

Historical Biology

An International Journal of Paleobiology

ISSN: 0891-2963 (Print) 1029-2381 (Online) Journal homepage: <http://www.tandfonline.com/loi/ghbi20>

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To cite this article: Víctor Sauqué , Alfred Sanchis & Joan Madurell-Malapeira (2017): Late Pleistocene leopards as a bone accumulator: taphonomic results from S'Espasa cave and other Iberian key sites, Historical Biology, DOI: [10.1080/08912963.2017.1343313](https://doi.org/10.1080/08912963.2017.1343313)

To link to this article: <http://dx.doi.org/10.1080/08912963.2017.1343313>



Published online: 04 Jul 2017.



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Late Pleistocene leopards as a bone accumulator: taphonomic results from S'Espasa cave and other Iberian key sites

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ABSTRACT

The Pleistocene faunal accumulations documented in caves have commonly been attributed to the activity of humans or carnivores. According to the palaeontological and archaeological literature, cave hyena (*Crocota spelaea*) was the main known bone accumulator in karstic environments. However, in recent times, the role of leopards as bone accumulators has been revealed, and recent research has identified this behaviour in the Iberian Pleistocene. Moreover, there are other caves where leopard could have been claimed as an accumulator such as S'Espasa. In this work we present its taphonomic study. This cave was compared with the actualistic studies of leopards. Besides, the site of S'Espasa was compared with the other leopard dens in the Iberian Peninsula. These sites present faunal assemblages composed mainly by leopard (*Panthera pardus*) and Iberian wild goat (*Capra pyrenaica*), the bones of this ungulate present a similar pattern of bone modification by carnivores, skeletal survival rate, and bone breakage. These features indicate that goats could have been accumulated by leopards. With the data from this work and the previous ones, we try to establish a pattern that will help in the future to identify other accumulations created by this big cat.

ARTICLE HISTORY

Received 28 February 2017
Accepted 13 June 2017

KEYWORDS

Panthera pardus; *Capra pyrenaica*; Taphonomy; Iberian Peninsula; Pleistocene

Introduction

Identifying the behaviour of bone collectors is a crucial aspect of taphonomic research, especially regarding archaeological studies of cave sites. Cave and rock shelters may have been occupied by various bone collectors including humans. Characteristic features of bone assemblages have been established, allowing animal-made bone accumulations to be distinguished from human-made assemblages at fossil sites (Cruz-Urbe 1991; Stiner 1991; Pickering 2002; Kuhn et al. 2010).

In this sense, Pleistocene faunal accumulations documented in caves have been normally attributed to the activity of humans or carnivores (Brain 1981; Blumenschine 1986, 1988; Fosse 1997; Mondini 1995, 2002, 2003; Diedrich 2011a, 2011b; Fourvel et al. 2014a, 2014b; Sauqué et al. 2014; Arriaza et al. 2016; Sala and Arsuaga, 2016). During the Late Pleistocene cave hyenas (*Crocota spelaea*, Goldfuss 1823) were the main non-anthropogenic accumulators of bone remains in caves (Fosse 1997; Diedrich 2014). As a consequence of their activity, hundreds of accumulations have been documented in European caves (Fosse 1997; Fosse et al. 1998; Diedrich and Žák 2006; Fourvel 2012; Diedrich 2014; Fourvel et al. 2014b). In the Late Pleistocene of the Iberian Peninsula, the cave hyena was a common element in large mammal assemblages, being recorded from numerous sites (Arribas

et al. 2010; Sauqué et al. 2017). However, in the last years other carnivores have been erected as possible accumulators such as dholes *Cuon alpinus* Pallas, 1811 (Morales et al. 2012; Mallye et al. 2012), red foxes *Vulpes vulpes* Linnaeus, 1758 (Krajcarz and Krajcarz 2014; Yravedra et al. 2014), lions *Panthera leo spelaea* Goldfuss, 1810 (Diedrich 2009; Arriaza et al. 2016) and leopards *Panthera pardus* Linnaeus, 1758 (Sauqué et al. 2014, 2016a, 2016b; Sauqué and Sanchis 2017).

During the fauna study of S'Espasa cave, a preliminary proposal was that the accumulation of herbivores may have been related to the activity of leopards (Estévez 1975–1976). The main goal of this work is to present the archaeozoological and taphonomic study of the herbivores found at this site, with the aim of determining the accumulation and modification agent of the bone remains, to thereby corroborate whether it was leopards or other bone accumulator.

S'Espasa cave: previous research

This cave is located close to the municipality of Sadernes (Alta Garrotxa, Girona) 370 masl in a ravine with vertical walls at a height of 35 m above the Oix river (Figure 1(a) and (b)). The access to the cave is complicated and it was discovered in 1973 by the *Grup Espeleològic d'Olot* who described and drew the elevation

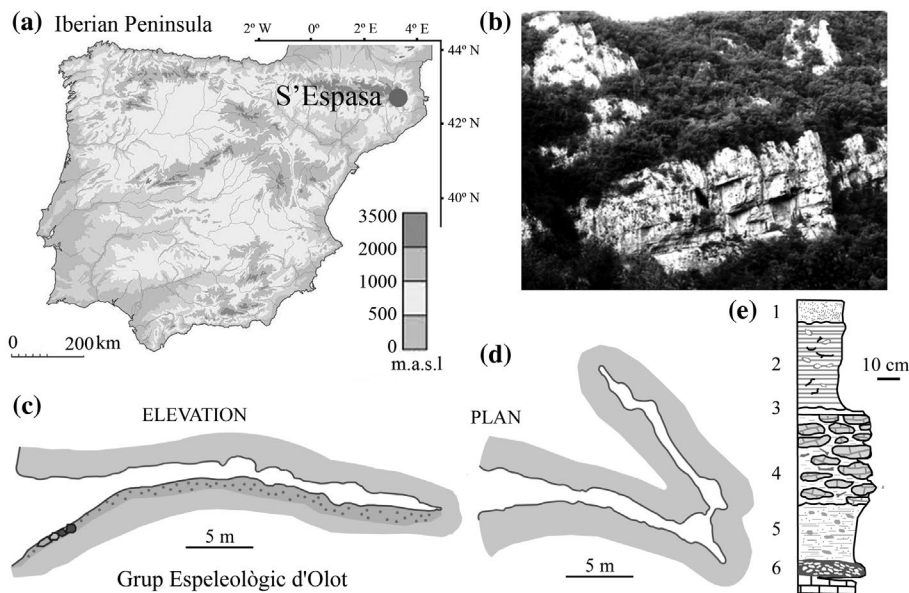


Figure 1. S'Espasa cave (a) Geographical location. (b) Panoramic view of the main entrance to the cave. (c) Elevation view. (d) Plan view. (e) Stratigraphic column of deposit in S'Espasa modified of Soler and Alcalde (1976). The parts c, d and e are modified from Soler and Soler (1978)

