

Another non-anthropogenic leporid accumulation in Southwestern Iberia? The case of a leporid sample from Morgado superior (Tomar, Portugal)

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Abstract

The Morgado superior rock shelter is located near the city of Tomar, in Central Portugal. This site presents important funerary contexts that according to published information encompass the Neolithic, Chalcolithic, and Bronze Age. Other non-funerary uses are not yet characterized but were briefly suggested. A faunal sample of the 1988 and 2012 interventions is analysed from a zooarchaeological and taphonomical perspective, focusing on the leporid remains that largely dominate the assemblage. Clear indicators of a human origin are absent, while a configurational approach allows the description of exogenous and intrusive origins. The characteristics of the registered consumption taphonomical indicators are suggestive of scat and non-ingested accumulation by foxes. Furthermore, this study allows us to discuss some aspects of the formation of the stratigraphy of this important cave necropolis, while also serving as an example of the expected results of foxes' action on leporid remains in an archaeological site.

Introduction

The acquisition of actualistic data that could allow for the assessment of leporid and other small prey accumulations in the archaeological record has been increasing in the last decades (e.g., Hockett 1991, 1996; Sanchis 2000, 2001; Hockett and Haws 2002; Yravedra 2006, 2007; Lloveras et al. 2008a, 2008b, 2009, 2012, 2014a, 2014b, 2018a, 2018b, 2020; Mallye et al. 2008; Mallye 2011; Sanchis et al. 2010, 2014; Sanchis and Pascual 2011; Rodríguez-Hidalgo et al. 2013a, 2015; Yravedra and Andrés 2013; Yravedra et al. 2014, 2019ab; Krajcarz and Krajcarz 2014; Arilla et al. 2019; Marin-Monfort et al. 2019). This large corpus of data has been largely applied to Palaeolithic and Mesolithic assemblages, aiming to understand possible human influence in their accumulation and modification (e.g. Aura et al. 2002, 2006; Cochard 2004; Hockett and Haws 2002; Ibáñez and Saladié 2004; Pérez Ripoll 2004, 2005; Sanchis and Fernández Peris 2008; Yravedra 2008; Lloveras et al. 2009, 2010, 2012; Llorente 2010; Rodríguez-Hidalgo et al. 2013b; Sanchis et al. 2011; Sanchis 2012; Martínez-Polanco et al. 2017; Rosado-Méndez et al. 2018, 2019; Rufà et al. 2018; Rufi et al. 2020; Almeida et al. 2022a). Southwestern Iberia Late Prehistory and Protohistory palaeoeconomy has been a matter of research in the last decades through archaeobotanical, isotopic and zooarchaeological studies. Focusing on faunal analysis, the variable importance of domesticates is observed during the Neolithic, Chalcolithic and Bronze Age, with economies mainly based on caprine and/or swine herding, as well as some cattle (recent synthesis in Valente and Carvalho 2014; Almeida et al. 2020, 2022c; Almeida and Valera 2021). Hunting seems to have been complementary, with regional variation probably being an adaptation to local characteristics and availability. Mostly red deer, probably wild boar and to a lesser extent aurochs are the main wild species being hunted, with leporids generally having a large number of remains but also a more complex taphonomical scenario (Almeida et al. 2022b).

Although commonly found in the archaeological records, the separation between exogenous, intrusive and human accumulations of leporids is not always clear. Specific methodologies aimed at characterizing these small prey accumulations are needed. The analysis of leporid remains in funerary contexts is of interest due to the possible association of leporids with funerary behaviour, the fact that they can have an intrusive or exogenous origin, and the characterisation of other non-funerary uses of these sites (Almeida 2020; Almeida et al. 2022a, 2022d;). A discussion on available data for the Neolithic of Southwestern Iberia emphasized that a lack of information exists, raising the need for the in-depth analysis and publication of leporid accumulations in Late Prehistory assemblages (Valente and Carvalho 2014; Almeida et al. 2022b). Among some of the cases mentioned was Morgado Superior leporid assemblage which remains unpublished. Here we present the results from this rock shelter faunal analysis, focusing on the larger part of the assemblage that comprises leporid remains, excavated in 1988 and 2012. Besides the presentation of data and discussion of accumulating and modification agents, we aim to contribute to a broader assessment of leporids accumulations by presenting a real case of an archaeological palimpsest accumulated by non-human predators that might help other colleagues working with small prey accumulations in different chronologies.

Materials And Methods

The Morgado superior site, hereinafter GMS, is a karstic rock shelter situated near the city of Tomar, in Central Portugal (Fig. 1). Two rooms have been recognized, a smaller one in the area where the walls start to close, and a larger one in the entrance. Archaeological excavations in 1988 were made in a 6 m² test pit where two layers (A and B) were described: a fireplace with some materials from the French Invasions (18th/19th century CE), and remnants of a Late Neolithic/Chalcolithic collective burial with incised and globular undecorated pottery, blades, bladelets, beads, and a bone ring (Oosterbeek and Cruz, 1988; Cruz 1997; Oosterbeek 1997; Tomé 2011). Laboratory anthropological studies found some evidence that it would correspond to a primary inhumation context (Tomé 2011; Tomé and Cunha 2015), later reinforced in the field and laboratory with at least 202 individuals having been identified (Cruz et al. 2018).

Following complaints of possible spoliation, an open area excavation was made between 2012 and 2019 (Cruz et al. 2013; Cruz and Berruti 2015; Cruz et al. 2018), but results are still being studied and largely unpublished. The materials that will be discussed were recovered in the 1988, 2012, and partially 2013 excavations that comprised a 11m² area. Two collective burial deposits separated by around 3 meters were identified: sepulchral zone 1 (squares E52, F52, E53, E54, F54) with artefacts relatable to the Chalcolithic/Early or Middle Bronze Age, and sepulchral zone 2 (squares J50, J51, K50, K51) (Cruz et al. 2013). One must emphasize that all excavations were conducted through 2 cm artificial levels and the sediment was completely sieved (2 mm mesh).

The unpublished results from the later excavations mostly comprised the continuation of the excavation of funerary contexts with associated Neolithic artefacts; the existence of structures, namely fireplaces, was considered to suggest non-domestic sporadic use of the shelter. Arrowheads, flakes, blades and bladelets, knapped pebbles, and at least one geometric, diverse pottery including carinated fragments were recovered, as well as a lagomorph zoomorphic statuette (Cruz et al. 2013), with the number of materials growing in later campaigns (Cruz et al. 2018).

Due to the context of strong post-depositional disturbance and the lack of secure provenance of the faunal material (besides the square of the excavation grid), the material was analysed as if a single context existed. However, the absolute dates (Table 1, Fig. 2) and material culture indicate a prolonged use of the rock shelter between the Early Neolithic and the Bronze Age, with sporadic historic uses.

