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Animal exploitation in Southwestern Iberia at the end of the second millennium BCE: insights from the Late Bronze Age of Outeiro do Circo (Beja, Portugal)

Nelson J. Almeida[1], Miguel Serra[2], Eduardo Porfírio[3], Sofia Silva[4]

Abstract. The Late Bronze Age was an important phase in European Prehistory but our understanding of its regional dynamics is unequal. Relevant knowledge of the peopling and material culture of Southwestern Iberia between 1170 and 730 BCE exists, but the exploitation and management of animals remain largely uncharacterized. We generally lack the taphonomical data that could allow for an in-depth understanding of faunal assemblages' formation, with relevance for the description of depositional environments if paired with relative and absolute chronologies.

We present two new absolute dates for the Outeiro do Circo Late Bronze Age and a zooarchaeological and taphonomical analysis of the total recovered faunal assemblage. Caprine, swine, and bovine primary and probably secondary products were of importance, with the hunting of red deer and wild boar being complementary. Other species such as leporids, equids, canids and several molluscs were recovered. The latter are mostly intrusive terrestrial gastropods but the scarce presence of scallops and peppery furrow shells can also relate to exchange networks. Taphonomical indicators of the butchering and consumption of animals and the secondary access by a large canid are well attested in the assemblage, as well as the culinary and non-culinary thermo-alteration of animals' bones.

Keywords: Late Bronze Age; Southwestern Iberia; Zooarchaeology; Taphonomy

[es] Explotación animal en el suroeste de Iberia a finales del segundo milenio a.C.: reflexiones desde el yacimiento del Bronce Final de Outeiro do Circo (Beja, Portugal)

Resumen. La Edad del Bronce final fue una fase importante en la Prehistoria europea, pero nuestra comprensión de sus dinámicas regionales es desigual. Existe un conocimiento relevante del poblamiento y la cultura material del suroeste de Iberia entre 1170 y 730 a.n.e., pero la explotación y el manejo de los animales siguen sin caracterizar. Además, en general carecemos de los datos tafonómicos que podrían permitir una comprensión profundizada de la formación de conjuntos faunísticos con relevancia para la descripción de ambientes deposicionales si considerados conjuntamente con datos cronológicos.

Presentamos dos nuevas fechas para la Edad del Bronce final de Outeiro do Circo y un análisis zooarqueológico y tafonómico del conjunto total recuperado. Los productos primarios y secundarios de caprinos, porcinos y bovinos fueron importantes, siendo complementaria la caza del ciervo y del jabalí. Se recuperaron otras especies como lepóridos, équidos, cánidos y moluscos. Estos últimos son sobretodo gasterópodos terrestres intrusivos, pero la escasa presencia de vieiras y almeja de perro puede relacionarse con redes de intercambio. Indicadores tafonómicos del descuartizamiento y consumo de animales y el acceso secundario por un gran cánido están bien atestiguados en el conjunto, así como la termoalteración con intuitos culinarios y no culinarios de huesos de animales.

Palabras clave: Idade del Bronce final; Sudoeste Ibérico; Zooarqueologia; Tafonomia

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[1] Uniarq, Centro de Arqueologia da Universidade de Lisboa, Faculdade de Letras da Universidade de Lisboa, Alameda da Universidade, 1600-214, Lisboa, Portugal. Departamento de História, Escola de Ciências Sociais, Universidade de Évora, Portugal. O Legado da Terra, Cooperativa de Responsabilidade Limitada, Portugal. https://orcid.org/0000-0002-3653-0850. nelsonjalmeida@gmail.com

[2] Divisão de Cultura e Património da Câmara Municipal de Serpa, Portugal. Centro de Estudos em Arqueologia, Artes e Ciências do Património – Universidade de Coimbra, Portugal. https://orcid.org/0000-0002-1247-8621. miguel.antonio.serra@gmail.com

[3] Câmara Municipal de Sintra, Portugal. Centro de Estudos em Arqueologia, Artes e Ciências do Património – Universidade de Coimbra, Portugal. https://orcid.org/0000-0001-9816-8327. eporfirio@gmail.com

[4] Axis Mundi – Heritage & Archaeology. https://orcid.org/0000-0003-4601-0493. sofiaeiras22@gmail.com

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1. Introduction

The Late Bronze Age, hereinafter LBA, is a period of important changes in Mediterranean Europe (Knapp & Van Dommelen 2014). A fragmented scenario exists, but some common broad trends can be observed, for example in social organization, trade, transcultural phenomena, and human mobility (Iacono *et al.* 2022). In Southwestern Iberia, this period is generally considered to be between around 1170/1050-780/730 BCE (Mataloto *et al.* 2013). The construction of imposing defensive walls becomes a characteristic image of the architectural expression of these communities, as shown by the emergence of large fortified settlements that clearly mark the new forms of social organisation (Serra 2021).