and plant (Figure 1(c) and (d)) of the cave and during this work they found pottery on the surface of the cave. Afterwards, J.M Mallarach visited the cave and drew a stratigraphic column (Figure 1(e)). During these works, six archaeological levels were distinguished (1–6), indicating the different depths. Levels 1–2 soil revealed prehistoric pottery. Level 3 is sterile. Level 4 presents a clay matrix and numerous limestone blocks (50 cm × 20 cm) and abundant Late Pleistocene fossil remains. Levels 5–6 are sterile (Figure 1(e)) (Soler and Soler 1978). The remains studied in this work have been recovered in level 4 in the previous study of Estévez, where the following taxa were identified: *Capra pyrenaica*, *Bos primigenius*, *Cervus elaphus*, *Panthera pardus*, *Vulpes vulpes*, *Lepus capensis*, *Oryctolagus cuniculus*, *Columba livia*, *Pyrrhocorax pyrrhocorax*, *Pyrrhocorax graculus*, *Corvus corvus*, *Corvus corax*, *Fringilla coelebs*, *Strix aluco* and *Bubo (Nyctea) scandiacus*. The fossil remains studied in the present paper are housed in the Museu de la Garrotxa (Olot).

The faunal association of level 4 S'Espasa indicates a probable age of Late Pleistocene. The earliest presence of the leopard in the Iberian Peninsula corresponds to the Middle Pleistocene levels of Lezetxiki (234 ky), although the vast majority of references come from the Late Pleistocene (Sauqué and Cuenca-Bescós 2013; Sanchis et al. 2015). The same is truth for *Capra pyrenaica*. It presents a wider distribution in the Iberian Peninsula during the Late Pleistocene (Yravedra and Cobo-Sánchez 2015). Furthermore, the binomial leopard and wild goat is characteristic in the Late Pleistocene of Iberian Peninsula sites (Sauqué and Sanchis 2017). In any case, the age of the 4 level from S'Espasa (Late Pleistocene) must be taken with caution because so far we do not have any radiometric age of this site.

Materials and methods

In order to quantify the S'Espasa remains, the number of remains (NR), number of identified specimens (NISF), minimum number

of elements (MNE) and individuals (MNI) were used. The anatomical representation of the different elements (%Surv) has been established in accordance with the studies of Brain (1981) and Lyman (1994). The age of death of the Iberian wild goat was determined using the criteria of Serrano et al. (2006) for the postcranial remains and Payne (1987) and Pérez Ripoll (1988) for the teeth. The age at death of the leopard was estimated by the state of tooth wear (Stander 1997).

Different types of carnivore tooth marks have been differentiated (pits, punctures, scores, furrowing, crenulated edges and impact points), according to the definitions of Haynes (1980), Brain (1981), Binford (1981) and Sala (2012). The measurements were taken with an electronic digital calliper. All measurements are given in millimetres. To identify the marks made by carnivores, they were compared to the data provided in the papers of Delaney-Rivera et al. (2009), Domínguez-Rodrigo and Piqueras (2003) and Saladié et al. (2011). To ascertain whether the bone fracture was caused perimortem or after its burial, as well as the possible causes of this fracture, the criteria proposed by Villa and Mahieu (1991) were adhered to. Furthermore, the fracture index is contemplated, which refers to the area of conserved diaphysis with regards the total length of said bone, both in terms of length and the circumference (see descriptions in Sauqué and Sanchis 2017). In order to study the fragmentation degree, Bunn (1983) has been followed. To distinguish the accumulations caused by carnivores from those of human origin, the criteria of Cruz-Urbe (1991), Pickering (2002), Kuhn et al. (2010), Domínguez-Rodrigo (1994a, 1994b), Fosse (1997), de Ruiter and Berger (2000), Domínguez-Rodrigo and Pickering (2010), Fourvel (2012), Sala (2012), Sauqué et al. (2014) and Sauqué and Sanchis (2017) have been followed.

The avian remains identified by Estévez (1975–1976) were not considered in this work.

Table 1. NISP (Number of Identified Specimens), MNE (Minimum Number of Elements), and Laterality by taxa from S'Espasa (level 4) faunal assemblage.

	<i>Panthera pardus</i>				<i>Capra pyrenaica</i>			
	NISP	MNE	Laterality		NISP	MNE	Laterality	
			Right	Left			Right	Left
Cranial								
Skull					9	1	1	
Mandible	1	1			7	6	3	3
Lower dentition								
c1	2	2	1	1				
p3					3	3	1	2
p4	1	1		1	5	5	2	3
m1	1	1		1	9	9	4	5
m2					11	11	7	4
m3					10	10	7	3
Incisives	2	2		2	17	17		
Upper dentition								
C1	2	2	1	1				
P2					1	1		1
P3	1	1		1	3	3	2	1
P4	1	1	1		4	4	2	2
M1					7	7	5	2
M2					8	8	4	4
M3					7	7	1	1
dP2					1	1		1
dP4					2	2	1	1
Teeth indet					27			
Axial								
Cervical V.	1	1			22	16		
Thoracic V.					23	16		
Lumbar V.					24	18		
Caudal V.					3	3		
Sternum					8	8		
Vertebrae indet					30	8		
Ribs					191	56		
Girdles								
Scapula					11	11	7	4
Pelvis	1	1		1	18	10	5	5
Fore limbs								
Humerus					16	14	7	7
Radius	3	2	1	1	23	14	7	7
Ulna	1	1		1	7	7	4	3
Hind limbs								
Femur	1	1	1		15	10	7	3
Tibia					13	10	6	4
Autopodium								
Mtt	5	5	2	3	20	17	7	10
Mtcp	3	2	1	1	16	14	5	9
Calcaneus	2	2	1	1	10	9	4	5
Astragalus	2	2	1	1	17	17	8	9
Patella					4	4	2	2
Centrotarsal					7	7	4	3
Scaphoid					6	6	2	4
Pyramidal					2	2	2	
Semilunate					2	2	2	
Hamate					2	2	2	
Trapezoid					3	3	3	
Cuneiform					1	1		1
3rd Pha					22	22		
2nd Pha					34	34		
1st Pha					55	55		
Sesamoid					4	4		
Mtc/Mtt	1	1			20			
Total	31	29			760	495		

Results

Quantification

At the level 4 of S'Espasa, 802 fossil remains of macromammals have been recovered (Table 1). Most of the remains belong to *C. pyrenaica*, followed by *P. pardus* and in a testimonial manner *V. vulpes*, *B. primigenius* and *C. elaphus* (Figure 2).