Table 1
Absolute dates from the Morgado superior site were calibrated with OxCal 4.4 [144] (Bronk Ramsey 2021) with atmospheric data from Reimer et al. (2020)

Sample	Lab. ref.	BP	Provenance	cal BP (2σ)	Reference
<i>Homo</i>	Beta-423526	5960 ± 30	F53-23	6890 – 6675	Cruz 2016
<i>Homo</i>	Wk-42855	5960 ± 20	G54-12	6885 – 6680	Cruz 2016
<i>Homo</i>	Wk-42854	5214 ± 20	F53-3	6105 – 5915	Cruz 2016
<i>Homo</i>	Beta-423527	4610 ± 30	G54-12	5465 – 5145	Cruz 2016
<i>Homo</i>	Wk-40440	4504 ± 20	J50-574	5295 – 5045	Cruz and Berruti 2015
<i>Homo</i>	Beta-359086	4260 ± 30	J51-904	4870 – 4655	Cruz and Berruti 2015
<i>Homo</i>	Beta-359087	4180 ± 30	J51-997	4850 – 4580	Cruz and Berruti 2015
<i>Homo</i>	Wk-40441	4168 ± 20	J50-946	4830 – 4585	Cruz and Berruti 2015

We will focus on the identified leporid remains that constitute the majority of the assemblage (Table 2). The distinction between *Oryctolagus cuniculus* and *Lepus* sp. follows metric and morphological criteria (Callou 1997). Demographic profiles are estimated based on Jones (2006), differentiating between infants with unfused appendicular bones and very fragile ossification (less than 2 months); juveniles with visible fusion line or not entirely fused epiphysis (between 2–10 months), and adults when bones were fully developed (> 10 bones). Results are presented according to standard indices from Binford (1984) and Grayson (1984), i.e., number of specimens (NSP), number of identified specimens (NISP), minimum number of elements (MNE), and minimum number of individuals (MNI). In order to compare the results obtained concerning body part representation with others published in actualist and non-actualistic studies, we use %relative abundance following Andrews (1990) and Dodson and Wexlar (1979). Indices commonly used for the comparison of proportions of leporid skeletal elements (Andrews 1990; Lloveras et al. 2008ab) are presented, namely the ratio of postcranial and cranial remains (PCRT/CR, PCRLB/CR), the loss of distal limb elements (AUT/ZE, Z/E), and the ration between elements of the forelimbs and hindlimbs (ANT/POST).

The assessment of breakage of long bones considers the completeness of shafts and circumferences, while diaphisary fragments are registered according to the breakage planes' outline (transverse, longitudinal, oblique), degree (oblique, right, mixed), and edge (smooth, jagged) (Villa and Mahieu 1991). All remains maximum size of the larger axis is measured, with diaphysis from immature individuals' long bones being considered complete elements. For comparative purposes, we also considered breakage categories defined by Lloveras et al. (2008b) and Fernández-Jalvo and Andrews (1992) for different bones, and isolated and "in situ" teeth. Altogether, these methodologies allow the characterization of the type of predominant breakage and comparison of patterns with actualistic data from several non-human predators.

Macroscopic and microscopic analysis of bone surface searching for bone surface modifications (BSM) was implemented throughout the study. Indicators related to butchering, preparation and consumption both by humans and non-human predators were registered according to type and location (portion, surface). Following Cáceres (2002) and others (Shipman et al. 1984; Nicholson 1993; Buikstra and Ubelaker 1994; Stiner et al. 1995), burnt damage is presented according to the following degrees: 0 = absent; 1 = lightly burned with some light brown spots; 2 = lightly burned with a relatively homogenous (darker) brown colour throughout the bone surface; 3 = carbonized with a blackish colour; 4 = greyish tonalities with occasional blue incisions; 5 = calcinated with white colour. Tooth marks are differentiated between punctures, pits, perforations/notches, scores, and crenulated edges (Binford 1981; Haynes 1983). Conspicuous and inconspicuous pits, punctures, and scores major and minor axis were measured with a digital calliper (in millimetres to two decimal places), by using strong diagonal light, a digital microscope or digital software. Tooth marks dimensions are compared with published actualistic data after calculating the range, mean, standard deviation and 95% confidence interval (CI). After Selvaggio (1994), the comparison of dimensions also takes the bone tissue (cancellous, cortical) into consideration. Regarding digestion damage, we follow Lloveras et al. (2008b) that after Andrews (1990) and Fernández-Jalvo and Andrews (1992) register the following degrees: 0 = null; 1 = light; 2 = moderate; 3 = heavy; and 4 = extreme).

The possible relationship between the mineral density of specific bones and bone portions with the anatomical representation of elements in a given assemblage can be informative on possible diagenetic mediate bone portion loss. For this, we compared the results obtained with the information provided by Pavao and Stahl (1999), followed by Pearson's correlation coefficient and probability tests. The GMS results are compared with others from different actualistic studies by means of multiple correspondence analysis (MCA) and principal component analysis (PCA) considering indices and taphonomical data in order to test for differences between assemblages.

Table 2
Absolute and relative Number of identified specimens and
Minimum number of elements

Taxa	NISP	NISP%	MNE	MNE%
<i>Bos taurus</i>	1	0.2	1	0.3
<i>Ovis aries</i>	11	2.5	6	1.8
<i>Ovis /Capra</i>	20	4.5	13	4.0
<i>Cervus elaphus</i>	2	0.5	2	0.6
<i>Capreolus capreolus</i>	2	0.5	2	0.6
<i>Sus</i> sp.	4	0.9	4	1.2
<i>Vulpes vulpes</i>	2	0.5	2	0.6
<i>Meles meles</i>	7	1.6	7	2.2
<i>Felis silvestris</i>	1	0.2	1	0.3
Carnivora ind.	4	0.9	4	1.2
<i>Lepus</i> sp.	2	0.5	2	0.6
<i>Oryctolagus cuniculus</i>	196	43.8	150	46.0
Leporidae	187	41.7	124	38.0
Aves ind.	9	2.0	8	2.5
<i>Sub-total determinate</i>	<i>448</i>	<i>100</i>	<i>326</i>	<i>100</i>
Indeterminate				
Weight group ind.	103	25.6		
Weight group < 20 kg	239	59.3		
Weight group < 100 kg	9	2.2		
Weight group 20–100 kg	36	8.9		
Weight group 20–300 kg	14	3.5		
Weight group > 100 kg	2	0.5		
<i>Sub-total indeterminate</i>	<i>403</i>	<i>100</i>		
Total	851			

Results

Taxonomy, anatomical representation, and age at death

Of an NSP = 851, a total of NISP = 448 (52.6%) were taxonomically identifiable, of which a NIP = 385 (45.2%) are from leporids, mostly European rabbit (NISP = 196), followed by Leporidae (NISP = 187), and *Lepus* sp. (NISP = 2). The NISP, MNE, and %RA values are presented separately for rabbit-only, and for all leporids in Table 3. The relative abundances of the “all leporids” show a higher frequency of long bones (femurs, tibiae, ulnae, humerus) and mandibles, and an

infra-representation of bones from the post-cranial axial (vertebrae, ribs) and extremities (metacarpals, carpal/tarsals, phalanges). If on focus the “rabbit only” sample, the mandibles, tibiae, femurs and innominate have higher relative abundances. Humerus, radius, metatarsals, and calcaneus have good representativeness, while the lower elements with lower relative abundances follow the pattern seen on the “all leporids” sample.