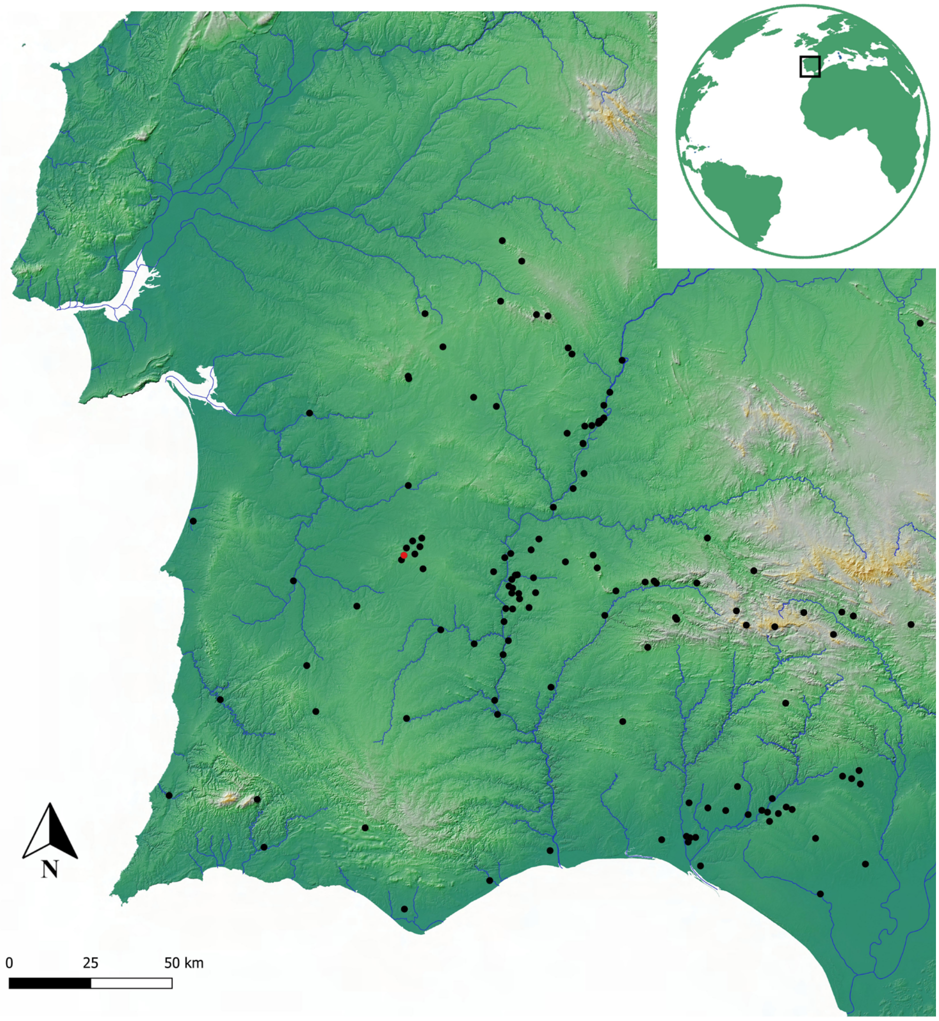

Figure 1. Location of Outeiro do Circo in red and other main Late Bronze Age sites in the Southwestern Iberia Peninsula (after Gómez Toscano 2006, 2010, 2012; Mataloto 2013; Oliveira 2012, 2013; Soares 2013). Iberian Peninsula hypsometry and hillshade after Servicio de Cartografía de la Universidad Autónoma de Madrid; altimetry after IGN Spain, IGN France, SRTM and others; hydrography after DGT Portugal and CNIG Spain.