Regarding the metatarsi of *C. pyrenaica*, ten right specimens have been recovered and they belong to various age classes (Figure 3), although adult (MNI 4) and senile (MNI 3) individuals dominate over juveniles (MNI 3). As regards the age at death of the leopard, it has its permanent dentition but it is not worn, so it could have been between 1.5 and 2 years old. Due to the scarcity of remains and their characteristics, it has not been

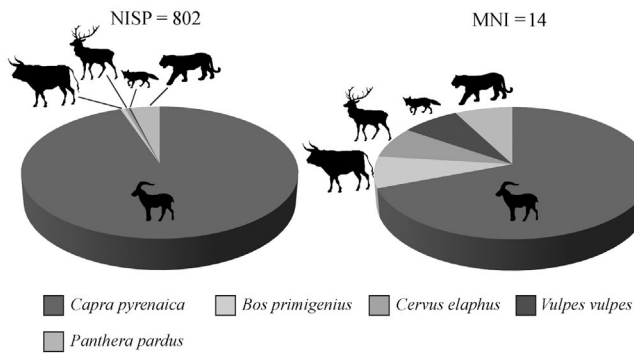


Figure 2. % NISP and % MNI of the faunal assemblage from S'Espasa (level 4).

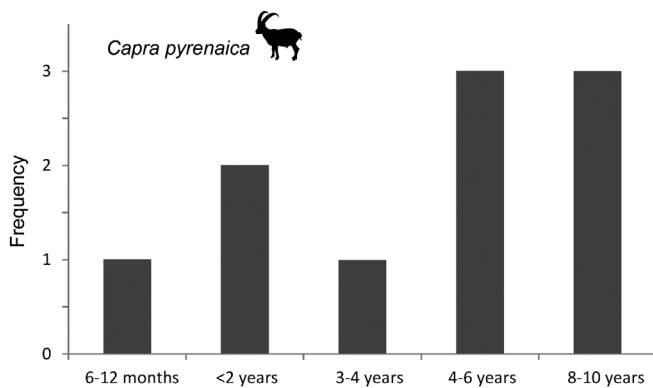


Figure 3. Mortality profile of Iberian wild goat (*Capra pyrenaica*) from level 4 of S'Espasa (MNI = 10).

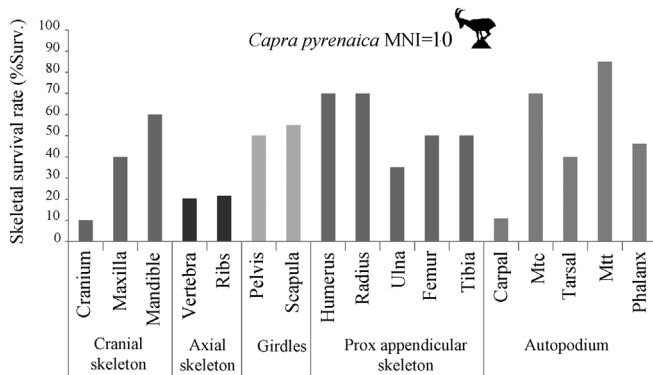


Figure 4. Graphical representation of skeletal survival rate (%Surv.) according to skeletal elements found in S'Espasa (level 4) faunal assemblage.

possible to infer the age of death of any other taxa present in this site but for the Iberian wild goat.

Anatomical representation

Concerning the *C. pyrenaica* and *P. pardus* remains, bones have been recovered from the appendicular, axial and cranial skeleton (Figure 2, Table 1).

The calculation of skeletal survival rate (%Surv) has been undertaken exclusively on the remains of the *C. pyrenaica* (Figure 4). The %Surv presents a profile with a very low frequency of crania, axial, elements and carpal bones, while the elements with the highest %Surv are the long bones (especially

metapodials, humerus and radius), mandibles, girdles and phalanges. In general terms, the profile for skeletal survival is quite balanced although there is a poor representation of small bones, possibly due to the method of excavation. Besides, subsequent occupation of the cave by prehistoric human groups or other agents might have partially destroyed or dispersed lower-density remains, such as vertebrae and ribs, or of larger volume, such as skulls.

Fracture pattern

151 *C. pyrenaica* complete bones have been recovered (Figure 5), which represents 37.3% of the postcranial MNE set. Also, both old and recent fractures could be observed in the bones. The angle of the fracturing in the S'Espasa sample is predominantly a right angle with a transverse delineation and an irregular fracture edge, characteristics associated to post-depositional fractures. In terms of the diaphysis length and the conserved circumference, the most highly represented type in the sample is C3-L2, followed by C3-L3, C3-L4 and C1-L1. (Figure 6).

Modifications caused by carnivores

Carnivore marks have been observed on 40 remains of the *C. pyrenaica* (5.3% of the NISP) at the level 4. The leopard remains also present marks caused by predators or scavengers on three bones (9.7% of the NISP). The modifications caused by carnivore bites found in the bones at S'Espasa level 4 are shown in Table 2. The most highly modified elements are ulnae, followed far behind by scapulae, pelvis and tibia (30%). Radius, cranial remains and phalanges in spite of having important values of representation are not affected by the action of carnivores (Table 2). Pits are the most common type of mark, observed in around 25 remains, the second most common modification being crenulated edges, seen in 13 remains; and scores were only confirmed in seven remains. Punctures are not common, being only presented in three remains. Additionally, fracturing caused by carnivores has been documented through the presence of a single impact point. Besides some consuming and bone reduction marks like crenulated edges and scoping out have been observed (Table 2, Figure 7).

The number of marks per bone is low. There is only one bone with more than 5 marks. This element is a vertebra with five pits and one crenulated edge. In the sample, no remains were found with any signs of digestion.

One of the main features of S'Espasa accumulation is the total absence of human processing. There are no percussion or cut marks on the remains.