Table 3
Number of specimens, Minimum number of elements, %Relative abundance, and MNE/NISP values for different elements for all Leporidae (rabbit, hare, rabbit/hare) and only *Oryctolagus cuniculus*

Element	“all leporids”					“rabbit-only”				
	NISP	NISP%	MNE	MNE%	%RA	NISP	NISP%	MNE	MNE%	%RA
Skull (maxilla)	10	2.6	4	1.4	11.1	9	4.6	3	2.0	16.7
Mandible	17	4.4	13	4.7	36.1	15	7.7	13	8.7	72.2
Isolated tooth	40	10.4				16	8.2			
Vertebrae	25	6.5	15	5.4	2.1	7	3.6	7	4.7	1.9
Ribs	9	2.3	8	2.9	1.9	0	0.0	0	0.0	0.0
Scapula	12	3.1	10	3.6	27.8	2	1.0	2	1.3	11.1
Humerus	22	5.7	17	6.2	47.2	10	5.1	7	4.7	39.9
Radius	13	3.4	11	4.0	30.6	9	4.6	7	4.7	38.9
Ulna	23	6.0	20	7.2	55.6	5	2.6	5	3.3	27.8
Metacarpus	12	3.1	12	4.3	6.7	12	6.1	12	8.0	13.3
Innominate	20	5.2	14	5.1	38.9	12	6.1	8	5.3	44.4
Femur	39	10.1	25	9.1	69.4	14	7.1	8	5.3	44.4
Tibia	35	9.1	22	8.0	61.1	17	8.7	10	6.7	55.6
Calcaneus	6	1.6	6	2.2	16.7	6	3.1	6	4.0	33.3
Astragalus	1	0.3	1	0.4		0	0.0	0	0.0	
Metatarsus	36	9.4	36	13.0	25.0	29	14.8	29	19.3	40.3
Carpal/tarsal	3	0.8	3	1.1	0.9	2	1.0	2	1.3	0.9
Metapodial	24	6.2	22	8.0		2	1.0	2	1.3	
Phalanges	38	9.9	37	13.4	4.1	29	14.8	29	19.3	6.2
Total	385	100	276	100		196	100	150	100	
MNE/NISP	0.72					0.75				

The Pearson’s coefficient test between the remains identified and the density of different bone portions based on Pavao and Stahl (1999) results in a statistically positive relation ($r = 0.605$, $p = 0.017$) for the “rabbit only” but not for the “all leporids” sample ($r = 0.459$, $p = 0.085$). Hence, it seems that bone density would have been relevant for the survival of specific body parts only in the “rabbit-only sample”. The fact that the majority of the remains identified as Leporidae is expected to correspond mostly to *Oryctolagus cuniculus* leads us to not consider this result as representative of broader interpretative inferences. The “all leporids” sample calculated indices show a higher value of postcranial skeleton

(PCRT/CR; PCRLB/CR), zeugopodia and stylopods in detriment of autopodium (AUT/ZE), forelimb in relation to hindlimb (ANT/POST), and zeugopodia are slightly better represented than stylopods (Z/E). This pattern occurs with slight differences if the “rabbit-only” sample is considered separately (Table 4).

Table 4
Proportions of different parts of the skeleton

Indices	Result “all leporids”	Result “rabbit-only”
PCRT/CR	821.2	242.7
PCRLB/CR	558.8	231.3
AUT/ZE	20.2	45.8
Z/E	126.2	146.7
ANT/POST	90.0	84.8

An estimate of MNI = 18 was achieved for leporids (Table 5). One adult hare is registered considering the proximal femur epiphysis fusion. Rabbits are represented by two infant individuals, as suggested by the presence of two left tibia distal portions (< 3 months). Four distal right femurs point to three juveniles/adults (> 5 months), and three proximal femurs indicate three adults (> 9 months). The presence of right and left mandibles with a good ossification and related to sub-adult/adult individuals agrees with this estimate, as well as the remaining registered elements. Taking into account the remains from hare and rabbit, we can still increase the MNI at least in the case of infantile individuals, as suggested by the MNE = 8 left femurs (< 4 months) and MNE = 8 left tibias (> 3 months) that based on ossification and general size of the elements should correspond to very young individuals with ages around 1 month.

Table 5
Estimate of the Minimum number of individuals per age group for hare, rabbit, and rabbit/hare

Taxa	Infant	Juvenile/adult	Adult	Total
<i>Lepus</i> sp.			1	1
<i>O. cuniculus</i>	2	4	3	9
Leporidae	8			8
Total	10	4	4	18

Breakage

A total of 330 leporid remains were measured, ranging from 5.97 mm to 95.82 mm in maximum size, with an average of 19.33 mm; around 11% of this sample presents < 10 mm, and 67% < 20 mm. Modern breakage was recorded in 55 (14.3%) cases. Complete elements (n = 104, 27%) from rabbit (n = 79) and Leporidae (n = 25) correspond mainly to metapodials (n = 35, 33.7%) and phalanges (n = 34, 32.7%) that together with carpal/tarsal bones (n = 6, 5.8%) correspond to 72.1% of the complete elements from these species. If epiphysial remains and others with recent breakage are not considered, the sample for the analysis of diaphysis completeness is small (n = 20). The completeness of length is between 25–50% in 10 cases (50%) and 50–75% in the other 10 cases (50%). The circumference is almost entirely < 25% (n = 18, 90%), with both 25–75% and > 75% having 1 case each (5% each). Breakage planes on diaphysis have a larger sample (n = 78): outlines are mostly curved (n = 44, 56.4%) and transverse (n = 25, 32.1%); degrees are frequently right (n = 36, 46.2%) and mixed (n = 13, 16.7%); and surfaces are mainly smooth (n = 62, 79.5%).

Breakage categories (Table 6) show a predominance of neurocranium (50%) and zygomatic arch (33%) parts in the cranium, and mandibles body with incisive part (53%) in the mandibles. "In situ" teeth are all complete, while isolated incisors (86%) and upper molars (88%) are mostly complete. Vertebrae are mostly represented by spinous processes (40%) and vertebral bodies (36%). Glenoid cavity plus neck part (67%) are the most numerous parts in scapulae, and innominate occurs mostly complete (40%) or acetabulum plus ischium (25%). Long bones occur mostly as proximal epiphysis (radius, 54%; ulna, 48%; femur, 33%), shaft (tibia, 49%), or shaft plus distal epiphysis (humerus, 50%). Patellae are absent, and ribs or carpal/tarsal bones are scarce. Phalanges are frequently complete (89%).

Table 6

Number and percentage of parts of the leporids skeleton per breakage category after Lloveras et al. (2008b). Long bones, metacarpals, and metatarsals were classified as complete (C), proximal epiphysis (PE), proximal epiphysis + shaft (PES), shaft (S), shaft + distal epiphysis (SDE), and distal epiphysis (DE); mandibles as complete (C), incisive part (IP), mandible body + incisive part (MBI), mandible body (MB), mandible body + branch (MBB), and condylar process (CP); cranium as complete (C), incisive bone (IB), incisive bone + maxilla (IBM), maxilla (M), zygomatic arch (ZA), and neurocranium (NC); innominate as complete (C), acetabulum (A), acetabulum + ischium (AIS), acetabulum + ischium + ilium (AISIL), acetabulum + ilium (AIL), ischium (IS), and ilium (IL); scapula as complete (C), glenoid cavity (GC), glenoid cavity + neck (GCN), neck + fossa (NF), and fossa (F); vertebrae as complete (C), vertebral body (VB), vertebral epiphysis (VE), and spinous process (SP); phalanges as complete (C), proximal fragment (P), distal fragment (D), and fragment (F); patella, carpal/tarsal, calcaneum, astragalus, ribs, and teeth as complete (C) and fragment (F)