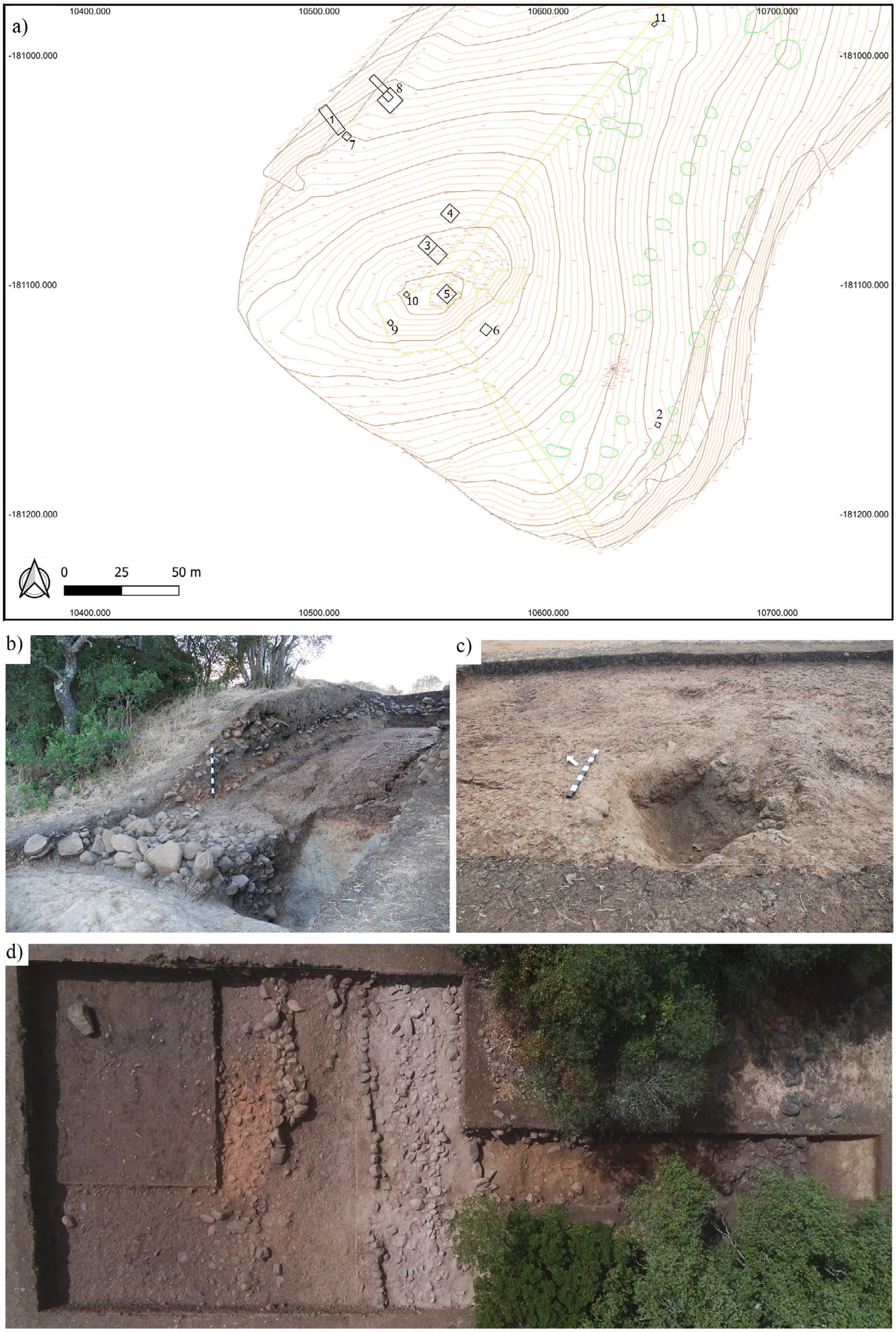

Figure 2. Location of the different sectors excavated in the Outeiro do Circo with a general overview of the sector's spatial relations (a), the wall identified in sector 1 (b), the pit/silo excavated in the site's inner area corresponding to sector 3 (c), and the wall present in sector 8 with its slope and undetermined structures in its inner part (d).

Information concerning these groups' exploitation and management of farm animals and the relation between farming and hunting strategies are poorly understood (but see Cardoso 1996). This relates mainly to the lack of published faunal assemblages or their poor information due to sample size and preservation. Moreover, characteristic large settlements generally lack a precise chronological framework that could allow for the in-depth discussion of results and broad geographic comparison based on material culture, absolute chronologies and economies.