Discussion

Paleoenvironmental context

The faunal association present at S'Espasa represents various types of landscape. The red deer (*C. elaphus*) suggests woodland habitats (Carranza et al. 1991; Carranza 2011), whereas the auroch (*B. primigenius*) can inhabit both woody environments and plains (Ekström 1993). However, the best-represented herbivore is the wild goat (*C. pyrenaica*). This taxon represents 99.2% of the NISP and 83.3% of MNI of herbivores and is associated



Figure 5. Iberian wild goat (*Capra pyrenaica*) remains from S'Espasa. (a) complete right humerus with diagenetic fractures; (b) left humerus with green fracture bone; (c) right humerus with a transversal fracture; (d)–(f) complete right tibiae; (g) complete left radius; (h) complete right radius; (i) right radius with diagenetic fracture; (j)–(l) left complete metatarsus; (m), (n) complete right metacarpus; (o) complete left metacarpus.

with high or medium mountain areas with abrupt reliefs (Alados and Escós 1996; Granados et al. 2001). In the cave of S'Espasa, the remains of just two carnivore taxa have been recovered: the leopard and the red fox. Both carnivores occupied a wide range of habitats during Pleistocene, from coastal or lying places to mountain areas around Europe (Sommer and Benecke 2005, 2006; Diedrich 2013; Sanchis et al. 2015). In this context, it is interesting to bear in mind that the site has also yielded remains of *Bubo* (*Nyctea*) *scandicus*. Nowadays the snowy owl is only present in the Scandinavian area associated to tundra areas (Cramp and Simmons 1994; Svensson et al. 2010). This taxa is a classic example of southwards expansion during the Late Pleistocene (Sánchez-Marco 2004; Ravensbaek-Holm and Svenning 2014; Núñez-Lahuerta et al., forthcoming; among others). Its presence indicates colder than current conditions.

Breakage patterns

The wild goat sample presents a degree of fragmentation of 64.7%, with 151 complete remains. In order to discuss the

breakage pattern, the data were compared with those from sites of similar chronology such as Pinilla del Valle (Arsuaga et al. 2012; Sala 2012), the Búho and Zaramora caves (Sala et al. 2011; Sala 2012), Los Rincones (Sauqué et al. 2014), Racó del Duc (Sauqué and Sanchis 2017) and Coro Tracito (Rabal-Garcés et al. 2012; Rabal-Garcés 2013). The first three were interpreted as cave hyena dens, the fourth and the fifth as leopard dens and the last one is a cave which was exclusively inhabited by cave bears (*U. spelaeus*), where the breakage was caused by a combination of the activity of the bears and the pressure of the sediment. Further comparisons were made with sites of similar chronology but where the cause of breakage was anthropic, such as Abric Romaní level B and Vanguard Cave (Cáceres 2002). Moreover, comparisons were drawn with Middle Pleistocene sites with breakage of an anthropic origin such as levels TG10C-D-TN5 of the site of Galería and Gran Dolina level 6, both located at Atapuerca, Burgos (Díez et al. 1999; Cáceres 2002), as well as with others where the breakage has been attributed to the activity of carnivores, such as Gran Dolina level 8 (Blasco López et al. 2011).

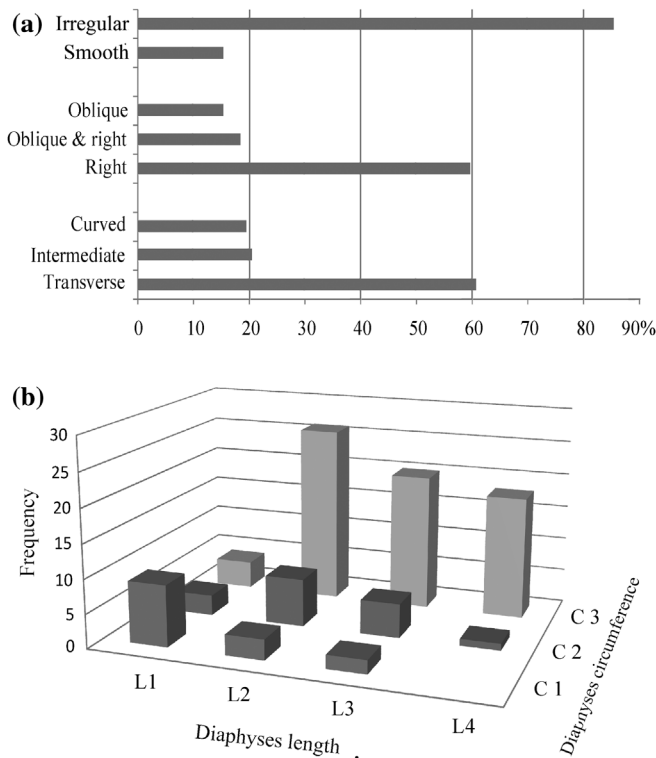


Figure 6. (a) Analysis of the breakage of long bones from S'Espasa (level 4), showing the abundance of each type of fracture according to the criteria analysed: angle, delineation and edge of the breaks. (b) Analysis of the breakage of the diaphyses in terms of circumference and length from S'Espasa (level 4).

Accumulations where the breakage occurred on fresh bone (green bone) display fractures with mainly oblique angles, smooth edges and curved delineations. In these cases the main agents of breakage are the primary consumers, i.e. the humans that extract the marrow by percussion or the carnivores that gnaw on and partially consume the bones, such as the cave hyena (Villa and Mahieu 1991; Díez et al. 1999; Cáceres 2002; Arsuaga et al. 2012; Sauqué et al. 2014).

However, the analysis of the remains from S'Espasa yielded results closer to those sites where the breakage occurred when the bone was no longer fresh, with a predominance of fractures

with right angles, transverse delineation and irregular edges (Figure 6). A similar pattern of bone breaking is described in the leopard dens of Los Rincones (Sauqué et al. 2014) and Racó del Duc (Sauqué and Sanchis 2017).

Anatomical representation

The survival profile of the Iberian wild goat remains is balanced if we exclude the crania and small bones. The skeletal elements present in the accumulation at S'Espasa do not match to those present in an accumulation that is geological in origin, since phenomena resulting in differential preservation, such as transportation in a watery medium, are directly related to the density of the bones (Lyman 1994; Coard 1999). Anatomically and taxonomically, the accumulation of S'Espasa remains of *C. pyrenaica* suggests the biological agent was a large carnivore. The skeletal pattern represented is more in agreement with the contributions of a solitary predator such as the leopard that usually transports complete carcasses to the caves, while the action of the hyenas or other gregarious carnivores and that also practice the carrion brings carcass remains (Domínguez-Rodrigo 1994a, 1994b).

Origin and possible accumulators

The characteristics of the accumulation of level 4 of S'Espasa indicate that the wild goats were taken to the cave by carnivores: the taxonomic composition with the presence of leopard and red fox, the survival profile of the wild goats, the fragmentation degree, and the absence of anthropic modification and the presence of marks caused by carnivores.

The appearance of two carnivores at S'Espasa, the leopard and the red fox, does not exclude the action of other carnivores as accumulators and/or modifiers of the wild goat bone remains (Yravedra 2006; Sauqué et al. 2014).

The large carnivores present in the Iberian Peninsula during the Late Pleistocene are the cave bear (*Ursus spelaeus* Rosenmüller, 1974), the brown bear (*Ursus arctos* Linnaeus, 1758), the wolf (*Canis lupus* Linnaeus, 1758), the dhole (*Cuon alpinus* Pallas, 1811), the cave lion (*Panthera leo spelaea* Goldfuss, 1810), the cave hyena (*Crocuta spelaea* Goldfuss, 1823), the lynx

Table 2. Carnivore marks by taxa and elements modified by carnivores from S'Espasa (level 4). In brackets, the MNE of each type of bone.

