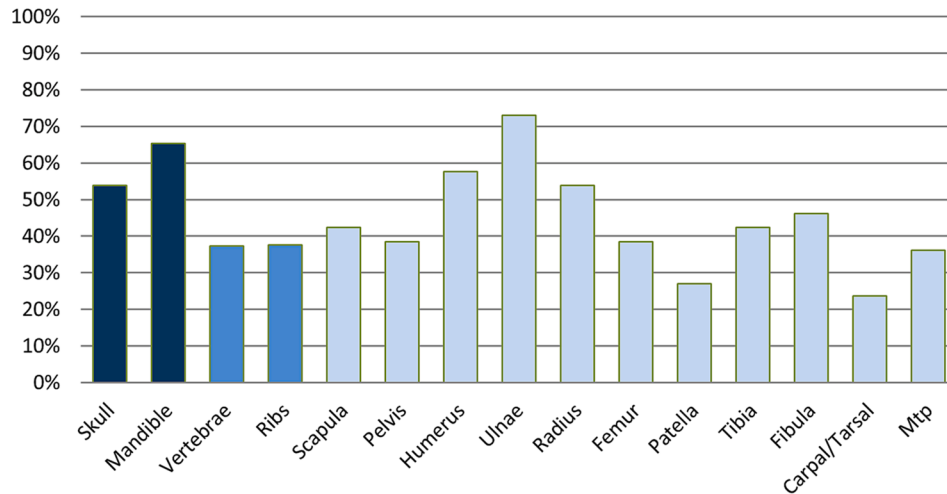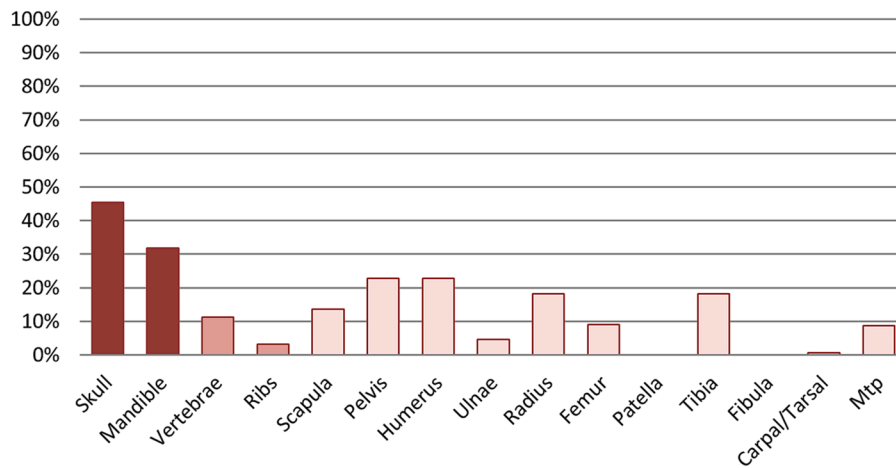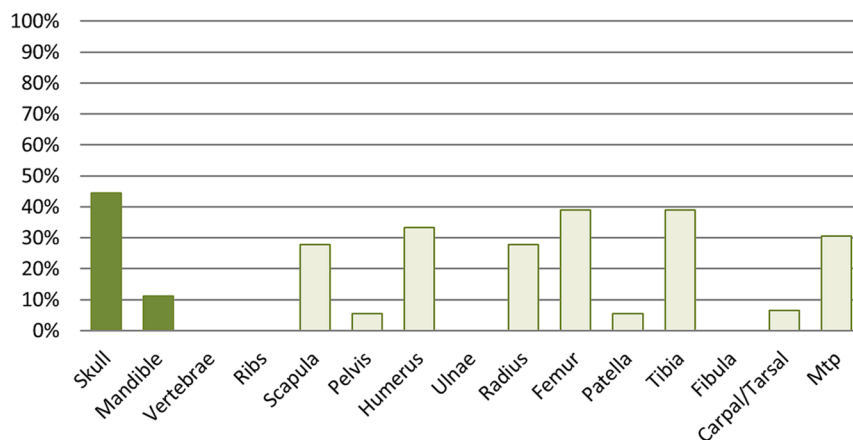
**Fig. 12.** Skeletal survival ratio of the unit h bone assemblage.

comparison between epiphyses and diaphysis preservation (Table 6) shed some light on the *peri*-mortem, post-mortem and post-depositional processes suffered by the assemblage. The almost total absence of epiphyses on juvenile cave bears was especially noticeable. It took more work to establish a clear pattern in herbivores, possibly due to the sample scarcity. However, it was observed that while smaller taxa (like Caprinae) usually lacked some epiphyses in bigger taxa (like *Bos/Bison* or *Coeolodonta*), the preservation of diaphysis was null.

**Table 5**

NISP reflecting the axial and apendicular regions identified in the unit h.

|  | *Ursus spelaeus* | Carnivora | Herbivores |
|---|---|---|---|
| Axial | 618 | 49 | 0 |
| Appendicular | 563 | 62 | 74 |
| Ratio | 1,1:1* | 0,79:1* | 0:1 |

*Decimals rounded.

### 3.4. Taphonomy: Spatial distribution

The spatial distribution of the identified specimens on the unit h topography showed a diffuse but consistent pattern (Fig. 13). A slight accumulation of specimens on the central band (band E) was observed, with 33F (15 % of the total remains) square being a remarkable divergence. In bands D and E, the remains decrease deeper in the cavity, while band F maintains their numbers except the square 33F previously mentioned. According to this, the *U. spelaeus*' remains showed a similar pattern to the general tendency related to their great abundance in the assemblage. Their remains were over 70 % of the total remains in each square. Other Carnivora taxa were more abundant in the extremes of the excavated area; it means bands 25, 27, 33 and 35. Herbivores were evenly dispersed in the unit h excavated area. Regarding the anatomical areas (Table 7), the cranial elements were more abundant in 25E, 27E, 33F and 35F, while the axial skeleton was in 27E, 29E and 33F, and the appendicular skeleton was in 25E, 27E, 31E and 33F. Notably, greater

accumulations collided in band E and, again, in square 33F. It must be considered that Unit H was not fully excavated in the extension of the cave. Thus, we only obtained a partial view of the remains and their distribution.

### 3.5. Taphonomy: Breakage pattern

The results of the breakage pattern study (Fig. 14) were very homogeneous with the curved delineation of the fracture (*U. spelaeus* 63.04 %, other Carnivora 71.43 %, herbivores 41.67 %), the irregular edge of the fracture (*U. spelaeus* 89.13 %, other Carnivora 92.86 %, herbivores 79.17 %) and the oblique angle of the fracture (*U. spelaeus* 69.57 %, other Carnivora 57.14 %, herbivores 77.08 %) dominating the sample. In the herbivore's case, there is a discrepancy in the frequency of the delineation pattern, where the longitudinal fractures outnumbered the curved fractures (45.83 % vs 41.67 %). Most longitudinal delineation fractures were described on *Cervus elaphus* and non-identified herbivore remains.

Regarding the preservation of the shaft, the three groups (*U. spelaeus*, other Carnivora and herbivores) showed an even distribution (Fig. 15). In *U. spelaeus*, the shaft total circumference (C3) was preserved at 86.76 %, the most frequent category combined with the shaft total length preservation at 35.29 % (C3 + L4). In other Carnivora taxa, the entire shaft circumference (C3) was preserved at 94.74 %. Still, contrary to the *U. spelaeus*, the most common category regarding the shaft complete

**Table 6**

Ratio of the epiphyses and diaphysis survival.

| Taxa | Skeletal element | Age | NISP | | | | | | Ratio |
|---|---|---|---|---|---|---|---|---|---|
|  |  |  | Com | Prox | Dist | Epi P | Epi D | Dia |  |
| *Ursus spelaeus* | Humerus | a | 3 | 1 | 6 | 3 | 1 | 2 | 1,74:1 |
|  |  | j |  |  |  |  |  | 3 | 0:1 |
|  | Ulna | a | 9 | 2 | 1 | 1 | 4 | 1 | 2,42:1 |
|  |  | j |  | 1 |  |  |  | 4 | 0,2:1 |
|  | Radius | a | 5 | 3 |  |  | 1 | 3 | 1,58:1 |
|  |  | j |  |  |  |  |  | 3 | 0:1 |
|  | Femur | a | 1 | 3 | 3 | 2 | 2 |  | 2,26:1 |
|  |  | j |  |  |  |  |  | 3 | 0:1 |
|  | Tibia | a | 2 | 1 | 2 | 1 | 2 |  | 2,67:1 |
|  |  | j | 1 | 1 |  |  |  | 2 | 0,75:1 |
|  | Metapodial | a | 82 | 1 | 6 | 2 | 2 | 1 | 1,97:1 |
| *Vulpes vulpes* | Humerus | a | 1 | 1 | 1 |  |  | 1 | 1,82:1 |
|  | Radius | a | 2 |  | 1 |  |  |  | 1,82:1 |
|  | Tibia | a | 1 |  | 1 |  |  |  | 2:1 |
|  | Metapodial | a | 5 | 3 | 3 |  |  |  | 1,78:1 |
| *Canis lupus* | Humerus | a |  |  |  | 1 | 1 |  | 2:0 |
|  | Radius | a | 1 |  |  |  |  |  | 2:1 |
|  | Femur | a |  |  |  |  |  | 1 | 0:1 |
|  | Tibia | a |  | 1 | 2 |  |  |  | 1,5:0,5 |
|  | Metapodial | a | 2 |  |  |  |  |  | 2:1 |
| *Panthera pardus* | Metapodial | a | 4 |  | 2 |  |  |  | 1,82:1 |
| *Crocuta* sp. | Femur | a |  |  | 1 |  |  |  | 1,33:1 |
|  | Metapodial | a | 1 |  |  |  |  |  | 2:1 |
| *Martes* sp. | Ulna | a |  | 1 |  |  |  |  | 2:1 |
| Caprinae | Humerus | a |  |  |  |  |  | 3 | 0:1 |
|  | Radius | a | 2 | 1 |  |  |  | 1 | 1,33:1 |
|  | Femur | a |  | 1 |  |  | 1 |  | 2,67:1 |
|  | Tibia | a |  |  | 2 |  |  | 1 | 1,33:1 |
|  | Metapodial | a | 2 | 1 |  |  |  | 1 | 0,86:1 |
| *Cervus elaphus* | Humerus | a |  |  | 2 |  |  | 1 | 0,89:1 |
|  | Femur | a |  | 1 |  |  | 1 |  | 2,67:1 |
|  | Tibia | a |  |  | 2 |  |  | 1 | 1,33:1 |
|  | Metapodial | a | 2 | 1 |  |  |  | 1 | 0,86:1 |
| *Bos/Bison* | Femur | a |  |  |  | 1 | 2 |  | 3:0 |
|  | Metapodial | a | 1 | 1 | 1 |  |  |  | 2,67:1 |
| *Coelodonta* cf. *antiquitatis* | Radius | a |  |  |  |  | 1 |  | 1:0 |
| *Lepus capensis* | Humerus | a |  |  | 1 |  |  |  | 2:1 |
|  | Metapodial | a | 1 |  |  |  |  |  | 2:1 |