Aiming to contribute to these questions we will focus on the Outeiro do Circo site, located in Mombeja (Beja, Portugal). This large walled settlement has been excavated almost continuously since 2008 resulting in the acquisition of important data concerning the LBA walled sites in Southwestern Iberia, with studies focusing on structures, materials, economy, and chronology (*e.g.*, Serra *et al.* 2015, 2016; Valério *et al.* 2013; Almeida *et al.* 2020; Porfírio *et al.* 2020; Dias *et al.* 2022). We present the zooarchaeological and taphonomical study of the entire faunal assemblage recovered so far, complemented by two new absolute dates obtained on faunal remains that help understand the accumulation chronology. Thus, we contribute to the characterization of this large settlement, and the discussion of animal exploitation and the regional periodization of the LBA.

2. Materials and Methods

2.1. Materials

The fortified settlement of Outeiro do Circo is located in the Lower Alentejo peneplain, near the city of Beja (Figure 1). This region is marked by a large flattened area with smooth reliefs and by the Sado and Guadiana hydrographic basins. The site is a 17-hectare fortified settlement positioned in an elongated elevation that dominates the immediate landscape. Outeiro do Circo is known at least since the 1970s due to field surveys that allowed for an initial inclusion of this site in the larger phenomena of the regional LBA fortified settlements (Parreira 1977; Parreira & Soares 1980). Field surveys and photo-interpretation followed (Serra *et al.* 2008) and the archaeological excavations started in 2008.

Test pits were made in the inner areas of the settlement but research has focused on the wall in the areas closer to the fortification due to their higher preservation (Figure 2a). The inner area of the site is highly affected and disturbed due to mechanized agriculture and natural erosion. However, a small pit/silo (Figure 2c) sealed with stones had faunal remains, LBA pottery, and one rock with crop marks (Serra *et al.* 2015, 2016; Dias *et al.* 2022). The wall was tested in sector 1 (Figure 2b) and, more recently, in sector 8 (Figure 2d). This resulted in the identification of a fairly preserved complex wall, formed by an upper stone wall, followed by a burnt clay ramp in the slope, and another stone wall at the base of the slope.

Regarding the materials recovered, pottery is generally coarse with rough surfaces, but some surface flatting, burnishing and polishing are registered, with only c. 1% of the sample being decorated (*e.g.*, burnishing, incise, combed, impressed, plastic). Pottery comprises medium and large size bowls and deeper bowls, globular recipients, and a small number of "S" shaped pots (Silva 2014). Lithic materials include sickle elements, hammers, projectiles, grindstones, and adornments; they are predominantly made in locally available raw materials such as jasper, chert and gabbro diorite, but exogenous materials occur (*e.g.*, flint) (Porfírio *et al.* 2020). Metal rings, one pendant, one bead, and remains associated with metallurgy were recovered (Valério *et al.* 2013; Porfírio *et al.* 2020).

Table 1. Absolute dates for Outeiro do Circo. Calibration of 14C dates using IntCal20 calibration curve (Reimer *et al.* 2020) and the OxCal v4.4 program (Bronk Ramsey 2009).

ref. lab.	sample	context	BP date	Cal BCE (2 σ)	reference
Beta-620548	*Ovis*/*Capra* ulna	[864]	2880±30	1197-1173 (3.5%) 1162-1143 (2.8%) **1130-973 (85.8%)** 956-933 (3.3%)	unpublished
Beta-620549	*Bos taurus* mandible	[302]	2830±30	1107-1096 (1.3%) 1082-1068 (1.7%) **1056-904 (92.4%)**	unpublished
Sac-2884	Fauna	layer 12	2880±45	**1207-928 (95.4%)**	Valério *et al.* 2013
Sac-2885	Fauna	layer 6	2900±45	**1222-971 (92.6%)** 957-932 (2.9%)	Valério *et al.* 2013