Long bones and metapodial			C		PE		PES		S		SDE		DE	
			N	%	N	%	N	%	N	%	N	%	N	%
Humerus			3	14	1	5	2	9	5	23	11	50	0	0
Radius			2	15	7	54	0	0	3	23	1	8	0	0
Ulna			0	0	4	17	11	48	7	30	1	4	0	0
Femur			4	10	0	0	13	33	11	28	9	23	2	5
Tibia			2	6	1	3	4	11	17	49	10	29	1	3
Metacarpus			10	83	0	0	2	17	0	0	0	0	0	0
Metatarsus			18	50	1	3	17	47	0	0	0	0	0	0
Metapodial			6	25	0	0	0	0	2	8	15	63	1	4
Mandible	N	%	Cranium	N	%	Innominate	N	%	Scapula	N	%			
C	0	0	C	0	0	C	8	40	C	2	17			
IP	3	18	IB	0	0	A	1	5	GC	0	0			
MBI	9	53	IBM	0	0	AIS	5	25	GCN	8	67			
MB	2	12	M	2	17	AISIL	3	15	NF	1	8			
MBB	1	6	ZA	4	33	AIL	2	10	F	1	8			
PC	2	12	NC	6	50	IS	0	0						
						IL	1	5						
Vertebra	N	%	Phalanges	N	%	Patella	N	%	Carpal/Tarsal	N	%			
C	6	24	C	34	89	C	0	0	C	1	33			
VB	9	36	P	1	3	F	0	0	F	2	67			
VE	0	0	D	3	8									
SP	10	40												
Calcaneus	N	%	Astragalus	N	%	Ribs	N	%		N	%			
C	4	67	C	1	100	C	1	11		1	11			
F	2	33	F	0	0	F	8	89		8	89			
Tooth	"In situ"					Isolated								

Long bones and metapodial	C		PE		PES		S		SDE		DE	
	N	%	N	%	N	%	N	%	N	%	N	%
	Incisors		Upper molars		Lower molars		Incisors		Upper molars		Lower molars	
	N	%	N	%	N	%	N	%	N	%	N	%
C	6	100	7	100	35	100	2	14	2	12	5	56
F	0	0	0	0	0	0	12	86	15	88	4	44

Burn damage

Burn damage is infrequent ($n = 8$, 2%) in the sample. All registered cases correspond to rabbit remains, including mandibles ($n = 2$), innominate ($n = 1$), tibia ($n = 1$), and appendicular bones proximal (tarsal, metatarsus, phalange, $n = 4$). Mandibles (MBI) show degree 2 of damage, one being completely affected while the other only has damage in the incisor part. The innominate (AIS) is affected in degree 2 (100%), and the tibia (S) in degrees 3(90%) and 4 (10%). The complete tarsal bone is entirely affected in degree 2, and the complete metatarsus is in degree 3 in the proximal portion and shaft. Both proximal phalanges are complete, one showing degree 1 (10%) in the distal part, the other with degree 2 in all portions.

Tooth marks and digestion

Carnivore-associated damage is registered in 139 (36.1%) remains of the leporids sample. Among tooth marks ($n = 35$, 9.1%), the most common type of damage are crenulated edges ($n = 15$), pits ($n = 12$), and punctures ($n = 11$), but notches ($n = 6$) and crushing ($n = 1$) are also present in different bones (Table S1). These types of consumption indicators are mostly found in long bones ($n = 18$, 1.4%), with femurs ($n = 11$, 31.4%) being prevalent, followed by innominate ($n = 7$, 20%), mandibles ($n = 4$, 11.4%).

Shaft cylinders are infrequent ($n = 7$, 1.8%), having been identified in rabbit ($n = 3$) and Leporidae ($n = 4$) femurs ($n = 3$), tibia ($n = 3$) and humerus ($n = 1$). They were generally easy to relate with carnivore action due to the presence of diagnostic tooth marks or digestion damage. These and other remaining shaft cylinders have small sizes, between 2 and 3 cm of maximum dimension. Hence, they are not comparable to anthropogenic shaft cylinders, which tend to have larger sizes (e.g., Hockett, 1991, 1995; Cochard, 2004; Bicho et al., 2006; Rufà et al., 2014).

Pits/punctures and scores dimensions are presented in Table 7 and were compared with published actualist data (Fig. 3). The results obtained for cortical length and width are very similar to Andrés et al. (2012) fox data both in terms of mean and C.I. 95%. For cancellous tissues, the C.I. 95% of these actualistic studies is somewhat higher, still the data we obtained is more similar to the aforementioned fox mean but with a smaller span. Due to the small sample, scores are not further compared, but the mean of 0.30 mm of maximum width is similar to the 0.34 mm registered for Iberian lynx (Rodríguez-Hidalgo et al., 2013) and inferior to the 0.42 mm from foxes (Andrés et al, 2012). Our results seem to be a little smaller than the pits/punctures and scores presented by Yravedra et al. (2014) on sheep bones.

Table 7

Descriptive statistics for the length and width (in mm) of pits/punctures* and scores[^] on cortical and cancellous tissues registered in leporid remains. SD = standard deviation; CI = confidence interval

	N	Mean	SD	CI+95%	CI-95%	Min	Max
*Cancellous length	37	1.49	1.08	1.84	1.14	0.49	6.22
*Cancellous width	37	0.98	0.50	1.13	0.82	0.33	2.25
*Cortical length	23	1.39	0.79	1.71	1.06	0.49	3.71
*Cortical width	23	0.93	0.50	1.13	0.73	0.36	1.96
[^] Cortical length	5	1.92	0.27	2.16	1.68	1.58	2.21
[^] Cortical width	5	0.30	0.03	0.33	0.28	0.27	0.33

The majority of the sample under study does not present digestion (n = 273, 70.9%), but when registered (n = 112, 29.1%) it occurs mostly in moderate (n = 46, 11.9%) and light (n = 38, 9.9%) degrees, followed by heavy (n = 22, 5.7%) and extreme (n = 6, 1.6%) degrees (Table 8). Isolated tooth (n = 29, 17.9%), metatarsus (n = 19, 17%), and indeterminate metapodial (n = 12, 10.7%) are prevalent. Femurs (n = 11, 9.8%) and phalanges (n = 10, 8.9%) are also numerous in comparison to other affected elements. Nonetheless, bones from all body parts are affected by digestion even if in different quantities and degrees.