Taxon	Element	% modified bones	Type of mark								
			Score	Pit	Puncture	Crenulated edge	Impact point	Furrowing	Scoping out		
<i>Capra pyrenaica</i>	Vertebrae	11 (61)	18.1		8 (22)		3 (3)				
	Ribs	3 (56)	5.4		3 (6)						
	Scapulae	4 (11)	36.4		2 (2)	1 (1)		1 (1)			
	Pelvis	3 (10)	30	1 (1)	2 (2)		3 (3)				
	Humerus	2 (14)	14.3	2 (2)			1 (1)			2 (2)	
	Ulna	5 (7)	71.4		2 (4)		3 (3)			3 (3)	
	Femur	2 (10)	20			2 (2)					
	Tibia	3 (10)	30								
	Calcaneus	1 (10)	10	1 (1)	1 (1)						
	Metacarpus	2 (14)	14.3	1 (1)	1 (1)						
	Metatarsus	2 (17)	11.8							2 (2)	
	Total	40 (495)	8								
	<i>Panthera pardus</i>	Pelvis	1 (1)	100	1 (1)	1 (2)		1 (1)			
		Femur	1 (1)	100						1 (1)	
Ulna		1 (1)	100	1 (1)	1 (3)					1 (1)	
Total		3 (29)	10.3								
Total	43 (524)	8.2	7 (7)	45 (25)	3 (3)	13 (13)	1 (1)	1 (1)	6 (6)		



Figure 7. Examples of carnivore damage from S'Espasa in Iberian wild goat (*Capra pyrenaica*) (a)–(c), (e)–(j) and leopard (*Panthera pardus*) (d). (a) atlas with crenulated edges; (b) axis with a puncture and crenulated edges; (c) rib with a pit; (d) left ulna of leopard with pit and scoping out; (e) right humerus with scoping out; (f) left humerus with scoping out; (g) left ulna with pits; (h) left ulna with pits and scoping out; (i) left ulna with pits and scoping out; (j) right ulna with pits and scoping out.

(*Lynx pardinus* Temminck, 1827) and the leopard (*Panthera pardus* Linnaeus, 1758). But as recorded in our previous work (Sauqué and Sanchis 2017), only the hyena and the leopard have the capacity to transport, accumulate and create large accumulations of skeletal remains of their prey in caves (Sala and Arsuaga, forthcoming; Domínguez-Rodrigo 1994a, 1994b; Domínguez-Rodrigo and Pickering 2010). Cave hyena (*C. spelaea*) is a carnivore that can be found in many sites in the Iberian Peninsula during the Late Pleistocene (Arribas et al. 2010; Varela 2011; Sauqué et al. 2017). The cave hyena presents a wide spectrum of prey ranging from small-middle-sized herbivores such as wild goat, deer to large preys like horse (*Equus ferus*), woolly rhino (*Coelodonta antiquitatis*), giant deer (*Megaloceros giganteus*) and woolly mammoth (*Mammuthus primigenius*) (Dusseldorp 2011; Fourvel 2012; Diedrich 2012a, 2012b, 2014). The cave hyena is considered the main non-anthropogenic bone accumulator in caves (Fosse 1997; Diedrich 2014). As a consequence of its activity, hundreds of accumulations have been recognised in European caves (Fosse 1997; Fosse et al. 1998; Diedrich and Žák 2006; Fourvel 2012; Diedrich 2014; Fourvel et al. 2014b). Therefore this carnivore will be considered a possible accumulator of the S'Espasa bone assemblage and for this reason the characteristics

of the accumulations generated by cave hyenas are discussed later.

During the Late Pleistocene the leopard was one of the most common carnivores in the faunal assemblages of the Iberian Peninsula (Sauqué and Cuenca-Bescós 2013; Sauqué et al. 2014; Sanchis et al. 2015; Sauqué and Sanchis 2017). The leopard is a solitary, territorial hunter (Bertram 1999; Hayward et al. 2006) that has an extensive range of prey, although it mainly targets those within a weight range of 20–80 kg (Mills and Harvey 2001). Therefore the leopard is forced to protect its catches from other social predators such as hyenas and canids. In Africa, this behaviour has been traditionally linked to the use of trees (Pienaar 1969; Sutcliffe 1973; Brain 1981; Cavallo and Blumenschine 1989) but in areas with caves they prefer to accumulate the carcasses inside them (Simmons 1966 and see references in de Ruiter and Berger 2000). In the case of the Iberian Peninsula, the extensive karst development in some geographical areas could have been an important factor that made leopards use the caves as a place to transport and accumulate prey (Sauqué and Sanchis 2017). Although we consider that the leopard was the main accumulator of the wild goats, the bone deposit could be created by complex palimpsest processes.

Table 3. Measurements in mm of the pits and scores found in level 4 of S'Espasa.

	Pits						Scores	
	Cancellous			Dense cortical			Cancellous	
	Width	Length	L/W	Width	Length	L/W	Width	Length
<i>Capra pyrenaica</i>								
Mean	2.43	3.27	0.74	1.7	2.67	0.64	1.36	8.68
SD	0.95	1.95	0.49	0.505	1.02	0.49	0.94	2.55
Min.	1.38	1.8	0.77	1.00	1.2	0.83	0.68	5.67
Max.	4.00	5.93	0.67	2.92	4.1	0.71	3	14.5
n	14	14		21	21		5	5

Besides, there are examples of dominant goat caves where the caves act as natural traps for herbivores that search for refuge in cavities, especially in winter (Moncel et al. 2008). Later the leopards could feed on that carrion.

Red foxes (*V. vulpes*) are medium-sized social carnivores. Red fox is the most widely distributed carnivore in the world (Larivière and Pasitschniak-Arts 1996; Wilson and Reeder 2005). This carnivore presents a great ability to adapt to different environmental conditions, being one of the most common carnivores in Europe during Pleistocene (Sommer and Benecke 2005; Krajcarz and Krajcarz 2014). They are considered generalist predators or opportunistic feeders because they can feed on a wide prey and food spectrum, depending on supply. Although leporids and, in particular rabbits, may be the most important resource of their diets (Lloveras et al. 2012). This carnivore visits caves, to which they bring large numbers of prey. Red foxes do not clear their dens (Goszczyński 1995), and therefore produce large collections of bones over many years (Krajcarz and Krajcarz 2014). The presence of red foxes in the association, added to its ability as bone accumulators, allow us to take the red fox as a possible maker of the S'Espasa assemblage. In addition the action of these scavengers could have produced the disappearance of some elements such as skulls and small bones.