Com: specimen complete or almost complete; prox: specimen of proximal epiphysis plus part of the diaphysis; dist: specimen of distal epiphysis plus part of the diaphysis; epi P: specimen of isolated proximal epiphysis; epi D: specimen of isolated distal epiphysis; dia: specimen of isolated diaphysis. age: a = adult (includes subadult); j = juvenile.
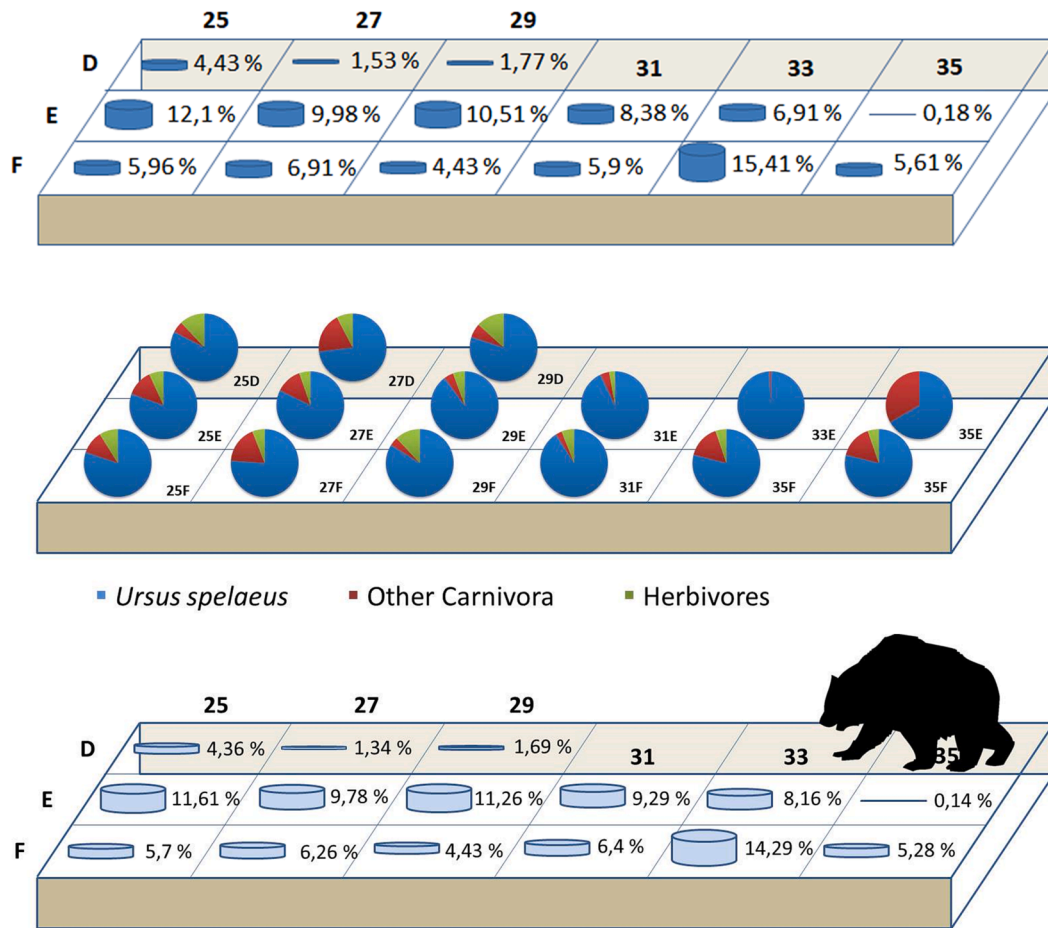
**Fig. 13.** Spatial distribution of the unit h bone assemblage. Top: total distribution of the identified remains in the excavated area of the unit h; middle: distribution of the identified remains in the excavated area of the unit h distributed by groups (blue for bears, red for carnivores and green for herbivores); bottom: distribution of *Ursus spelaeus* remains in the excavated area of the unit h. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

length preservation was less than the original half (C3 + L2, 31.58 %). In herbivores, the preservation of the shaft circumference was 68.75 %, still dominating the sample as in the Carnivora taxa cases but less common. The most common category was C3 + L2 (27.08 %), as in the other Carnivora taxa. It must be outlined that, in the herbivore's case, the preservation of less than a third of the shaft circumference appears in 29.17 %, a much higher percentage than in *U. spelaeus* and other Carnivora.

### 3.6. Taphonomy: Toothmarks

The toothmarks affected 13.05 % of NISP described in the unit h bone assemblage (Table 8). This percentage varied depending on the taxa and its abundance. Thus, herbivores showed more of these alterations than carnivores (Fig. 16). In absolute terms, *U. spelaeus* is the most affected taxa due to its dominance in the bone assemblage, holding 68.28 % of the NISP affected by the toothmarks studied but with only 10.29 % of its own NISP affected. Herbivores were massively affected by these alterations in relative terms; *Bos/Bison* had 66.67 % of its NISP affected, while *Cervus elaphus* had 51.28 % and Caprinae 39.57 %. Inside the Carnivora taxa, *Canis lupus* is the most affected by carnivore toothmarks, with 52.17 % of its NISP showing them. *Panthera pardus* and *Vulpes vulpes* presented these alterations in 16.98 % and 11.11 % of their NISP. Regarding the body parts affected by toothmarks, the most affected skeletal elements by total NISP were the femur (88.46 %), humerus (83.87 %), ulna (73.91 %), radius (70.83 %) and tibia (64.29 %).

Just considering the NISP affected by toothmarks, the distribution of anatomical regions was cranial 0.88 %, axial 25.55 % and appendicular 73.57 % (Table 9). Stylopodial and zeugopodial areas were the most affected inside the appendicular skeleton, with 49 and 58 NISP, respectively. Thus, stylopodial affected NISP represented 21.59 % while zeugopodial was 25.55 % of the NISP affected by toothmarks, followed by decreasing order by metapodial 10.57 %, basipodial 6.61 %, pelvic and scapular girdles 6.17 % and acropodial 3.08 %.

According to the typology of the toothmarks, the most common types of alteration were pits, punctures and pitting, representing 60.95 % of the toothmarks, followed by scores at 16.88 %, furrowing at 14.59 %, crenulated edges at 4.29 %, scooping out 2.72 % and impact points 0.57 % (Table 10). The results obtained by measuring the length and width of pits and punctures on epiphysis described according to the body mass categories are in Table 11. Regarding the frequency of toothmarks on specimens by taxa, *U. spelaeus* presents 67.53 % of them, followed by Cervus elaphus 10.30 %, Bos/Bison 5.44 % and Caprinae 5.29 %. Inside the Carnivora taxa, besides *U. spelaeus*, Canis lupus is the most affected, with 4.86 %.

### 3.6.1. Toothmarks affecting to Ursus spelaeus

According to the methodology established by Pinto-Llona et al. (2005), the percentage of the cave bear long bones affected by toothmarks was over 45 % in adults (46.03 %) and juveniles (45 %) (Table 12). In adults, the most affected bone was the humerus (68.75 %), followed by the femur (63.64 %) and tibia (62.50 %), while in juveniles was the femur (66.67 %), closely followed by the ulna (60 %). A similar pattern was shown regarding the total amount of toothmarks. We

**Table 7**
Spatial distribution of the unit h taxa regarding the skeletal regions. Cr: cranial, Ax: axial, Ap: appendicular, Co: coprolites.