Table 8
Different remains with digestion damage per element and degree of damage

Element	Light		Moderate		Heavy		Extreme		Total	
	N	%	N	%	N	%	N	%	N	%
Maxilla	0	0.0	1	2.2	1	4.5	0	0.0	2	1.8
Mandible	0	0.0	3	6.5	0	0.0	0	0.0	3	2.7
Isolated tooth	11	28.9	6	13.0	3	13.6	0	0.0	20	17.9
Vertebra	3	7.9	1	2.2	3	13.6	0	0.0	7	6.3
Humerus	0	0.0	4	8.7	1	4.5	0	0.0	5	4.5
Radius	0	0.0	3	6.5	1	4.5	1	16.7	5	4.5
Ulna	3	7.9	1	2.2	1	4.5	0	0.0	5	4.5
Metacarpus	2	5.3	0	0.0	1	4.5	0	0.0	3	2.7
Innominate	1	2.6	1	2.2	1	4.5	1	16.7	4	3.6
Femur	1	2.6	5	10.9	3	13.6	2	33.3	11	9.8
Tibia	2	5.3	2	4.3	0	0.0	0	0.0	4	3.6
Calcaneus	0	0.0	2	4.3	0	0.0	0	0.0	2	1.8
Metatarsus	8	21.1	7	15.2	3	13.6	1	16.7	19	17.0
Metapodial	5	13.2	5	10.9	2	9.1	0	0.0	12	10.7
Phalange	2	5.3	5	10.9	2	9.1	1	16.7	10	8.9
Total	38	100	46	100	22	100	6	100	112	100

Discussion

The accumulation of leporid remains in Morgado superior

The leporid accumulation of Morgado superior does not present clear indicators of human influence (Hockett 1991, 1995; Bicho et al. 2000, 2003, 2006; Aura et al. 2002, 2006; Hockett and Haws 2002; Chochard 2004; Pérez Ripoll 2004, 2005; Ibáñez and Saladié 2004; Sanchis and Fernández Peris 2008; Yravedra 2008; Lloveras et al. 2009a, 2011; Rodríguez Hidalgo et al. 2011; Sanchis et al. 2011; Sanchis 2012; Rufà 2013). The burn damage is infrequent and cannot by itself be related to an anthropogenic influence in the accumulation of these individuals. In fact, this could be a byproduct of the use of the fireplaces recognized on the site. Another indicator commonly associated with human action is shaft cylinders, but they were largely relatable with carnivore action due to the presence of consumption indicators, or after considering their small size were discarded as being human-made.

Skeletal profiles deserve further discussion regarding some similarities with human accumulated assemblages. Innominate and scapula are averagely represented, with posterior elements being less frequent than anterior, the mandibles more common than the cranium (especially if we consider the "rabbit-only" sample), autopodium and the axial skeleton are infra-represented (Chochard 2004). However, there is no lack of epiphysis and the carnivore action is well represented through different consumption indicators.

If the “all leporids” sample is considered, the elements with a higher relative abundance group long bones, innominate and mandibles; vertebrae, carpal/tarsal bones and ribs are lacking. The only difference if one considers the “rabbit-only” sample is the higher value of mandibles and metatarsus. The good representativeness of mandibles has parallels in Iberian lynx scats (Lloveras et al. 2008a) and Egyptian vulture nests (Lloveras et al. 2014b); the higher general abundance of long excrements has parallels with fox scats (Lloveras et al. 2012). As for the low relative abundances, the more similar examples are Iberian lynx scats (Lloveras et al. 2008a) and non-ingest samples (Rodríguez-Hidalgo et al. 2013), and non-ingested fox samples (Lloveras et al. 2012). GMS is a mixture of ingested and non-ingested material, so the results cannot be easily compared with the abovementioned studies. Nonetheless, we see a higher frequency of the post-cranial skeleton and a reduced higher frequency of distal and posterior elements that have similarities mostly with non-ingest Iberian lynx (Rodríguez-Hidalgo et al. 2013, 2015) and fox (Lloveras et al. 2012) samples.

The higher frequency of null and moderate digestion is more similar to what is registered in the Eurasian eagle-owl (Lloveras et al. 2009b) but the frequency of extreme degrees in the sample is not in agreement with this. In the “rabbit-only” sample we recognized attrition-mediated selective destruction of bone parts; to some extent, the most developed digestion damage can be reduced due to survivability. Beak marks appear to be absent from this sample and tooth marks (9.1%) have high values similar to the ones registered in non-ingest fox (9.5%) samples (Lloveras et al., 2012). Pits/punctures also are similar to published foxes’ tooth mark measurements, especially to Andrés et al. (2012) and this carnivore is identified in the assemblage of Morgado superior.

In face of the evidence discussed, it seems clear that indicators of an important anthropic accumulation and modification of leporid remains is absent from the Morgado superior sample analysed, while several indicators suggest that a fox was the main accumulator. The presence of younger individuals with ages around 2/3 months, or even younger around 1 month, possibly suggests the existence of burrows. The absence of indicators of their accumulation leads us to consider that leporids in Morgado superior have an intrusive and exogenous origin.

An MCA with the indices already mentioned and the % of tooth marks, complete bones and complete long bones results in a cumulative of 77.485% if the GMS sample is compared to other fox and Iberian lynx samples (Fig. 5a). The results show large similarities with scats and non-ingested fox samples published by Lloveras et al. (2012). Dimensions 1 and 2 (97.4%) of a PCA statistical analysis using NISP values demonstrates a closer similarity between Morgado Superior and published fox actualistic assemblages (Fig. 5b). This analysis shows that nocturnal raptors tend to produce different profiles, while diurnal raptors as an important accumulator in this assemblage can be discarded based on taphonomical criteria as well.

Available data indicates that the larger part of the context and materials recovered in Morgado superior are from the Neolithic and Chalcolithic and correspond to funerary contexts, even if more recent and eventually circumscribed non-funerary uses are registered (Cruz 1997; Oosterbeek 1997; Cruz et al. 2013, 2018). The 2013 published results indicate that two sepulchral areas existed, related to the protohistoric and prehistoric funerary use (Cruz et al. 2013). The sepulchral area 1 was recorded in squares E52, F52, E53 and F53; Sepulchral area 2 in squares J50, J51, K50, and K51. The acknowledgement of a strong admixture of deposits and materials related to the type of funerary behaviour (Tomé 2011; Tomé and Cunha 2015) exists, with the data here presented pointing to add disturbance due to carnivore action and burrowing animals. The low compactness of the sedimentary matrix, especially in layer A has been indicated (Cruz 1997; Oosterbeek 1997) as well as historic spoliation. The presence of leporid remains with <3 months, of scarce or small mobility, is suggestive of the existence of burrows (Jones 2006). When not recently made or abandoned, these can be difficult to define during excavation, but can result in severe disturbance of deposits, thus contributing to the low compactness.

The dispersion of remains in the excavation area

An analysis of the dispersion of the faunal sample studies was made considering the provenance by squares that were made available by the responsible for the excavations. A spatial horizontal separation was initially described between the two sepulchral areas (Cruz et al. 2013; Cruz and Berruti 2015). The remains of leporids (Fig. 5 c1), carnivores (Fig. 5 c2), and carnivore action (Fig. 5 c3) are concentrated around the sepulchral areas identified, with a higher number in area 1; according to published information, the majority of remains by 2015 are from squares I51/52, J50/51/52/53 and K50/51/52 (Curto et al. 2016), but the older absolute dates published are from squares F53 and G54 (Cruz 2016). Overall, the high breakage evidenced in both human and animal remains (Almeida 2010, 2017) coincides with a context of high disturbance that might help explain the state of these different contexts.

Conclusions

The distinction between the anthropogenic, exogenous and intrusive accumulation of small prey has become a research hot topic in the last couple of decades. In this sense, leporids, most notably the European wild rabbit, became a focus of actualist studies, both experimental and naturalistic. We applied these methodologies and a corpus of comparative data to better understand a sample of leporids remains from Morgado superior. This rock shelter presents a complex stratigraphy, largely unpublished, with funerary and possible non-funerary uses from Late Prehistory (Neolithic and Chalcolithic) and Protohistory (Bronze Age).

Through the in-depth taphonomical analysis we conclude that the leporids accumulation is not the result of human action as recently occurred in several other SW Iberia Late Prehistory contexts. The influence of nocturnal or diurnal raptors is discarded, with the accumulating and modification agent being a terrestrial carnivore. The comparison with these animals' information suggests that this accumulation of scats and non-ingested material results largely from the activity of foxes.