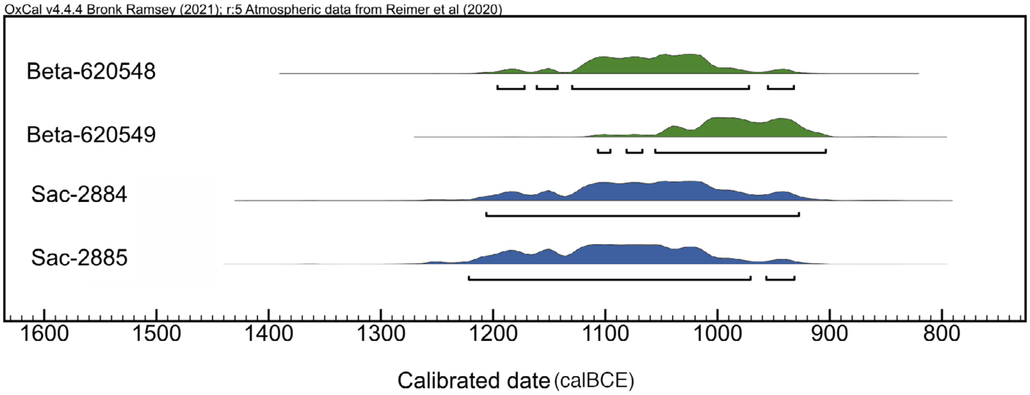

Figure 3. Plot of the available radiocarbon dates described in Table 1.

The published radiocarbon dates are reinforced with two new unpublished results, one for the pit/silo from sector 3, and one for the top of the wall (Table 1). Altogether, these results indicate that the site was occupied during the transition from the second to the first millennium BCE, specifically during the last quarter of the second millennium BCE and the first quarter of the first millennium BCE, thus consistent with the material culture evidence (Figure 3). Further wider analysis of material culture, stratigraphies and chronological frameworks are being prepared and are expected to be published in the near future.

2.2. Methods

This paper presents the complete faunal assemblage recovered from Outeiro do Circo from 2008 to 2021. The recently published zooarchaeological results from a small sample from sectors 1 and 3 were presented in 2017 (Dias *et al.* 2022), and the zooarchaeological and taphonomical data from a small sample from sector 8 was presented and published in 2020 (Almeida *et al* 2020). Here we present the first complete zooarchaeological and taphonomical analysis of all the remains from the different archaeological excavations, following the same methodological framework. The assemblage provenance is diverse and comprises remains from several stratigraphical units, independently of the degrees of bioturbation and affectation: sectors 1 (n = 402, 14.3%), 3 (n = 205, 7.3%), 7 (n = 200, 7.1%), 8 (1964, 70%), indeterminate sector (n = 34, 1.2%). Considering provenance by stratigraphic units or layers, the majority of the collection is from [864] (n = 322, 11.5%), [862] (n = 248, 8-8%), [303] (n = 139, 5%), [867] (n = 138, 4.9%), and [842] (n = 137, 4.9%), with the other records being from different areas of the excavated sectors. Hence, as indicated in the materials section, a large amount of the remains under analysis are from sectors 1, 7 and 8, thus corresponding to the trench pits made in the slopes and inner areas of the well-preserved composite wall; a comparatively smaller part was recovered in the pit/silo from trench 3 (Figure 2).

The remains were analysed following zooarchaeological and taphonomical methodologies for the study of archaeofauna (Lyman 1994; Reitz & Wing 2008). The data is presented according to the number of specimens (NSP), the number of identified specimens (NISP), the minimum number of elements (MNE), and the minimum number of individuals (MNI) (Grayson 1984; Lyman 2008). All remains were included in a database with the indication of the portions and surfaces preserved in relation to the complete original. This allowed for the MNE estimate to consider both diaphysis (Marean & King 1998) and epiphysis (Stiner 1994), as well as other aspects considered in the MNI estimate such as laterality, age, sex, and size. The MNI was calculated as a general cumulative counting not considering differences between stratigraphic units (MNIg), useful for the discussion of kill-off patterns but probably represents an underrepresentation of individuals. An estimate taking into consideration the different stratigraphic units (MNIsu) is also presented, but it is a high overrepresentation, particularly of poorly represented species and of species with a large number of isolated teeth. Considering this, kill-off patterns do not consider this estimate for discussion purposes.