| Taxa | | Topography | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 25D | 25E | 25F | 27D | 27E | 27F | 29D | 29E | 29F | 31E | 31F | 33E | 33F | 35E | 35F |
| *Ursus spelaeus* | Cr | 3 | 3 | 1 | | 5 | 1 | 1 | 1 | 1 | | 2 | 3 | 5 | | 3 |
| | Ax | 33 | 5 | 38 | 8 | 55 | 39 | 1 | 65 | 34 | 49 | 3 | 51 | 74 | | 27 |
| | Ap | 25 | 74 | 34 | 8 | 58 | 37 | 9 | 7 | 22 | 62 | 39 | 53 | 86 | 2 | 38 |
| *Canis lupus* | Cr | | | | | | | | | | | | | | | 2 |
| | Ax | | 1 | 1 | | | | | 2 | | 1 | | | 1 | | 3 |
| | Ap | | 2 | 3 | | | | | | | | | | 5 | | 2 |
| *Vulpes vulpes* | Cr | | 1 | 1 | 1 | 2 | | | | | 1 | 2 | | 8 | | 2 |
| | Ax | | | | | | | 1 | | | 2 | | | 1 | | 2 |
| | Ap | 1 | 1 | 2 | | 3 | 5 | 1 | 2 | | | 1 | | 11 | | 3 |
| *Panthera pardus* | Cr | | 1 | | 3 | 6 | 3 | | | | | | | 1 | | |
| | Ax | | 8 | 1 | | 3 | 5 | | 1 | 2 | | | | 5 | | |
| | Ap | 1 | 4 | 1 | 1 | 4 | 2 | | | | 1 | | | | | |
| *Crocuta* sp. | Cr | | | | | | | | | | | | | 1 | | |
| | Ap | | 2 | | | 1 | | | | | 1 | | | | | |
| | Co | 3 | 3 | 1 | | 1 | 5 | 2 | 3 | | 2 | 4 | 1 | 2 | | |
| *Cuon alpinus* | Cr | 1 | | 1 | | | | | | | | | | | | |
| *Meles meles* | Ap | | | | | | | | | | | | | | | 1 |
| *Martes* sp. | Ap | | | | | | | | | | | | | 1 | | |
| Caprinae | Cr | 1 | | | | | | | | | | | | 1 | | |
| | Ap | 2 | 2 | 6 | 1 | 1 | | 1 | 2 | 2 | 1 | 2 | | 6 | | 2 |
| *Cervus elaphus* | Cr | | 1 | | | | | | | 1 | | | | | | |
| | Ap | 4 | 7 | 2 | | 3 | 7 | 1 | 2 | 3 | 2 | 1 | | 3 | | 1 |
| *Bos/Bison* | Cr | | | | | | | | | | | 1 | | | | 1 |
| | Ap | | 1 | | | | | | 2 | | | 3 | | 1 | | |
| *Coeolodonta* cf. *antiquitatis* | Ap | | | | | | | | | 1 | | | | | | |
| *Equus* sp. | Ap | | 1 | | | | | | | | | | | | | |
| *Lepus capensis* | Ap | | | 1 | | | | | | | | | | | | 1 |
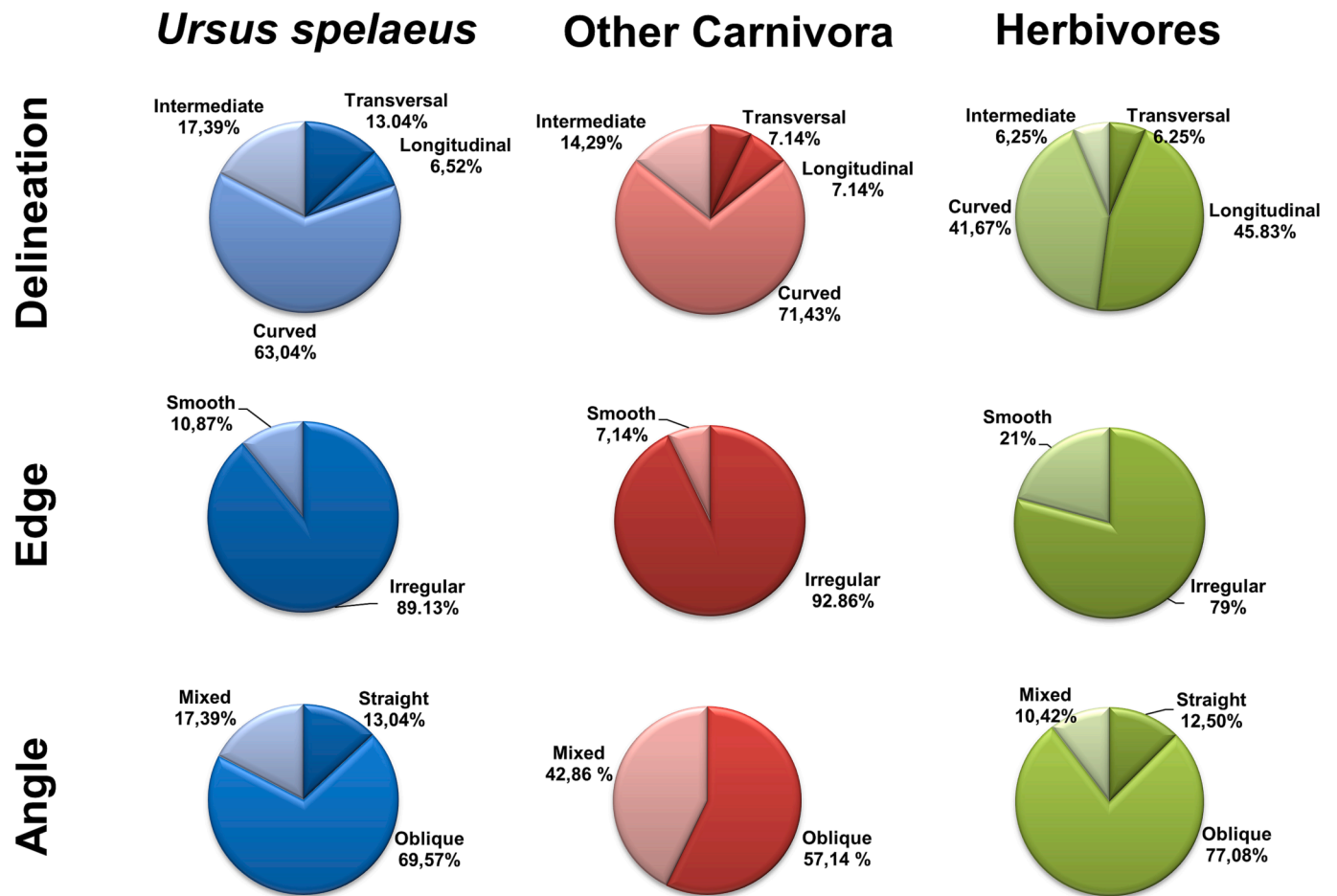


**Fig. 14.** Breakage pattern of the unit h bone assemblage according to the typology of the fracture delineation, edge and angle and distributed by the affected groups.
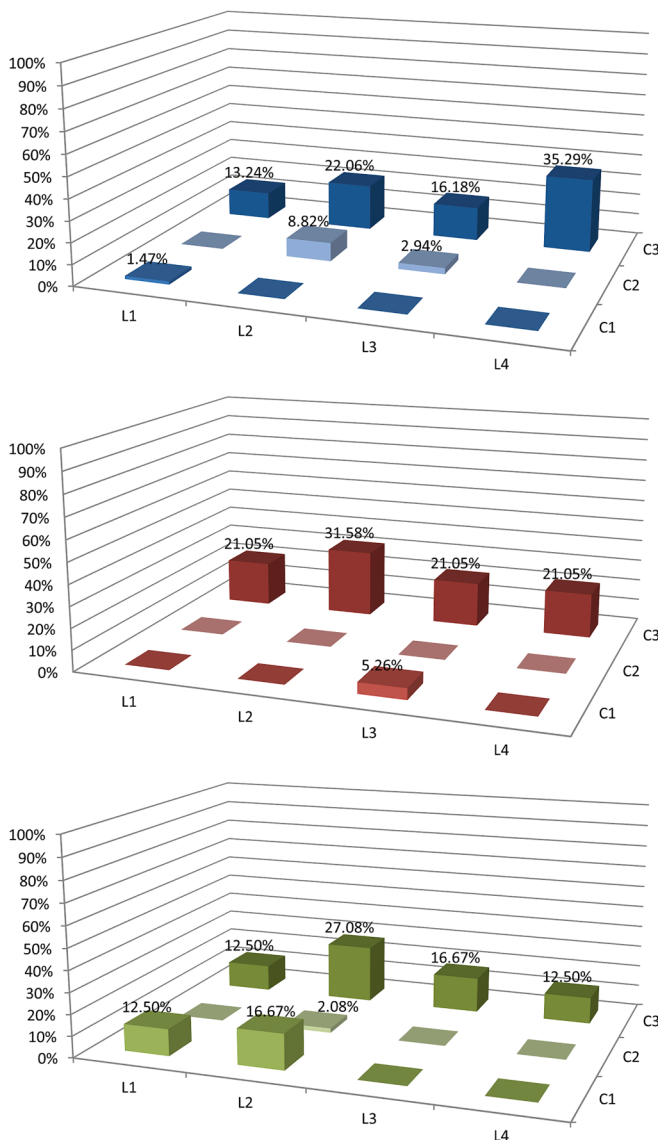
**Fig. 15.** Distribution of the circumference of the shaft preserved on the fractures described. Top: *Ursus spelaeus*; middle: other Carnivora taxa; bottom: herbivores.

observed two different trends regarding the type of marks and their size affecting adults and juveniles (Table 13). In adults, the most abundant were type C (pits and punctures on epiphysis, 65.49 %), which were especially numerous on the humerus and femur. In contrast, type A (pits and punctures on diaphysis) were far less common, at 5.63 %. Scores (types B and I) were less frequent but more abundant on epiphysis than on diaphysis (8.45 % vs 4.23 %). Finally, notches on transversal fractures were more frequent than those on curved fractures (13.38 % 2.82 %). No notches on longitudinal fractures were described. The most common typology in juveniles was type B (scores on diaphysis, 40 %), while pits and punctures were far less common and more abundant on diaphysis than on epiphysis (15 % vs 10 %). This was related to a remarkable absence of epiphyses on the cave bear juvenile remains described. Also, it is directly related to the size of the more frequently registered marks (Table 14). In adults, the most common size categories were II (2.5–5 mm, 30.28 %), III (5–7 mm, 26.06 %), and I (<2.5 mm, 23.94 %). Pits and punctures (types A and C) were spread through all size categories, but it must be outlined that inside size VI (>11 mm), it represented 69.23 %. Scores were mainly located in size I (61.11 % of types B and I), with those placed on diaphysis (type B) at 11.76 % of size

I and on epiphysis (type I) at 26.47 %. Finally, notches (types D, E and F) were 16.2 % of all toothmark types, distributed through all the size categories but size I. Remarkably, 30.77 % of size VI marks were notches, but due to these typologies being associated with fractures, those are not the most reliable types to guess the agent's size causing them.