This study allows us to envisage the possible problems of comparing archaeological samples with published actualistic data since the latter will hardly fit clearly with the expected results of a specific predator. Nonetheless, in this case, this was achieved in broader terms. At the same time, it allows us to better understand the formation of the archaeological record of the Morgado superior rock shelter and its characteristics. The future publication of results from the more recent archaeological excavations and the assessment of zooarchaeological and taphonomical pieces of evidence will allow us to better discuss the hypothesis here presented.

Declarations

The authors declare no competing interests. All authors contributed to the study. The first draft of the manuscript was written by Nelson J. Almeida and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Availability of data and material

Data generated during this study are included in the manuscript and supplementary material.

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Figures

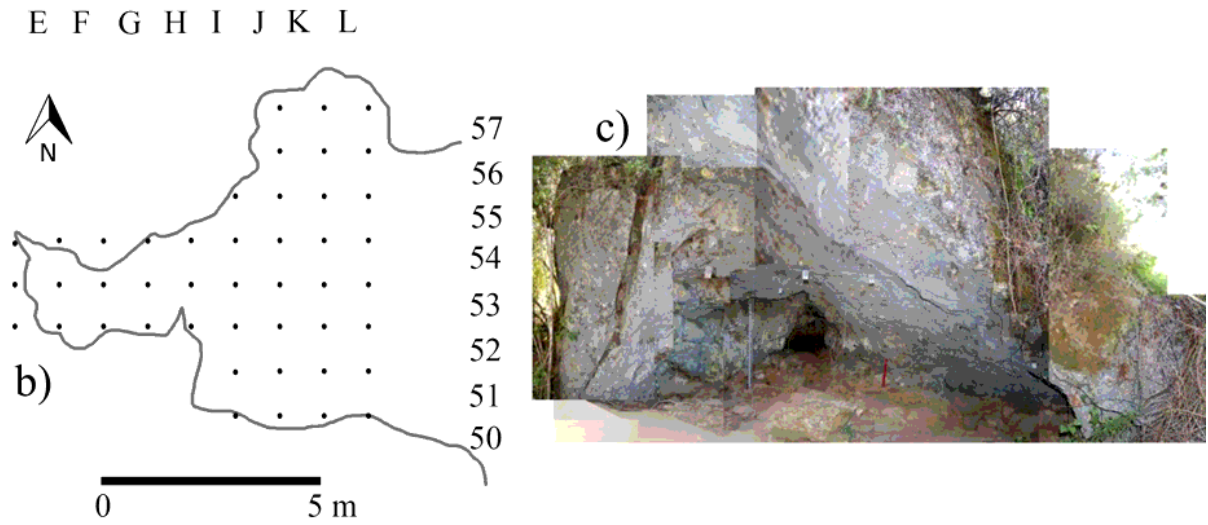
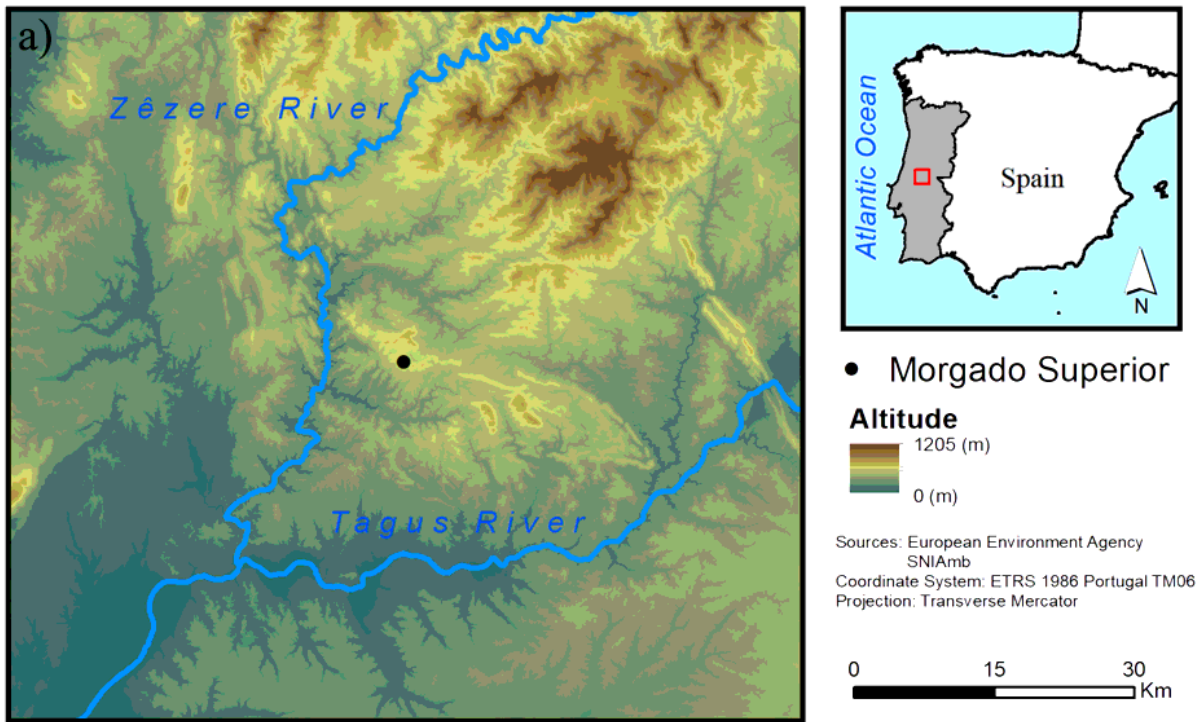


Figure 1

Location of Morgado superior in the Iberian Peninsula (a), plan of the rock shelter with the excavation grid according to CPH-IPT (b), and general view of the area in 2016 (photo-montage by Ana Rosa Cruz – IPT Archaeology Centre archive)