Linear biometric data was tentatively obtained from bones and teeth with a Lux digital calliper (Driesch 1976; Payne & Bull

1988; Davis 1996; Albarella *et al.* 2005; Davis *et al.* 2017b; Salvagno & Albarella 2017). This was made to better ascertain taxonomy, mainly in close similar species, by comparison with regionally published measurements, with a special focus on chronologically roughly "contemporaneous" data. This, together with morphological characteristics, was considered to better describe bovine, swine, caprine and leporids (Boessneck *et al.* 1964; Boessneck 1970; Callou 1997; Zeder & Pilaar 2010; Zeder & Lapham 2010). Taxonomically indeterminate fragments were tentatively classified into a weight group, hereinafter WG (Brain 1981; Bunn 1983, 1986), *i.e.*, indeterminate (WG 0), very small (WG 1 = <20 kg), small (WG 2 = 20-100 kg), medium (WG 3 = 100-300 kg), and large (WG 4 = >300 kg). Kill-off patterns were estimated according to bone and teeth development for the main species identified in the assemblage (Payne 1973, 1987; Bull & Payne 1982; Grant 1982; Jones 2006; Zeder 2006; Lemoine *et al.* 2014; Zeder *et al.* 2015). After Almeida and Valera (2021), these results were grouped into general classes, *i.e.*, neonate (absent in the assemblage), infant, juvenile, sub-adult, adult, and senile.

Taphonomical analysis aiming to characterize breakage patterns was implemented. After Bunn (1983) and Villa & Mahieu (1991), breakage planes were analysed according to diaphysis length and section completeness in relation to their original. Diaphysis fragments' outline, angle and surface were recorded following Villa & Mahieu (1991). Macroscopic and microscopic analysis of remains surfaces was implemented to register bone surface modifications, hereinafter BSM, such as anthropogenic breakage (Binford 1981; Brain 1981; White 1992; Pickering *et al.* 2013), cutmarks (Binford 1978, 1981; Shipman 1981), tooth marks and other consumption indicators (Binford 1981; Shipman 1981; Saladié 2011; Saladié *et al.* 2013), and thermal alterations (White 1992; Stiner *et al.* 1995; Solari *et al.* 2015). The location, disposition, relations, typology, morphology, size and intensity of these taphonomical indicators were registered (Almeida 2017). The location and typology of cutmarks were used to infer butchery stages following Binford (1978, 1981), Bunn & Kroll (1986), Nilssen (2000), Pobiner *et al.* (2008) and Almeida (2010, 2017). Tooth marks characterisation considered bone tissue type (Selvaggio & Wilder 2001; Domínguez-Rodrigo & Piqueras 2003; Andrés *et al.* 2013), differentiating their location between cortical and cancellous tissues. Other indicators related to the sedimentary environment were quantitatively and qualitatively registered (Almeida 2017), namely weathering (Behrensmeyer 1978), vermiculations (Lyman 1994), oxide precipitation (López-González *et al.* 2006), chemical dissolution (Fernández-Jalvo *et al.* 2002), trampling (Behrensmeyer *et al.* 1986; Shipman & Rose 1984), or concretions (Courty *et al.* 1989).

Table 2. Absolute and relative values obtained for the taxonomically identified and unidentified faunal remains according to the number of identified specimens (NSP), Minimum number of elements (MNE), minimum number of individuals by stratigraphic unit (MNIsu) and minimum number of individuals general (MNIg).

	NSP	%	MNE	%	MNIsu	%	MNIg	%
MAMMALIA								
Bos taurus	33	6.3	20	6.6	18	7.3	4	3.2
Bos sp.	14	2.7	2	0.7	7	2.9	-	-
Capra hircus	10	1.9	7	2.3	10	4.1	2	1.6
Ovis aries	5	1.0	2	0.7	3	1.2	1	0.8
Ovis/*Capra*	171	32.5	64	21.1	29	11.8	4	3.2
Cervus elaphus	24	4.6	19	6.3	17	6.9	2	1.6
Sus sp.	102	19.4	54	17.8	33	13.5	6	4.8
Equus sp.	2	0.4	1	0.3	1	0.4	1	0.8
Herbivore	21	4.0	-	-	-	-	-	-
Canis sp.	5	1.0	3	1.0	3	1.2	1	0.8
Oryctolagus cuniculus	9	1.7	9	3.0	7	2.9	2	1.6
Lepus sp.	4	0.8	4	1.3	3	1.2	1	0.8
Leporidae	5	1.0	5	1.7	1	0.4	-	-
Microfauna	1	0.2	1	0.3	1	0.4	1	0.8
Sub-total Mammalia	406	77.2	191	63.0	133	54.3	26	21