In juveniles, the results differed from the adult ones. The most common size was I (<2.5 mm, 55 %), followed by size II (2.5–5 mm, 30 %). This is related to the abundance of scores (types B and I) because, by definition, they are narrower than pits and punctures. On juveniles, these were 72.72 % of the size I toothmarks; inside it, those located on diaphysis (type B) were 68.18 % (vs 4.54 % on epiphysis). Pits and punctures were poorly represented by comparison, with six of them described on diaphysis vs four on epiphysis. Interestingly, those pits and punctures located on diaphysis fall in size categories I and II (<2.5–5 mm), while those on epiphysis are distributed on sizes III, IV and VI (>5 to >11 mm). This fact increases the average size of the pits and punctures on juveniles over those on adults.

## 4. Discussion

### 4.1. Paleontology: Taxonomy and Ursus spelaeus population

All identified taxa from the unit h were common in Eurasia during the Upper Pleistocene (Kurtén, 1968). The environment associated with the herbivore species identified ranges from prairies to woodlands and even high mountain conditions. On the carnivore's side, we could find a similar range with representative species of different hunting and social behaviour patterns. *U. spelaeus* and hyenas were habitual in faunal assemblages from Eurasian karst environments (Kurtén, 1976; Musil, 1980; Chauvet et al., 1996; Stiner et al., 1996; Baryshnikov, 1998; Rabeder, 1999; Rabeder et al., 2000; Baryshnikov, 2007). Leopards were described as a species with a wide range distribution (Kurtén, 1968) and as bone accumulators (Sauqué, 2015).

Cave bears (*Ursus deningeri* and *Ursus spelaeus sensu lato*) were relatively common in Pleistocene Eurasian karst environments. In the Iberian Peninsula, their presence was mainly circumscribed to the northern half of that territory, distinguishing five main areas of distribution (Torres, 1988; Torres et al., 2014) and reaching high mountain environments (Rabal-Garcés, 2013; Rabal-Garcés and Sauqué, 2017), ranging from Middle Pleistocene to 24,000 yr (Dabney et al., 2013; Grandal-d'Anglade and Vidal-Romaní, 1997). *U. spelaeus* seemed particularly attached to karst compared to brown bears, and some authors point out that it could obey behavioural causes (Villaluenga, 2009; García-Vázquez et al., 2015). The simultaneous presence of both species was infrequent, and when it occurred, brown bears seemed to prefer mountainous regions, while *U. spelaeus* thrived in lower regions (García-Vázquez et al., 2015). Some authors (Bocherens et al., 2011) suggested even a niche partition and a slight deviation in their dietary habits, with a tendency to hipercarnivorism, affecting the brown bears where they cohabited with *U. spelaeus* – species considered mainly herbivores. *U. spelaeus* have been described in caves where they were the exclusive dwellers, such as Coro Tracito (Huesca, Spain) (Rabal-Garcés, 2013) or sharing the space with other species and even human beings, such as Las Caldas (Asturias, Spain) (Corchón, 2014) or Valdegoba (Burgos, Spain) (Díez et al., 2014).

The *U. spelaeus* population of Abauntz was described through well-defined traits and contained thirteen individuals at least. The mortality studied through the age classes match the attritional profile. As previously cited, senile and immature were dominant in the population, which made sense considering they were the most vulnerable members. Combining different approaches lies in the possibility of splitting between the age classes (immature, prime adult and senile) and inside them for better accuracy. Regarding that, it is necessary to outline that inside Stage I (immature), cohort 3 dominates over any other. This cohort represents the late juvenile individuals, so we could infer that

**Table 8**
Specimen bones (NISP) affected by toothmarks according to the type of bone and taxa.

| | Ursus spelaeus | Caprinae | Cervus elaphus | Bos/ Bison | Lepus capensis | Canis lupus | Panthera pardus | Vulpes vulpes | Crocuta sp. | Martes sp. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Skulls | | | 1 (2) | | | | | | | | |
| Mandibles | | | | | | | | 1 (4) | | | |
| Atlas | | | | | | 1 (1) | | | | | |
| Axis | | | | | | 1 (2) | | | | | |
| Ribs | 11* | | | | | 5 (6) | | | | | |
| Vertebrae | 34 (151) | | | | | | 3 (21) | | | | |
| Sacrum | | | | | | | 1 (1) | | | | |
| Esternebrae | 2 (8) | | | | | | | | | | |
| Scapulae | 4 (27) | 3 (4) | 1 (2) | | | | | 1 (2) | | | |
| Pelvis | 3 (12) | | | | | | | 1 (2) | | | |
| Humerus | 16 (19) | 2 (3) | 2 (2) | | 1 (1) | 2 (2) | | 3 (4) | | | |
| Ulnae | 16 (23) | | | | | | | | | 1 (1) | |
| Radius | 12 (15) | 4 (4) | | | | 1 (1) | | | | | |
| Femur | 13 (14) | 1 (2) | 5 (5) | 2 (3) | | 1 (1) | | | 1 (1) | | |
| Tibiae | 12 (12) | 1 (3) | 3 (6) | | | 1 (3) | | 1 (2) | | | |
| Fibulae | 6 (14) | | | | | | | | | | |
| Carpal/ Tarsal | 7 (66) | | | | | | | | | | |
| Astragalus | 5 (13) | | | | | | | | | | |
| Calcaneus | 2 (7) | 1 (1) | | | | | | | | | |
| Metacarpal | 4 (41) | 1 (1) | 1 (2) | 1 (1) | | 1 (1) | | 2 (2) | | | |
| Metatarsal | 7 (46) | 1 (1) | | 1 (1) | | | | 1 (2) | | | |
| Metapodial | 1 (7) | 1 (2) | 1 (2) | 1 (1) | | | | | | | |
| Phalanx | | | 6 (9) | 1 (1) | | | | | | | |
| Total | 155 (1506) | 15 (38) | 20 (39) | 6 (9) | 1 (2) | 12 (23) | 9 (53) | 7 (63) | 1 (5) | 1 (1) | 227 (1739) |

In hyphens the total amount of specimens described. *total amount of *Ursus spelaeus* ribs are not included due to the high fragmentation.

those animals were juveniles who just left their mother's care and collapsed during their first winter alone due to failing to accumulate enough fat for hibernating purposes (Stiner, 1998; Weinstock, 2000). Also, they were more vulnerable to predator attacks than any adult. We split the adults into two stages: prime adult and senile (Fig. 8). In this case, we observed that senile individuals were more abundant than prime adults. Again, we could infer that those individuals were so old that they could not feed themselves properly, as their eroded teeth assessed, and could collapse during hibernation. The age distribution of most *U. spelaeus* sites in the Iberian Peninsula shows a significant dominance of juvenile groups (newborns, cubs, and juveniles) (Torres et al., 2005). According to Torres et al. (2005), the only exception to that trend is the Arrikrutz population, which shows an adult's dominance. In the case of Abauntz, the dominance is split between late juveniles and the senile individuals who place our assemblage in an intermediate position relating to the mortality profile but stands as a rarity in the Iberian Peninsula frame. The sexual dimorphism distribution is remarkably dominated by males, as stated in Section 3.2.1.2. As previously pointed out, not every skeletal element of *U. spelaeus* reflects sexual dimorphism evenly, but the statistical approach allowed observing a trend. Again, the Abauntz population stands out of the general tendency in the Iberian Peninsula, whose *U. spelaeus* population were usually dominated by females (Torres et al., 1991; Grandal-d'Anglade, 1993). We could presume the presence of immature individuals in Abauntz was linked to females and, given the abundance of males in the assemblage, it could be inferred that the accumulation of their bones took a long time to produce, if no more complex social behaviour is considered, as suggested by Grandal-d'Anglade et al. (2018).

*4.2. Taphonomy: Skeletal survival ratio, spatial distribution and breakage pattern*

The results of the breakage pattern study (Fig. 14) were very homogeneous, with the curved delineation, the irregular edge and the oblique angle of the fractures dominating the sample, even if we considered the slight discrepancy present on herbivore bones (longitudinal delineation 46 % vs curved delineation 42 %). According to

different authors (Lyman, 1994; Villa and Mahieu, 1991), complete diaphysis and curved delineated fractures are common in post-depositional environments. This effect can also be caused by diverse factors, including falling, trampling or anthropic action (Lyman, 1994). The fact that the *Cervus elaphus* remains presented more longitudinal fractures than any other taxa didn't imply that they were affected by anthropic activity. Carnivores usually affect epiphyses with the gnawing activity, but once the epiphyses are removed, the long bone diaphysis can collapse, producing longitudinal fractures (Lyman, 1994).

The survival of anatomical elements sheds some light on the herbivore's side, showing the lack of axial elements in the assemblage. This phenomenon is related to predatory activity, and as such, it could be inferred that the presence of herbivores inside the cavity is the effect of the carnivores' accumulation (Lyman, 1994). Conversely, the Carnivora taxa preserved the three anatomical regions but significantly differed in the axial vs appendicular ratio. *U. spelaeus* skeleton preserved more axial than appendicular elements, while in the other Carnivora taxa, it was the opposite. A possible explanation for this could be related to the size, shape and weight of the *U. spelaeus* bones, making them less susceptible than lighter taxa to post-mortem dispersal by non-anthropic or carnivore's actions. Regarding to that, the presence of gravel pockets in the unit h was interpreted as the action of water flows inside the cavity during the formation of the stratigraphic level (Mazo et al., 2012). Again, the lack of data related to the location and placement of the remains prevents us for further conclusive insights.