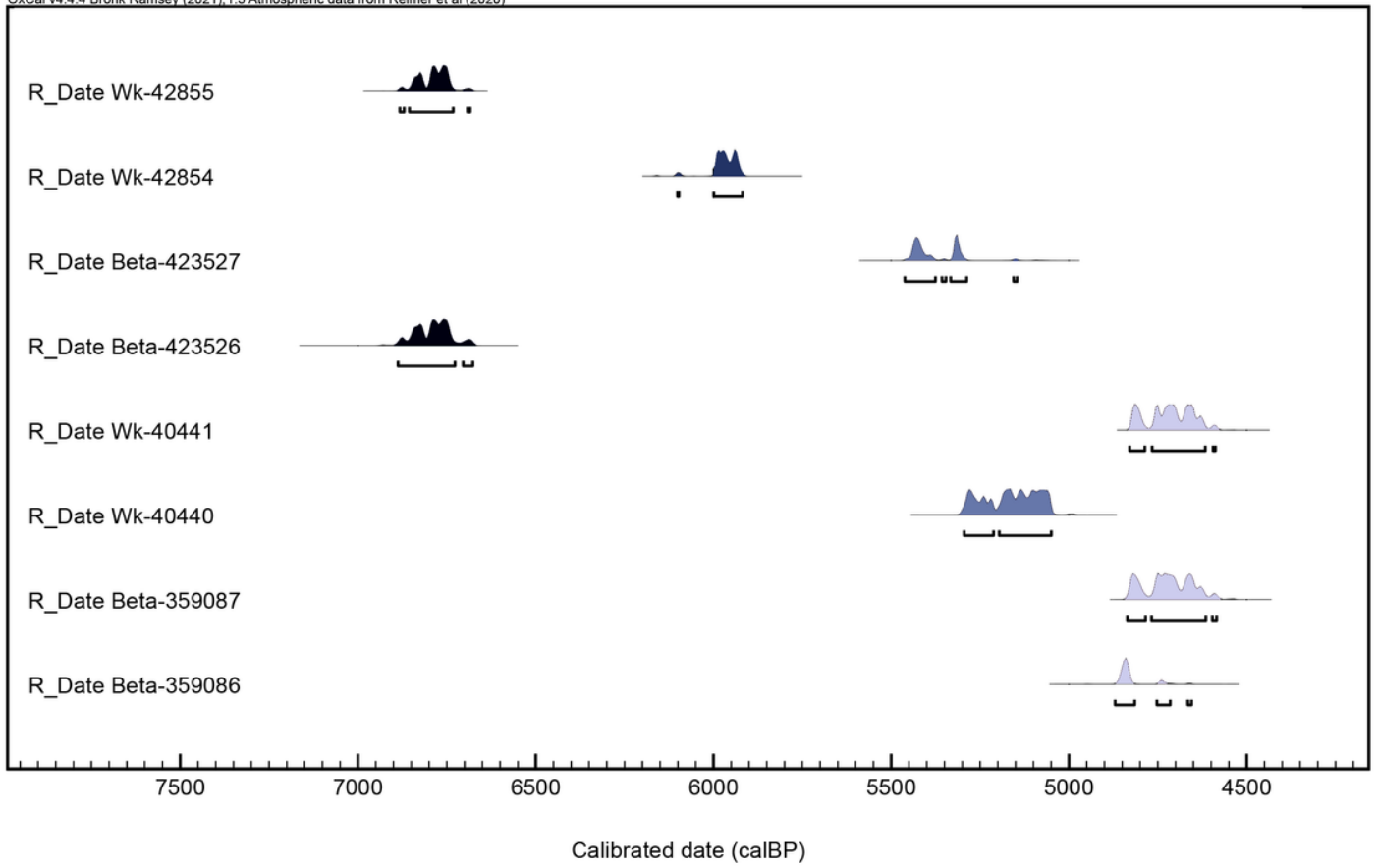


Figure 2

Plot of the absolute dates presented in Table 1

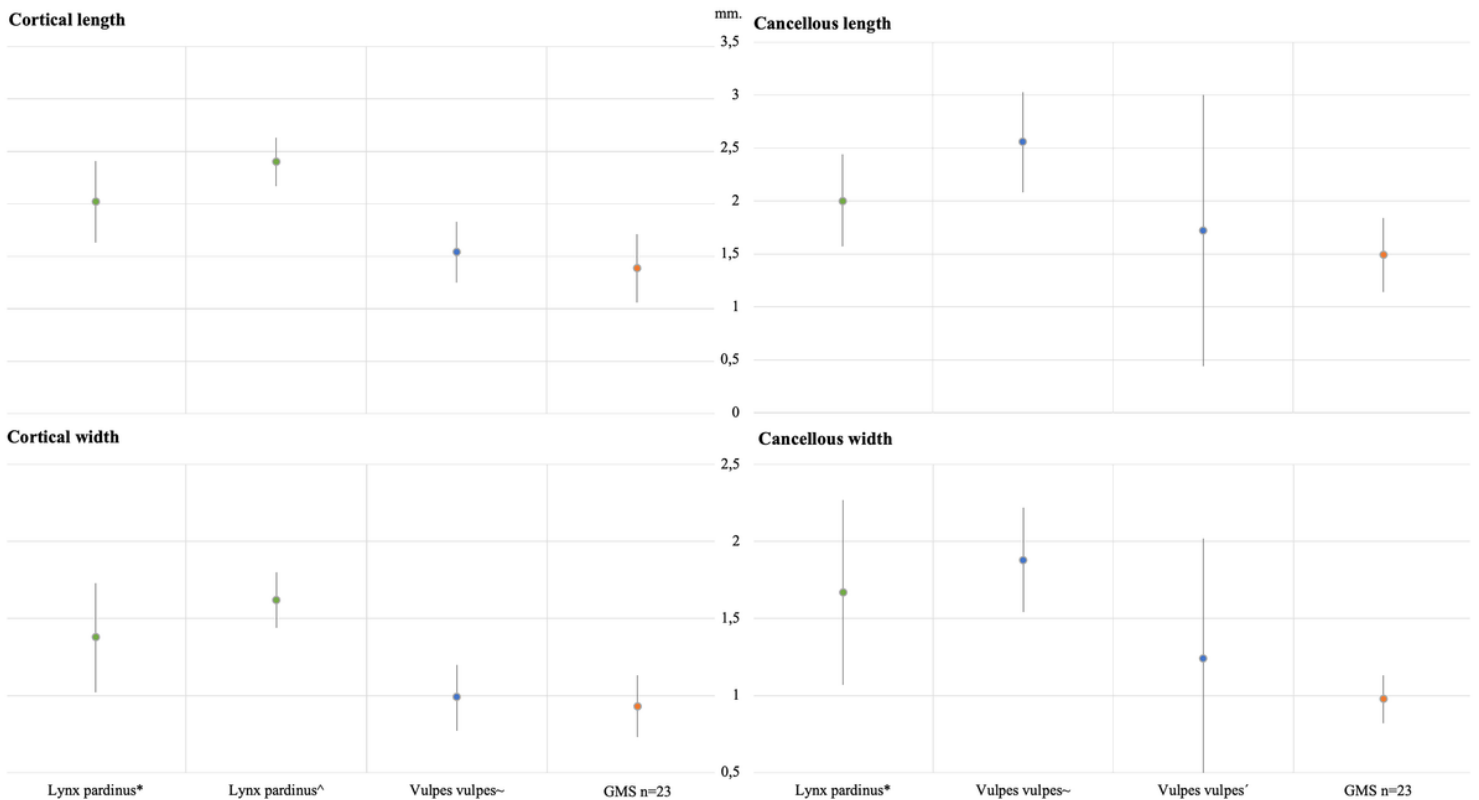


Figure 3

Comparison of results obtained for the maximum length and width of pits/punctures recorded in Morgado superior (GMS) according to the type of bone, in comparison to Rodríguez-Hidalgo et al. (2013a) (*), Rodríguez-Hidalgo et al. (2015) (^), Andrés et al. (2012) (~), and Delaney-Rivera et al. (2009) ('). Values presented are the mean and C.I. 95%