In recent years has shown the potential of lynx as a goat accumulator in Iberian Pleistocene sites such as in Buraca Escura (Aubry et al. 2001; Arceredillo et al., forthcoming). No lynx remains have been recovered at S'Espasa but we cannot rule out the hypothesis that this carnivore sporadically affected or accumulated goats remains.

Mortality profiles

The mortality profiles created by leopards reflect a light trend of prey selection towards adults and seniles. This is due to a hunting technique based on ambush (Kingdon 1977; Myers 1986). In the level 4 of S'Espasa the mortality profile shows no bias towards juvenile or senile individuals. In this case there are more adult and senile individuals although there are also representation of immature individuals. This pattern fits better with a predator based on an ambush hunting strategy, such as the leopard (Domínguez-Rodrigo and Pickering 2010). Anyhow, the sample is small and there is not a clear trend so this data shall be taken with caution.

Damage to the bone surface

The *C. pyrenaica* sample from S'Espasa shows 8% of carnivore marks. The only long bone with a modification over 50% of the MNE is the ulna, whereas the rest of the long bones have carnivore marks values of less than 50%. Additionally, the element with more marks is a vertebra with five pits and a crenulated edge.

This pattern of bone modification is similar to the pattern found in leopard accumulations where the bones do not usually present bit marks on over 25% of the remains (Brain 1981; Domínguez-Rodrigo 1994a), and the long bones have tooth marks in less than 50% of the NME. Leopards commonly leave individual marks on bones because they do not chew the bones like hyenas and canids do. Consequently, the bones modified by leopards do not normally have more than two marks, while those modified by hyenas have a higher number (Domínguez-Rodrigo and Pickering 2010). In relation to the frequency of individual marks on each bone, leopards rarely produce more than 10 marks (<5% of the total MNE) (Selvaggio 1994; Domínguez-Rodrigo and Pickering 2010). In the fossil record of the Iberian Peninsula there are two Late Pleistocene sites recently related with the action of leopards that show a low number of remains affected by bites: the level F–G of Racó del Duc, where carnivore marks have been observed in 9.6% of the *C. pyrenaica* remains (Sauqué and Sanchis 2017); in Los Rincones a 16.3% of the sample is affected by carnivore marks (Sauqué et al. 2014).

By contrast, the accumulations generated by hyenas normally show a high degree of modification that affects 60–100% of the sample (Blumenschine 1988; Blumenschine and Marean 1993; Domínguez-Rodrigo 1994a; Marean and Kim 1998; Yravedra 2006), with values of over 40% in fossil sites. In the European fossil record there are some dens with accumulations by cave hyenas that presents a high number of remains affected by carnivore modifications are: level 2 (72.3%) and level 1c (66.5%) of Bois Roche (Villa et al. 2010); Cueva del Camino (56%) (Huguet et al. 2010); level III (53%) and Unit IV (40%) of Esquilieu Cave (level III) (Yravedra 2006), and Cueva de la Zarzamora (42%) (Sala 2012). Nevertheless, there are some cave hyena dens with an exceptional low frequency of tooth marks such as Fouvent, with only 12.4% of the remains (including teeth) with marks (Fourvel et al. 2014b).

In the case that in our sample we include teeth, the marks are present only in a 5.3% of the remains and in a 8.2% of the MNE, so this pattern of modification is not consistent with an accumulation created by hyenas. In addition, it should be bear on mind that the degree of carnivore marks is not only presented in terms of the number of remains with marks but in the numbers of marks in each bone. Hyenas usually create bone accumulations in which the remains have many individual modifications, with up to 42 marks in a single bone (Selvaggio 1994; Domínguez-Rodrigo and Pickering 2010). At S'Espasa there are no bones with more than ten marks, which also supports the idea that the accumulator agent was not the hyena, but the leopard.