The outstanding presence of *U. spelaeus* inside the cavity may be related to the diffuse pattern shown by the spatial distribution. Previously to the hibernation period, bears could alter the soil to accommodate it as a 'bed' (Koby, 1953; Philippe and Fosse, 2003; Quilès et al., 2006). Moreover, *U. spelaeus*' anatomy showed more robust forelimbs than other ursids (Torres, 1988), making them more capable of quickly altering the soil. All these combined factors help to draw an image of the accumulation of the assemblage inside the cave during the MIS 3. First, *U. spelaeus* played a major role in the accumulation as a passive accumulator and possibly affected the spatial distribution and the breakage pattern of the assemblage through soil alterations and trampling. Their demise inside the cavity was probably related to their collapsing during

**Fig. 16.** Herbivore bones affected by carnivore toothmarks. 1, *Cervus elaphus* right femur (Ab 25D.496.43) with pits, punctures, and scores on lateral side view; 2, *Cervus elaphus* right femur (Ab 25D.496.43) on ventral view; 3, *Bos/Bison* right femur (Ab 31F.532.67) with pits, punctures, scores and furrowing on lateral side view; 4, *Bos/Bison* right femur (Ab 31F.532.67) on medial side view.

**Table 9**

Skeletal segments affected by toothmarks according to the NISP.

|  |  | *Ursus spelaeus* |  | Carnivora |  | Herbivores |  | Total |  |
|---|---|---|---|---|---|---|---|---|---|
| Cranial |  |  |  | 1 |  | 1 |  | 2 |  |
| Axial |  | 47 |  | 11 |  |  |  | 58 |  |
| Appendicular | Girdles | 108 | 7 | 18 | 3 | 41 | 4 | 167 | 14 |
|  | Stylopodial |  | 29 |  | 7 |  | 13 |  | 49 |
|  | Zeugopodial |  | 46 |  | 4 |  | 8 |  | 58 |
|  | Basipodial |  | 14 |  |  |  | 1 |  | 15 |
|  | Metapodial |  | 12 |  | 4 |  | 8 |  | 24 |
|  | Acropodial |  |  |  |  |  | 7 |  | 7 |
| Total |  | 155 |  | 30 |  | 42 |  | 227 |  |

The second column indicates the NISP affected in the areas inside the appendicular skeleton.

**Table 10**

Total amount of toothmarks described according to the taxa and typology.

| Taxa | Pitting | Scoring | Crenulated edge | Furrowing | Scooping out | Score | Pit | Puncture | Impact point | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| *Ursus spelaeus* | 77 | 26 | 20 | 72 | 18 | 37 | 108 | 110 | 4 | 472 |
| Caprinae | 11 | 11 | 3 | 4 | 1 | 3 | 4 | 0 | 0 | 37 |
| *Cervus elaphus* | 9 | 12 | 3 | 9 | 0 | 11 | 17 | 11 | 0 | 72 |
| *Bos/Bison* | 3 | 3 | 0 | 3 | 0 | 0 | 9 | 20 | 0 | 38 |
| *Lepus capensis* | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 2 | 0 | 4 |
| *Canis lupus* | 11 | 3 | 1 | 4 | 0 | 4 | 6 | 5 | 0 | 34 |
| *Panthera pardus* | 4 | 2 | 1 | 5 | 0 | 1 | 2 | 1 | 0 | 16 |
| *Vulpes vulpes* | 5 | 3 | 2 | 2 | 0 | 0 | 3 | 6 | 0 | 21 |
| *Crocuta* sp. | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 3 |
| *Martes* sp. | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 |
| Total | 121 | 60 | 30 | 102 | 19 | 58 | 149 | 156 | 4 | 699 |

**Table 11**

Pits and punctures measurements registred according to Bunn (1986) bodymass classification.

| Pits and punctures on epiphyses |  |  |  |  |  |
|---|---|---|---|---|---|
| Type | Mayor axis |  | Minor axis |  | N |
|  | m | sd | m | Sd |  |
| 2 | 3,51 | 1,81 | 2,73 | 1,29 | 14 |
| 3A | 7,56 | 4,24 | 6,15 | 2,50 | 17 |
| 3B | 7,59 | 5,31 | 5,49 | 3,37 | 89 |
| 4 | 6,94 | 3,71 | 4,98 | 1,91 | 26 |

M = mean, sd = standard deviation, N = number of the sample.

hibernation rather than the result of predatory activity, and the toothmarks were most likely produced by the scavenger's activity. Second, the anthropic activity has been minimised due to the lack of links between the osteological assemblage and the lithic tools. Finally, the remarkable presence of toothmarks on the assemblage, which directly relates to carnivores' activity on the bones as active accumulator agents, indicates the other major role played by other Carnivora taxa.

### 4.3. Taphonomy: Morphometry of toothmarks on cave bear bones

Our results have been compared to others from different caves in the Iberian Peninsula (Rabal-Garcés et al., 2012) (Fig. 17). Abauntz results were located on the average of the samples compared, with adults slightly more affected by toothmarks than juveniles. Regarding the most common typology type described in adults, pits and punctures on epiphysis (C type) dominated the trend in all cases. On the contrary, the Abauntz sample showed more notches on transverse fractures than curved ones, which is the trend in other caves. Regarding toothmarks on juvenile *U. spelaeus*, the Abauntz sample showed a predominating B-type toothmarks proportion (scores on diaphysis, 40 %), which were not found in other locations (Tito Bustillo, Eiros or Coro Tracito). A possible explanation could be related to the absence of epiphyses on juveniles and a smaller sample (N 40), so it could not be statistically significant.

**Table 12**

Total amount of cave bear's long bones specimens affected by toothmarks according to Pinto-Llona et al. (2005) analysis.

| Bone | Age | Complete |  | Proximal |  | Distal |  | Epiphysis P |  | Epiphysis D |  | Diaphysis |  | N |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | L | R | L | R | L | R | L | R | L | R | L | R |  |  |
| Humerus | a | 1/3 | 1/1 | 0 | 1/1 | 2/3 | 2/3 | 1/1 | 2/2 | 0 | 0/1 | 0 | 1/1 | 11/16 | 12/19 |
|  | j | 0 | 0/2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1/1 | 1/3 |  |
| Ulna | a | 1/5 | 1/4 | 1/1 | 1/1 | 0/1 | 0 | 0 | 0/1 | 0/2 | 0/2 | 0/1 | 0 | 4/18 | 7/23 |
|  | j | 0 | 0 | 1/3 | 0 | 0 | 1/1 | 0 | 0 | 0 | 0 | 0 | 1/1 | 3/5 |  |
| Radius | a | 0/4 | 0/2 | 0 | 1/2 | 0 | 0/1 | 0 | 0 | 0 | 0 | 0 | 1/1 | 2/10 | 4/15 |
|  | J | 1/4 | 1/1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2/5 |  |
| Femur | a | 0 | 2/2 | 1/1 | 2/2 | 0 | 1/2 | 1/1 | 0/1 | 0/1 | 0/1 | 0 | 0 | 7/11 | 9/14 |
|  | J | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1/1 | 1/2 | 2/3 |  |
| Tibia | a | 0 | 2/2 | 0/1 | 0 | 0 | 2/2 | 1/1 | 0 | 0/1 | 0/1 | 0 | 0 | 5/8 | 6/12 |
|  | J | 0 | 0/1 | 0/1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1/1 | 0/1 | ¼ |  |
| Total a |  |  |  |  |  |  |  |  |  |  |  |  |  | 29/63 | 38/83 |
| Total j |  |  |  |  |  |  |  |  |  |  |  |  |  | 9/20 |  |

Complete: specimen complete or almost complete; proximal: specimen of proximal epiphysis plus part of the diaphysis; distal: specimen of distal epiphysis plus part of the diaphysis; epiphysis P: specimen of isolated proximal epiphysis; epiphysis D: specimen of isolated distal epiphysis; diaphysis: specimen of isolated diaphysis. age: a = adult (includes subadult); j = juvenile (includes infantile and newborn, if applies). N: number of the sample; L: left; R: right.

**Table 13**
Total amount of toothmarks distributed by the affected bone and the typology of the toothmark according to Pinto-Llona et al. (2005) analysis.

| Bone | Age | S | Sa | A | B | C | D | E | F | I | N | Sa/S | MDS |
|------|-----|---|----|---|---|---|---|---|---|---|---|------|-----|
| Humerus | a | 16 | 11 | 1 | 2 | 44 | 4 | 1 | 0 | 2 | 54 | 68,75 % | 4,91 |
| | j | 3 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 33,33 % | 2,00 |
| Ulna | a | 18 | 4 | 4 | 0 | 9 | 0 | 0 | 0 | 2 | 15 | 22,22 % | 3,75 |
| | j | 5 | 3 | 4 | 3 | 3 | 0 | 2 | 0 | 0 | 12 | 60,00 % | 4,00 |
| Radius | a | 10 | 2 | 2 | 0 | 0 | 0 | 7 | 0 | 0 | 9 | 20,00 % | 4,50 |
| | j | 5 | 2 | 0 | 1 | 1 | 2 | 1 | 0 | 2 | 7 | 40,00 % | 3,50 |
| Femur | a | 11 | 7 | 0 | 0 | 30 | 0 | 7 | 0 | 8 | 45 | 63,64 % | 6,43 |
| | j | 3 | 2 | 2 | 12 | 0 | 0 | 2 | 0 | 0 | 16 | 66,67 % | 8,00 |
| Tibia | a | 8 | 5 | 1 | 4 | 10 | 0 | 4 | 0 | 0 | 19 | 62,50 % | 3,80 |
| | j | 4 | 1 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 3 | 25,00 % | 3,00 |
| Total a | | 63 | 29 | 8 | 6 | 93 | 4 | 19 | 0 | 12 | 142 | 46,03 % | 4,90 |
| Total j | | 20 | 9 | 6 | 16 | 4 | 2 | 10 | 0 | 2 | 40 | 45,00 % | 4,44 |
| Total | | 83 | 38 | 14 | 22 | 97 | 6 | 29 | 0 | 14 | 182 | 45,78 % | 4,79 |

Age: a = adult (includes subadult), j = juvenile (includes infantile and newborn, if applies). S: total amount of specimens; Sa: total amount of specimens affected by toothmarks; MDS: mean density of toothmarks by specimen affected. A: pits and punctures on diaphysis, not on fractured edges; B: scores on diaphysis; C: pits and punctures on epiphysis; D: notches on curved or spiral fracture; E: notches on transverse fracture; F: notches on longitudinal fracture; I: scores on epiphysis or on fractured edges.