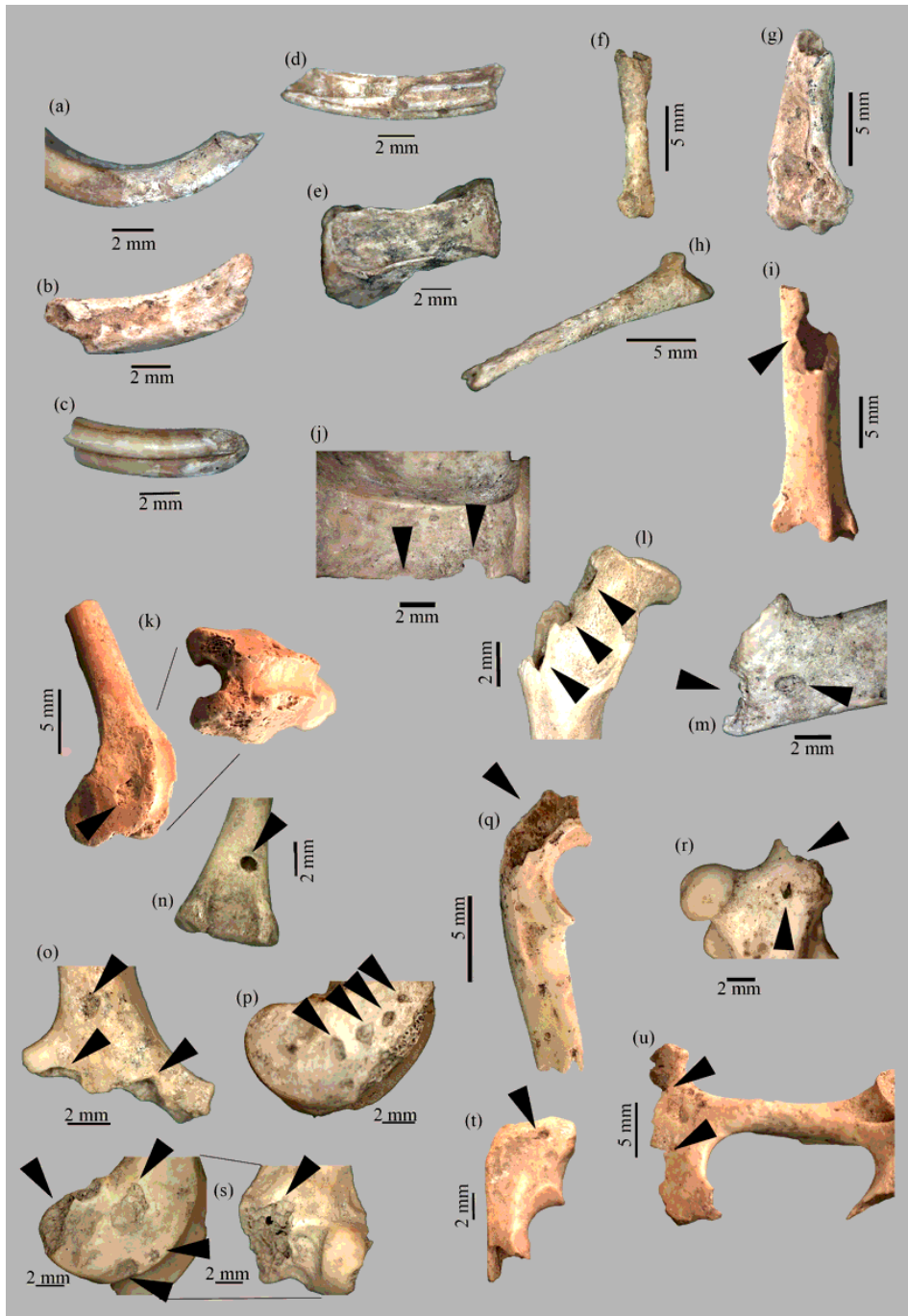


Figure 4

Selection of leporid remains with bone surface modifications created by a carnivore: digestion on lower (a), upper incisors (b, c) and molar (d), vertebra (e), first phalange (f), humerus (g), and radius (h); different types of tooth marks in a tibia (i), vertebra (j), femur (k, l, p, r, s), innominate (m, o, u), humerus (n), and ulna (q, t)

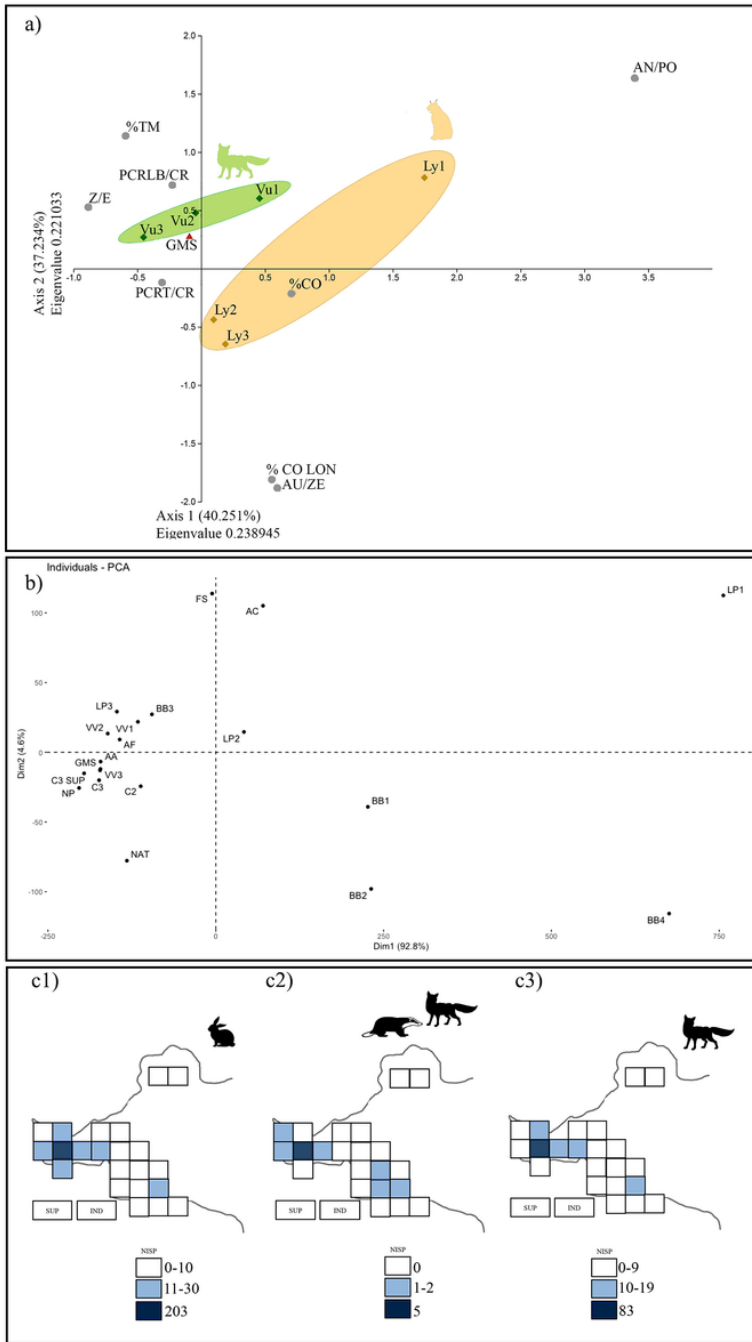


Figure 5

a) Multiple correspondence analysis, comparing the data obtained for GMS with published actualistic scats and non-ingested samples from fox and Iberian lynx (Lloveras et al 2012; Rodríguez-Hidalgo et al. 2013, 2015). %TM = %tooth marks, %CO = %complete bones, %CO LON = %complete long bones. b) Principal component analysis comparing GMS with other published actualistic and experimental studies (Table S2), c) dispersion of leporid remains (c1), carnivore remains (c2) and carnivore action, probably foxes (c3).

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [TableS1.xlsx](#)
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