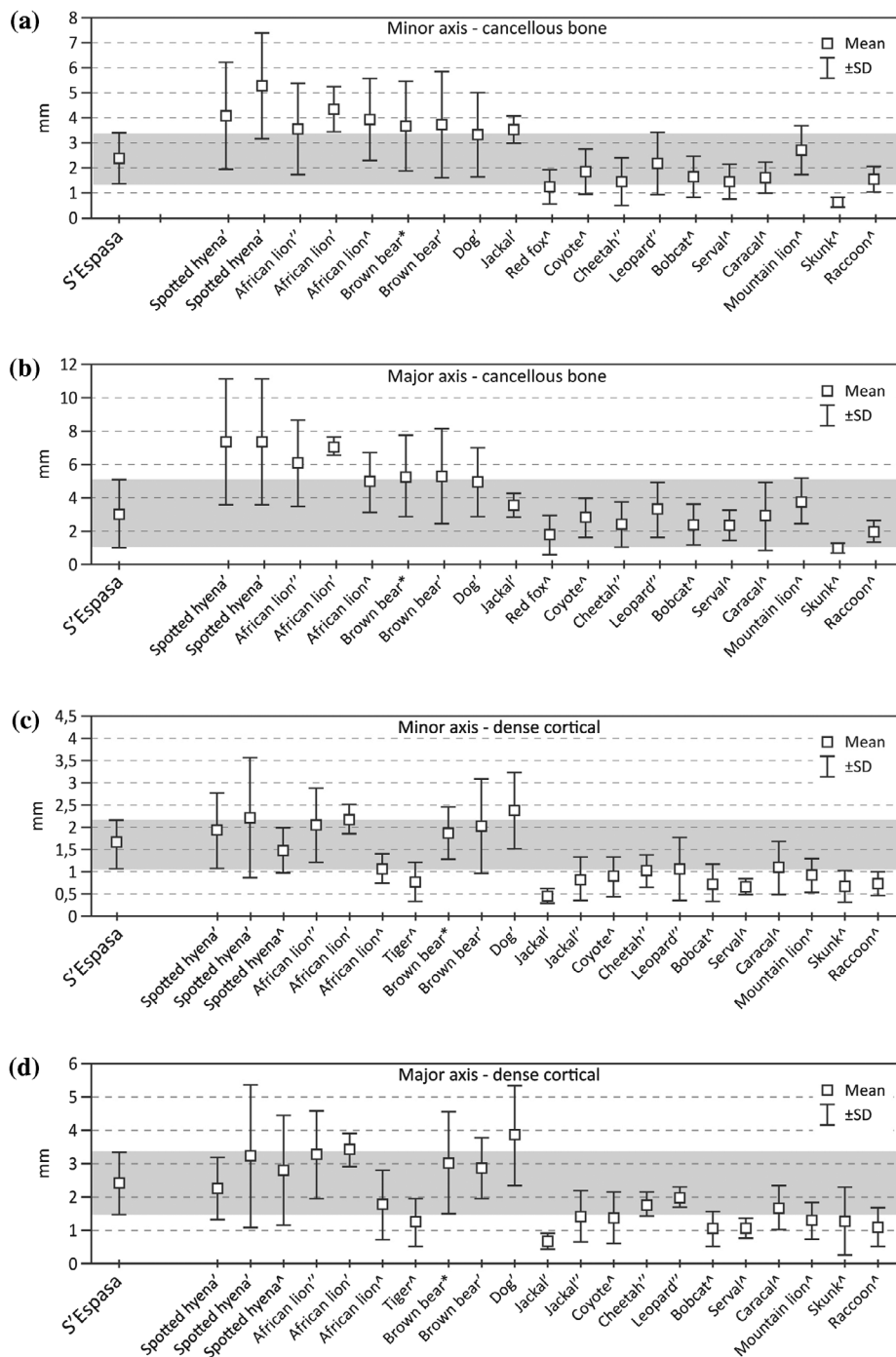


Figure 8. Average pit marks according to length and width for the S'Espasa. The average pits of current day carnivores according to bone type (cancellous or cortical bone) and length/width.

Notes: Key to the data: ¹Selvaggio & Wilder 2001; ²Domínguez-Rodrigo & Piqueras 2003; ³Delaney-Rivera et al. 2009; *Saladié 2009.

Bone consumption pattern

The consumption pattern of the different bones is a key criterion to distinguish between the intervention of leopards and hyenas (Domínguez-Rodrigo and Pickering 2010; Domínguez-Rodrigo et al. 2012). The humeri consumed by leopards present modification of the proximal epiphysis and normally display an intact distal epiphysis. This pattern may be observed in the humeri recovered at S'Espasa (Figure 7), which is similar to the fossil leopard dens of the Iberian Peninsula, such as Racó del Duc

(Sauqué and Sanchis 2017) and Los Rincones (Sauqué et al. 2014).

There is an important difference in the way that hyenas and leopards modify ulnae and radius. Both carnivores act on the proximal part, but leopards only modify the olecranon of the ulna, while hyenas intervene on the ulna and radius (Domínguez-Rodrigo and Pickering 2010). In S'Espasa assemblage, the ulna is the element most modified by tooth marks (71.4% of the MNE) while the radius show no sign of carnivore modification

(Figure 7). This pattern of bone modification is similar in the sites of Los Rincones and Racó del Duc (Sauqué et al. 2014; Sauqué and Sanchis 2017). This would support the idea that the Iberian wild goat at S'Espasa was taken there by leopards and not hyenas.

In the case of the metapodials, felines barely modify them, but the hyenas normally leave tooth marks in a great portion of them. In the bone sample of S'Espasa, 14.3% of the metacarpals and 11.76% of metatarsals were modified. Furthermore, S'Espasa metapodials are commonly found complete (Figure 5). This pattern of consumption of metapodials is similar in the leopard dens of Los Rincones (Sauqué et al. 2014, 2016b) and Racó del Duc (Sauqué and Sanchis 2017), indicating a low degree of modification and fragmentation that does not seem consistent with the intervention of hyenas (Figure 5).

Measurements of the carnivore marks

Regarding the size of the tooth marks, it should be borne in mind that most of the marks are found on *C. pyrenaica* remains. The size of the modifications caused by bites to the wild goats remains at S'Espasa (Table 3) were compared to those left by present-day carnivores, applying the data obtained in the experiments carried out by several authors (Figure 8). At S'Espasa, the width of the pits on cancellous bone is between 1.4 and 4 mm and the length is between 1.8 and 5.9 mm. These values include marks left by middle and large size carnivores such as the fox, lynx, wolf, bear and leopard. On top of the fact that these values are consistent with those of leopards, they are also lower than those seen in hyenas and lions. Especially in the case of length, there is a little overlap with the measurements of marks created by hyenas, with values between 4 and 11 mm from the limits of the \pm SD average (Table 3). Furthermore, the average length and width of pits in cancellous bone corresponds very well with the average of leopards. Despite the leopard not being the only carnivore to have been recovered in the site, we consider this feline to be the most likely producer of the accumulation and modification of the Iberian wild goat remains. However we must not forget the possibility that the fox, present in the sample, has produced any of these marks.

Comparison with other sites from European Pleistocene

The bone accumulations generated during the Pleistocene present different features depending on the carnivore responsible for the accumulation. In the case of cave hyena dens, it is common to find remains of this taxon and in the majority of cases it is the predominant carnivore. This can be seen in numerous European sites ($N = 22$) where the hyena represents 33.2% of the total NR (Fosse 1997). Also in some sites, decidual teeth have been recovered. The presence of these remains of juveniles points out that the cave was used as a breeding den (Pickering 2002; Kuhn et al. 2010; Villa et al. 2010; Arsuaga et al. 2012). In Las Caldas (Álvarez Lao 2002), Cueva de la Zarzamora (Sala et al. 2011) and Cueva del Camino (Arsuaga et al. 2012) juvenile remains have been recovered. Although the presence of coprolites is not exclusive to hyenas (Sanz et al. 2015) the presence of these is a factor that frequently indicates the activity of cave hyenas within the cave or in its immediate surroundings (Sutcliffe 1970; Kruuk 1972;

Pickering 2002; Kuhn et al. 2010; Villa et al. 2010; Fourvel 2012). In the Iberian Peninsula coprolites have been recovered in many cave hyena dens such as: La Parte (Álvarez-Lao and García 2006), La Valiña (Fernández Rodríguez et al. 1995), Caldeirão (Davis 2002), Cueva del Camino (Arsuaga et al. 2012), Gabasa I (Blasco Sancho and Montes 1997), Las Ventanas (Carrión et al. 2001), Labeko Koba IX (Arrizabalaga et al. 2000), Nerja (Jordá et al. 2011), Cueva de la Zarzamora (Sala et al. 2011), Terrasses de la Riera dels Canyars (Daura et al. 2013) and Cova Negra (Pérez Ripoll 1977; Villaverde et al. 2014). The cave hyenas can produce an intense modification of the long bones creating diaphyseal cylinders in which the two epiphyses are lacking (Cruz-Urbe 1991). This is observed in several dens in the Iberian Peninsula such as Terrasses de la Riera dels Canyars (Daura et al. 2013), Cueva del Camino (Arsuaga et al. 2012) and Cueva de la Zarzamora (Sala 2012) and in Central Europe such as Balve Cave (Diedrich 2011b), Koněprusy Caves–Prošek Dome, Nad Kačákem, Turská Maštál Cave (Diedrich and Žák 2006), Bottrop (Diedrich 2012a) and Westeregeln (Diedrich 2007). Furthermore, hyenas are able of swallowing bone fragments that usually are preserved with signs of dissolution by gastric acid. The presence of these digested bones is a good criterion to identify accumulations created by hyenas in the archaeological record (Cruz-Urbe 1991; Pickering 2002; Kuhn et al. 2010). Digested bones have been recovered in various Iberian Pleistocene sites such as the Cueva del Camino (Arsuaga et al. 2012), Cueva de la Buena Pinta (Huguet et al. 2010), Cueva de la Zarzamora, where they constitute 20.5% of the total NR (Sala 2012), in Caldeirão (Davis 2002), in Gabasa I (Utrilla et al. 2010) and in Terrasses de la Riera dels Canyars (Daura et al. 2013). Nevertheless, neither the presence of coprolites and digested bones nor the lack of them allows us to ascertain whether hyenas may have created the aforementioned accumulations (Marchal et al. 2009; Prendergast and Domínguez-Rodrigo 2008; Domínguez-Rodrigo and Pickering 2010).