**Table 14**
Total amount of toothmarks according to the category size and the toothmark tipology.

| Size | Age | A | B | C | D | E | F | I | N |
|------|-----|---|---|---|---|---|---|---|---|
| I (≤2,5mm) | a | 2 | 4 | 19 | 0 | 0 | 0 | 9 | 34 |
| | j | 3 | 15 | 0 | 0 | 3 | 0 | 1 | 22 |
| II (>2,5–5 mm) | a | 3 | 2 | 29 | 1 | 8 | 0 | 0 | 43 |
| | j | 3 | 1 | 1 | 1 | 5 | 0 | 1 | 12 |
| III (>5–7 mm) | a | 2 | 0 | 28 | 0 | 5 | 0 | 2 | 37 |
| | j | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 2 |
| IV (>7–9 mm) | a | 1 | 0 | 5 | 0 | 3 | 0 | 1 | 10 |
| | j | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 2 |
| V (>9–11 mm) | a | 0 | 0 | 3 | 0 | 2 | 0 | 0 | 5 |
| | j | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| VI (>11 mm) | a | 0 | 0 | 9 | 3 | 1 | 0 | 0 | 13 |
| | j | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 2 |
| Total | a | 8 | 6 | 93 | 4 | 19 | 0 | 12 | 142 |
| | j | 6 | 16 | 4 | 2 | 10 | 0 | 2 | 40 |
| | | 14 | 22 | 97 | 6 | 29 | 0 | 14 | 182 |

Also, we must consider that those caves were mono-specific sites while other Carnivora taxa have been described in unit h of Abauntz. In that sense, the toothmark density in unit h was higher than in most sites, excluding Troskaeta, which was similar.

Regarding the score marks, there was a double trend in mono-specific sites; on some of them (Troskaeta and Coro Tracito), they were remarkable, while in others (Tito Bustillo and Eiros), they were hardly noticeable. Abauntz's results were closer to those of the former group. Altogether, these results suggested the activity of different carnivores on the unit h bone assemblage, which correlates to the other taxa described.

As mentioned, the most common size type in unit h is II (2.5–5 mm), like the Arrikrutz site, where other taxa than *U. spelaeus* were described (Fig. 18). However, it was remarkable the prevalence of the most significant size type of marks (size VI, >11 mm) in Abauntz (8.91 % in adults, 10 % in juveniles) compared to other sites (5.34 % in Tito Bustillo), showing a very different pattern. In mono-specific sites like Tito Bustillo, Eiros and Coro Tracito, the combination of type and size of the toothmarks was inferred as a possible scavenger behaviour of *U. spelaeus* (Pinto-Llona et al., 2005; Rabal-Garcés et al., 2012), species widely considered prone to a herbivore diet (Baca et al., 2016; Bocherens, 2019; Pérez-Ramos et al., 2020). Unfortunately, the presence of other Carnivora taxa in the assemblage prevented us from concluding it, or at least we must consider the intervention of various carnivores besides the ursids. Gnawing is supported by the analysis of the toothmarks presented in the surface of the bones following Pinto-Llona et al. (2005). We are aware that there is a differential destruction produced by the same
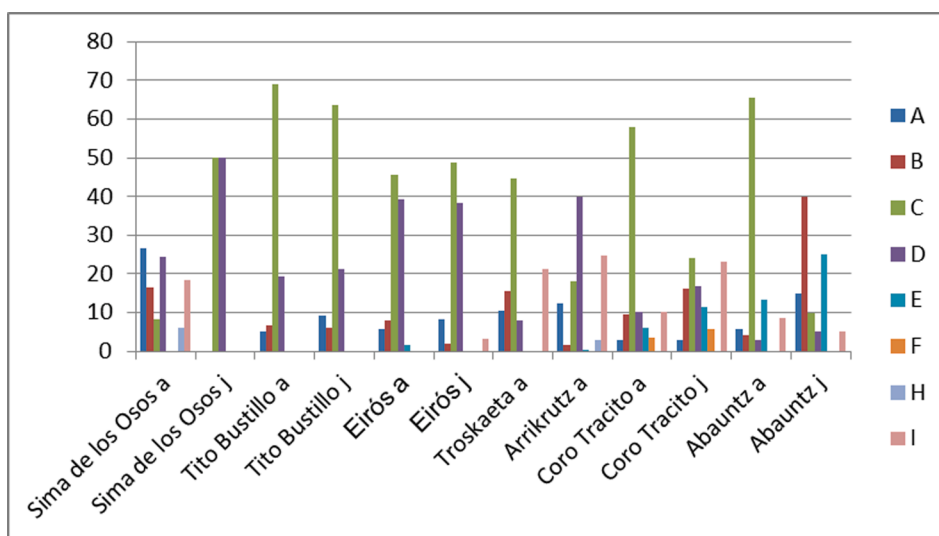


**Fig. 17.** Distribution of the toothmarks tipology according to the percentage that each one represents in different sites of the Iberian Peninsula. a: adult (includes subadult), j: juvenile (includes infantile and newborn, if applies).
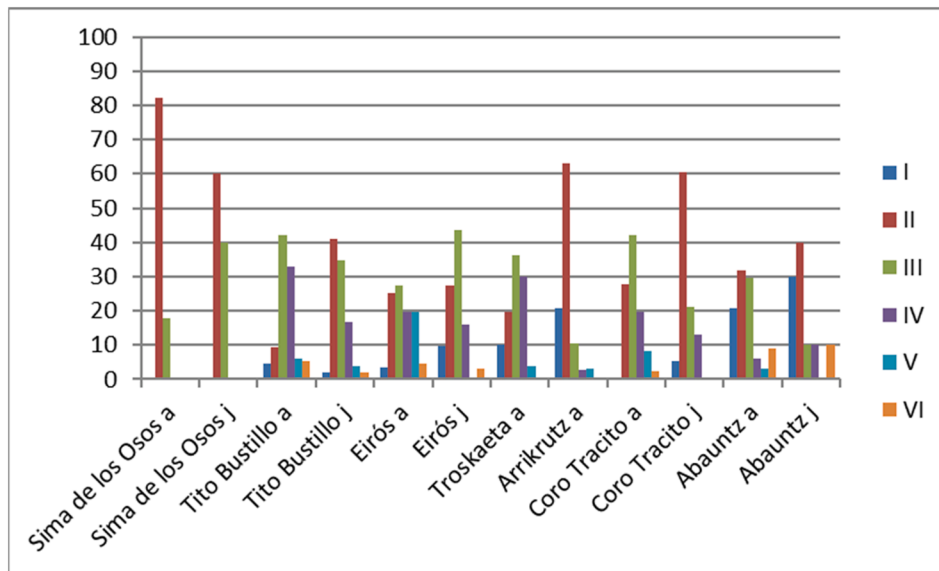
**Fig. 18.** Distribution of the toothmarks (only typologies A + C; pits and punctures on diaphysis and epiphysis respectively) size categories according to the percentage each one represent in different sites of the Iberian Peninsula. a: adult (includes subadult), j: juvenile (includes infantile and newborn, if applies).

carnivore taxon on subadult or adult elements of the same taxon, in this case we may suppose that scavenging activity of hyenas on cave bear remains, cannot have a similar result, inmature are systematically destroyed. Nevertheless, what is undeniable is some activity of large Carnivora taxa on the bone assemblage of the unit h.

### 4.4. Taphonomy: A comparison of the pits and punctures on the bone assemblage with extant mammal carnivores

In order to analyse the pits and punctures affecting the bone assemblage, we have considered the specimens according to the body mass categories (Bunn, 1986). The results showed two trends in the average size of the toothmarks (Fig. 19). The first affects the type 2 members (taxa under 100 kg according to Bunn, 1986), which showed marks with an average size like those made by current wolves, but also the results were in the higher range of the marks left by leopards. Anyway, we must consider that the width values of the pits and punctures affecting type 2 members of the unit h (m 2.73 mm) were in the frame where most of the extant carnivores' toothmarks overlap (Domínguez-Rodrigo and Piqueras, 2003). On the contrary, types 3 and 4 (taxa over 100 kg, according to Bunn, 1986) showed much bigger marks. The average value for the width of pits and punctures on *U. spelaeus* from unit h was 5.49 mm. This value was close to the 5.88 mm obtained in Coro Tracito (Rabal-Garcés et al., 2012). As we previously discussed, we could not establish the same conclusions regarding the possible scavenger behaviour of *U. spelaeus* because of the presence of other Carnivora taxa, but we cannot reject it either. In that sense, Cruz-Uribe (1991) established some factors to consider when analysing bone assemblages: time, weather, accumulator agents' behaviour and post-depositional process. Moreover, this author also established some criteria to determine if the accumulator agent were hyenas. Pickering (2002) reviewed them and, attending to different experiments, added two more factors to the criteria, which became the only ones currently accepted (Kuhn et al., 2010): the presence of juvenile hyena remains and coprolites from this taxon. In the unit h, 27 coprolites of *Crocuta* genus have been described. Thus, according to the results obtained, we had an assemblage of complex compositions in which various agents could be involved. Medium size canids were likely the central accumulator of bones from taxa lesser than 100 kg, but medium to large felids like leopards could be involved too because the average index for the toothmarks caused by these two groups overlap. *U. spelaeus* remains

inside Abauntz were most likely the result of animals collapsing during hibernation (Stiner, 1998; Weinstock, 2000), but they were affected by some post-depositional process through toothmarks. Some authors suggested possible scavenger behaviour in these species (Pinto-Llona and Andrews, 2003; Pinto-Llona et al., 2005; Rabal-Garcés et al., 2012), and thus, we should consider it too. Also, we have described the hyena as another possible accumulator agent for the unit h. None of those explanations are mutually excluded, so given the number of remains described, it could be inferred that the interactions inside the cave during the formation process of the unit h were more complex than previously thought.

### 4.5. Paleoenvironment and a possible Abauntz' occupation pattern during the MIS 3

In Abauntz, the presence of human beings, *U. spelaeus* and carnivores depict an interesting landscape and possible environmental relationships. In Moros de Gabasa (Huesca, Spain), a pattern was established for the cave occupation where these three groups were described in the Middle Paleolithic level (Blasco, 1995). It was suggested that human beings could have used the cave as a hunting halt during the summer, while *U. spelaeus* availed it as a winter shelter, with carnivores using the cave in unspecific periods. The abundance of the *U. spelaeus* remains, and the high proportion of their skeletal survival ratio supported this idea. If an individual collapsed during hibernation, it could be thought that any carnivore or scavenger around likely took advantage of it (Gargett, 1996; Stiner et al., 1996). We could infer a similar pattern for Abauntz occupation by these same agents but with a lower intensity of human activity. In the Ebro Basin, it has been described other caves with similar characteristics, such as level 8 of Cova de les Llenes (Rosell et al., 2014b). As we previously pointed out, human activity can affect the presence of carnivores in the assemblages. Such was the case of the Middle Paleolithic level of Lezetxiki (Gipuzkoa, Spain), where increasing anthropic activity reduced the carnivore's abundance (Álvarez-Alonso and Arrizabalaga, 2012).

On the contrary, human activity of lesser intensity could be affected by the action of ursids like *U. spelaeus*, as we previously suggested. The alteration of the soil by bears for hibernation purposes could contribute to blurring any print left by humans. Some examples of these effects near the Ebro Basin are level 1 of L'Arbreda (Girona, Spain) (Soler et al., 2014) and levels 2 and 3 of Teixoneres (Barcelona, Spain) (Rosell et al.,
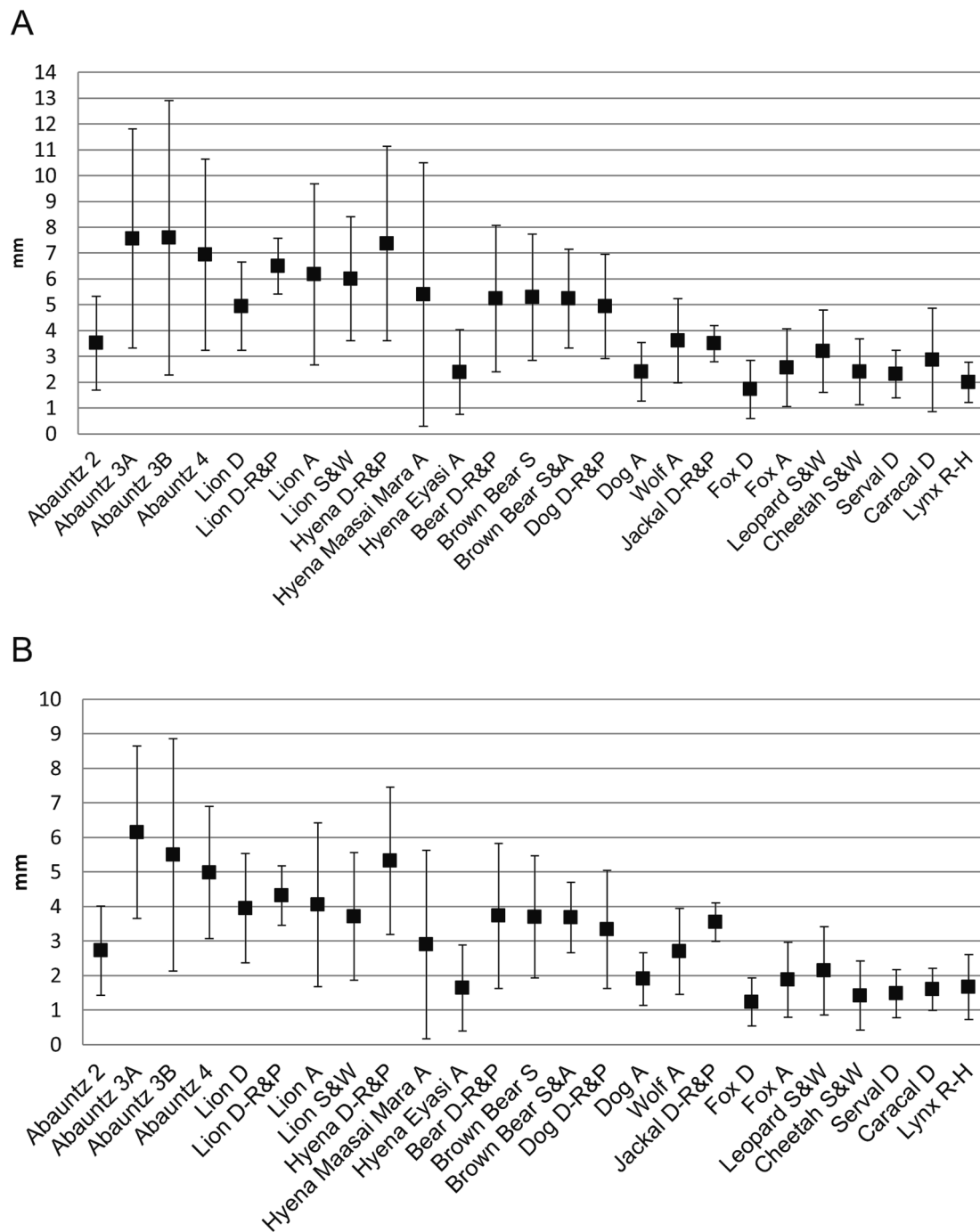
**Fig. 19.** Mean and standard deviation of the pits and punctures size described on the unit h taxa distributed according to the bodymass category (Bunn, 1986) and located on the epiphyses compared to the toothmarks left by different extant Carnivora taxa. Top: Mayor axis, Bottom: Minor axis. Abauntz 2: includes Caprinae, Canis lupus and *Ursus spelaeus* juvenile; Abauntz 3A: Cervus elaphus; Abauntz 3B: *Ursus spelaeus* adult; Abauntz 4: Bos/Bison; D: Delaney-Rivera et al., 2009; D-R&P: Domínguez-Rodrigo and Piqueras, 2003; A: Andrés et al., 2012; S: Saladié et al., 2011; S&A: Sala and Arsuaga, 2013; S&W: Selvaggio and Wilder, 2001; R-H: Rodríguez-Hidalgo et al., 2013.

2014a). In the unit h, the relationship to the distribution of the lithic assemblage found regarding the human occupation could not be established (Mazo et al., 2012), maybe because of its shortness. Similar circumstances were described in the Middle Paleolithic level of Mollet 3 (Girona, Spain) (Maroto, 2014). In that sense, in Teixoneres, it was suggested that the human population lived in small size groups which occupied the cave seasonally as they wandered through their territory, which could have allowed carnivores and bears to use the cave more frequently (Rosell et al., 2014a). Something similar could happen in the unit h of Abauntz. The faunal assemblage of the unit h contained more

quantity and variety of the order Carnivora taxa than any other archaeological level inside Abauntz (Altuna et al., 2001–2002; Blasco, 1995–1996; Mazo et al., 2012). Indeed, a relationship depending on human activity inside the cave and carnivores could be inferred as we compare it across the levels (Table 15). The abundance of human activities seems to affect the carnivores' presence negatively. It is interesting to highlight the human agent related to the activity regarding the species. In the unit h, Neanderthals were the most plausible creators of the lithic assemblage (Mousterian), meanwhile in younger levels, human activity should be assigned to Anatomically Modern Humans

(AMH) (Solutrean to postpaleolithic levels). Whether this should be related to the demography of the Neanderthal population around Abauntz during MIS 3 has to be determined. While there were at least four big predators in the unit h – hyena, leopard, wolf and dhole- only the wolf thrived in upper levels, joining some felids – the lynx and the wildcat from Solutrean to Calcolithic levels and the cave lion in the Middle Magdalenian level, which remarkable presence is merely supported because of one phalanx specimen. The unit h bone assemblage contains more than 2,300 remains from 8 Carnivora taxa. Even excluding the cave bear remains, the other Carnivora taxa build up over 250 remains, equivalent to all carnivore remains of the latter archaeological levels where the human presence has been assessed inside the cave.