In the case of leopard dens, they are usually placed in mountainous zones or difficult to access areas such as Amalda VII (Yravedra 2006), Boquete de Zafarraya (Barroso et al. 2006), Los Rincones (Sauqué et al. 2014, 2016a) and Racó del Duc (Sauqué and Sanchis 2017). These sites are situated in steep areas with a scarce or non-existent human presence (Sauqué and Sanchis 2017). The site of S'Espasa is located in a very sloping hillside that has a very complicated access (Figure 1). The location of these cavities in steep areas determines the herbivores that live in the surrounding area. Accordingly, at the leopard dens, the main herbivores are rupicolous taxa such as wild goats (*C. pyrenaica*) and chamois (*Rupicapra pyrenaica* Bonaparte, 1845) (Sauqué and Sanchis 2017). The faunal assemblage in leopard dens predominantly comprised these taxa. The main herbivore in Boquete de Zafarraya is the Iberian wild goat (78% of the NISP), (Barroso et al. 2003; Caparrós et al. 2012). At Los Rincones, the main herbivore is also the Iberian wild goat (58% of the NISP) (Sauqué et al. 2014, 2016a, 2016b). In Racó del Duc the main taxon is the Iberian wild goat (92% of the NISP) (Sauqué and Sanchis 2017). Finally, in Amalda VII, *Rupicapra* (55% of the NISP) is more abundant than *Capra pyrenaica* (6% of the NISP) (Yravedra 2006). In the faunal composition of S'Espasa, the Iberian wild goat is the main ungulate represented (95% of the NISP).

Another characteristic of leopard dens is the presence of leopard remains. 245 remains (7% of the NISP) in Boquete de Zafarraya (Barroso et al. 2003), three remains (0.3% of the NISP) in Amalda VII (Yravedra 2006), 110 remains (12% of the NISP) in Los Rincones (Sauqué et al. 2016a), 40 remains (8% of the NISP) in F-G level of Racó del Duc (Sauqué and Sanchis 2017), and 31 remains (3.8% of the NISP) in S'Espasa.

The leopard dens present a low number of ungulate remains affected by bites: 6% of bones in F-G level of Racó del Duc (Sauqué and Sanchis 2017; 16.3% of bones in Los Rincones (Sauqué et al. 2014); 20% of bones of *Capra* and 12% of *Rupicapra* from Amalda VII were affected (Yravedra 2006), and in S'Espasa 5% of the wild goat remains were affected by carnivores.

Leopards produce accumulations with a low modification of the long bones. This is observed in various dens in the Iberian Peninsula such as Los Rincones and Racó del Duc, with many complete bones of Iberian wild goat (Sauqué et al. 2014, 2016b; Sauqué and Sanchis 2017). At the site of S'Espasa, only a 5.3% of the bones had tooth marks. Also several complete long bones have been recovered. These features fit well with the characteristics of Pleistocene leopard dens.

In S'Espasa there are also modifications in the leopard remains. These modifications have been also noticed in other leopard dens as Los Rincones (Sauqué et al. 2014). It is difficult to assign the carnivore that produces these marks although it is important to bear in mind that the damage could be done by leopards as it occurs with the wild goats remains. In fact, the leopard presents an exceedingly broad range of prey comprising as many as 92 species in Africa and with only exceptional cases of cannibalism on record (Steyn and Funston 2006).

Conclusions

The faunal assemblage of the level 4 at S'Espasa is composed by two carnivores, the leopard and the red fox, and three herbivores, the Iberian wild goat, the red deer and the auroch. The main herbivore in S'Espasa is the Iberian wild goat that represents 94.8% of NISP and 71.4% of MNI. The main carnivore in S'Espasa is the leopard that represents 3.9% of NISP and 7.1% of MNI. The wild goat and the leopard at the aforementioned level are the only ones that show modifications undertaken by carnivores. The absence of lithic industry and non-existent modification produced by humans indicate that the accumulation of remains in the cave was caused by carnivores.

The Iberian wild goat remains found at level 4 of S'Espasa show a skeletal profile where the majority of elements are present, although with less frequent presence of the skull, axial remains and small bones. There are no elements with more than six marks per element. The main types of mark are pits and the size of the marks matches those produced by a medium-sized feline. These features, together with the low degree of bone breakage, the pattern of bone consumption, the attritional mortality profiles with no predominance of juvenile or senile individuals, and a scarce percentage of marks of 5% of the NISP and 7% of the MNE, suggest that the accumulation of Iberian wild goats was produced by leopards, which fed mainly on this sort of prey in the Iberian Peninsula during the Pleistocene.

The bone assemblage of level 4 at S'Espasa presents similar characteristics to the other leopard dens from Iberian Peninsula,

such as Los Rincones and Racó del Duc. These sites present a similar faunal composition made up by wild goats and leopards. Finally, this taphonomic work supports the previous hypothesis of Estévez (1975–1976) about the role of leopard as main accumulator of the Iberian wild goats of the level 4 of this archaeological site.

Acknowledgements

The authors would like to thank the organizers of the ICAZ, celebrated in Paris, especially to the organizers of the editors of the special issue on Taphonomy (Proceedings of the IVth Taphonomy working group meeting): C. Denys & J.P. Brugal.

We would like to thank Museu Comarcal de la Garrotxa, for the support and interest it has shown for this project. Thanks to Dr. Sonia Serrano-Zabaleta for the revision of the text. Finally the authors want to thank the ICP (Institut Català de Paleontologia).

Funding:

VS is supported by the Ministerio de Ciencia, Tecnología e Innovación Productiva, Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) of Argentina (Postdoctoral Fellowship) (Resoluci on N° 4256).

Disclosure statement

No potential conflict of interest was reported by the authors.

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