## 5. Conclusions

The relevance of Abauntz goes further away than its discoveries (Utrilla et al., 2015). Abauntz's location is an excellent example of how humans and other animals use the landscape and environment; to the north, it is close to the Cantabrian Sea and also to the southern France prairies, while to the south, opens to the Ebro valley, a link to the Mediterranean sea. A testimony of that is the stratigraphic sequence of Abauntz which shows more than 50,000 years of human occupation, with astonishing finds such as those from the level e, like the only *Saiga tatarica* remains found in the Iberian peninsula, or the level f, with a

lithic tool assemblage that shows features interpreted as resembling Cantabrian and Mediterranean styles and techniques (Utrilla et al., 2015).

The bone assemblage of the unit h presented some characteristics that make it stand out over other faunal assemblages of Abauntz. The study of the faunal bone assemblage found in the unit h of the cave of Abauntz has resulted in the identification of 2,426 remains belonging to 14 different taxa and established an MNI of 33. *U. spelaeus* are the most predominant taxon over any other, followed by other Carnivora taxa and herbivores to a lesser extent. The biodiversity of the assemblage must be outlined as an environmental factor and could be considered along with the presence of human activity inside the cave.

The skeletal survival ratio of the *U. spelaeus* suggested that their presence inside the cave was due to them collapsing during hibernation, which contrasts with the herbivore's presence, even when their bones suffered post-depositional alteration expressed through toothmarks. Regarding that, two trends have been established related to the origin of the toothmarks. Taxa under 100 kg seemed to be affected by marks corresponding to predators like wolves or leopards, while heavier taxa show an index higher than toothmarks made by extant spotted hyenas and opens diverse possibilities. This implies that large Carnivora taxa, like hyenas, were likely involved in the post-depositional processes that affected to the bone assemblage but also the potential scavenger behaviour of the *U. spelaeus* has to be considered. The spatial distribution of the bone assemblage suggests possible soil alterations made by

**Table 15**
Biostratigraphy of the described taxa in the cave of Abauntz distributed according to the stratigraphic level they belong.

| Taxa | Unit H NR | Unit H MNI (a/i) | Level F NR | Level F MNI (a/i) | Level E NR | Level E MNI (a/i) | Level 2r NR | Level 2r MNI (a/i) | Level b4 NR | Level b4 MNI (a/i) | Levels b1 & b2 NR | Levels b1 & b2 MNI (a/i) | Level b0 NR | Level b0 MNI (a/i) | Level a NR | Level a MNI (a/i) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Lepus capensis* | 2 | 1 (1/-) | 9 | 2 (2/-) | 30 | 3 (2/1) | 1 | 1 (1/-) | 5 | 1 (1/-) | 11 | 3 (3/-) | | | | |
| *Erinaceus europaeus* | | | 2 | 1 (1/-) | | | | | 2 | 1 (1/-) | 4 | 2 (2/-) | | | | |
| *Sus scrofa* | | | 2 | 1 (-/1) | 4 | 1 (1/-) | 1 | 1 (1/-) | | | 65 | 5 (2/3) | | | | |
| *Sus* sp. | | | | | | | | | 7 | 2 (1/1) | | | | | | |
| *Sus domesticus* | | | | | | | | | | | | | | | 10 | 4 (2/2) |
| *Capreolus capreolus* | | | | | 1 | 1 (1/-) | | | 1 | 1 (1/-) | 1 | 1 (1/-) | | | 1 | 1 (-/1) |
| *Rangifer tarandus* | | | 1 | 1 (1/-) | 2 | 1 (1/-) | 1 | 1 (1/-) | | | | | | | | |
| *Cervus elaphus* | 49 | 3 (3/-) | 18 | 3 (1/2) | 91 | 5 (2/3) | 19 | 3 (2/1) | 2 | 1 (1/-) | 6 | 1 (1/-) | | | 2 | 1 (1/-) |
| *Saiga tatarica* | | | | | 6 | 1 (1/-) | | | | | | | | | | |
| *Bos taurus* | | | | | | | | | 3 | 1 (1/-) | 34 | 4 (2/2) | 4 | 2 (1/1) | 7 | 1 (1/-) |
| *Bovini* | | | 4 | 1 (1/-) | 27 | 4 (1/3) | 5 | 1 (1/-) | | | | | | | | |
| *Bos/Bison* | 9 | 1 (1/-) | | | | | | | | | | | | | | |
| *Ovis aries/Capra hircus* | | | | | | | | | | | 135 | 9 (4/5) | 8 | 4 (2/2) | 18 | 3 (1/2) |
| *Capra pyrenaica* | | | 13 | 3 (2/1) | 82 | 4 (3/1) | 23 | 1 (1/-) | 2 | 1 (1/-) | 3 | 1 (1/-) | | | | |
| *Rupicapra rupicapra* | | | 26 | 2 (2/-) | 186 | 10 (5/5) | 19 | 1 (1/-) | 2 | 2 (1/1) | | | | | | |
| Caprinae | 49 | 2 (2/-) | | | | | | | 13 | 1 (1/-) | | | | | | |
| *Equus caballus* | | | | | | | | | | | | | 1 | 1 (1/-) | | |
| *Equus* cf. *Gallicus* | | | 12 | 2 (1/1) | 120 | 4 (3/1) | 45 | 3 (2/1) | | | | | | | | |
| *Equus* sp. | 1 | 1 (1/-) | | | | | | | 6 | 2 (1/1) | 20 | 2 (1/1) | | | | |
| *Coelodonta antiquitatis* | 1 | 1 (1/-) | 1 | 1 (-/1) | | | | | | | | | | | | |
| **Felis silvestris** | | | | | 4 | 1 (1/-) | | | 1 | 1 (1/-) | 7 | 1 (1/-) | | | 1 | 1 (1/-) |
| **Lynx pardina** | | | | | | | | | 2 | 1 (1/-) | 9 | 2 (2/-) | | | | |
| **Panthera leo** | | | | | 1 | 1 (1/-) | | | | | | | | | | |
| **Panthera pardus** | 69 | 2 (2/-) | | | | | | | | | | | | | | |
| **Crocuta sp.** | 5 | 1 (1/-) | | | | | | | | | | | | | | |
| **Canis lupus** | 26 | 1 (1/-) | 2 | 1 (1/-) | 1 | 1 (1/-) | | | | | | | | | | |
| **Canis familiaris** | | | | | | | | | | | 9 | 4 (2/2) | 5 | 1 (-/1) | | |
| **Cuon alpinus** | 20 | 2 (2/-) | | | | | | | | | | | | | | |
| **Vulpes vulpes** | 85 | 4 (4/-) | 16 | 2 (2/-) | 163 | 7 (6/1) | 25 | 2 (2/-) | 4 | 2 (2/-) | | | | | 1 | 1 (-/1) |
| **Canidae** | | | | | | | | | | | | | | | 1 | 1 (1/-) |
| **Ursus arctos** | | | 2 | 1 (1/-) | 8 | 2 (1/1) | 2 | 1 (1/-) | | | | | | | | |
| **Ursus spelaeus** | 2053 | 13 (8/5) | | | | | | | | | | | | | | |
| **Martes martes** | | | | | | | | | 1 | 1 (1/-) | 2 | 2 (2/-) | | | 1 | 1 (1/-) |
| **Martes sp.** | 1 | 1 (1/-) | | | 1 | 1 (1/-) | | | | | | | | | | |
| **Meles meles** | 1 | 1 (1/-) | | | 4 | 1 (1/-) | | | | | 3 | 1 (1/-) | | | | |

NR: number of remains; MNI: minimal number of individuals, a: adult, I: inmature. Modified from Altuna et al. (2001–2002), Blasco (1995-1996), Mazo et al. (2012). In bold, the Carnivora taxa.

the *U. spelaeus*, diffusing or erasing any previously existing pattern.

There are two critical features to consider in the formation of lithic and osteologic assemblages during the MIS 3 in Abauntz: the variety of the agents causing them and the dominance of the *U. spelaeus*. As was discussed, the different agents (humans, bears, carnivores and herbivores) increase the complexity of the relationships and, therefore, any inference because of the side effects triggered. In any case, the abundance of *U. spelaeus* was vital for interpreting the analyses. For example, the presence of *U. spelaeus* defines the assemblage and the stratigraphy itself. However, they also affected the post-depositional process differently, potentially in its spatial distribution and breakage pattern. In that sense, the abundance of *U. spelaeus* directly relates to the scarcity of human activity in Abauntz during MIS 3. Finally, the carnivores' abundance in the unit h compared through the biostratigraphy to other archaeological levels (Altuna and Mariezkurrena, 1996; Altuna et al., 2001–2002; Blasco, 1995–1996; Mariezkurrena and Altuna, 1982, Mazo et al., 2012) could be inferred as an ecological indicator suggesting a lower impact of human activity around Abauntz during the MIS 3. The presence of human beings inside the cave of Abauntz during the MIS 3 has been assessed through the lithic assemblage (Mazo et al., 2012), but their relationship to bone accumulation should be minimised. The breakage pattern analysis showed a homogeneous result, and the spatial distribution of the bones suggested an unlikely relation to human activity. In that case, we could reduce the human occupation of the cave to a fruitful but exceptional episode for the unit h.

The occupation pattern of Abauntz during the MIS 3 could be widely explained as seasonal activities in which the different agents used the cave sequentially, with *U. spelaeus* hibernating when weather conditions got harsh and carnivores accessing it in undetermined moments of the year outside winters. In contrast, humans accessed it briefly and sporadically. As was previously mentioned, the presence of Neanderthals, proved through the lithic tools, with a lesser impact of the activity during the MIS 3 inside the cave, could be related to a low number of their population compared to the AMH later occupations of Abauntz.

## CRediT authorship contribution statement

**Víctor Jerjotoma-Ortín:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Data curation. **Gloria Cuenca-Bescós:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Carlos Mazo:** Writing – review & editing, Supervision.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

Data will be made available on request.

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## Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2024.104409.

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