	NSP	%	MNE	%	MNIsu	%	MNIg	%
AVES								
Aves indeterminate	1	1	1	1	1	0.4	1	0.8
Sub-total Aves	1	0.2	1	0.3	1	0.4	1	0.8
MOLLUSCA								
Bivalvia								
Scrobicularia plana	1	0.2	1	0.3	1	0.4	1	0.8
Pecten sp.	2	0.4	2	0.7	2	0.8	1	0.8
Sub-total Bivalvia	3	0.6	3	1.0	3	1.2	2	1.6
Gastropoda								
Rumina decollata	83	15.8	78	25.7	78	31.8	78	62.9
cf. *Helix* sp.	15	2.9	12	4.0	12	4.9	-	-
Cepaea nemoralis	7	1.3	7	2.3	7	2.9	7	5.6
Cochlicella acuta	3	0.6	3	1.0	3	1.2	3	2.4
Osteophora barcula	2	0.4	2	0.7	2	0.8	2	1.6
Theba pisana	6	1.1	6	2.0	6	2.4	6	4.8
Sub-total Gastropoda	116	22.1	108	35.6	102	41.6	96	77.4
Sub-total Mollusca	119	22.7	111	36.6	105	42.9	98	79.0
Sub-total identified	526	100	303	100	245	100	124	100
Indeterminate								
Weight group ind.	989	43.4						
WG <20 kg	10	0.4						
WG <100 kg	126	5.5						
WG 20-100 kg	812	35.6						
WG 20-300 kg	141	6.2						
WG 100-300 kg	51	2.2						
WG >100 kg	92	4.0						
WG >300 kg	58	2.5						
Sub-total indeterminate	2279	100						
Total	2805							

Table 3. NISP(MNE) values estimate for the Outeiro do Circo assemblage. EQ = *Equus* sp., BT = *Bos taurus*, B = *Bos* sp., CEE = *Cervus elaphus*, CH = *Capra hircus*, OA = *Ovis aries*, OC = *Ovis*/*Capra*, HER = Herbivore, S = *Sus* sp., ORC = *Oryctolagus cuniculus*, LEP = *Lepus* sp., L = Leporidae, CAN = *Canis* sp., IND = Indeterminate.

	EQ	BT	B	CEE	CH	OA	OC	HER	S	ORC	LEP	L	CAN	Ind.	Total
axial cranial skeleton															
horn core/antler				1(1)	3(3)									5	9
cranium (maxilla)							2(2)		3(3)					45	50
mandible		8(3)	2(1)	2(1)			7(6)		6(6)	3(3)		1(1)	2(1)	14	45
loose tooth	1	8	11	3	3	2	95	16	45				1	19	204
axial post-cranial skeleton															
vertebra												1(1)	1(1)	56	58
rib														88	88
appendicular skeleton															
scapula							3(2)		6(6)	1(1)				8	18
humerus							8(8)		3(2)	1(1)				3	15
radius		1(1)		2(2)			12(8)		1(1)	1(1)	1(1)			4	22
ulna							3(3)		2(2)	1(1)	3(3)			1	10
metacarpal			1(1)	1(1)			8(6)		1(1)						11
pelvis	1(1)						5(3)		2(2)	1(1)		1(1)		5	15
femur				2(2)			4(4)		3(3)	1(1)		2(2)		7	19
patella		1(1)													1
tibia				1(1)			3(3)		1(1)					3	8

	EQ	BT	B	CEE	CH	OA	OC	HER	S	ORC	LEP	L	CAN	Ind.	Total
fibula									3(3)						3
metatarsal		2(2)		2(2)			2(2)		3(3)						9
astragalus		2(2)		2(1)	2(2)	3(2)	3(3)	2	5(4)					1	20
calcaneus		1(1)			1(1)		3(3)		1(1)						6
carpal/tarsal		2(2)		2(2)			2(2)		2(2)					5	13
metapodial		1(1)		3(3)			6(4)	3	4(3)					4	21
phalange 1		2(2)		2(1)	1(1)		5(5)		6(6)				1(1)		17
phalange 2		4(4)		1(2)					2(2)						7
phalange 3		1(1)							3(3)						4
phalange														1	1
other															
long bone														794	794
flat bone														457	457
indeterminate bone														759	759
Total	2(1)	33(20)	14(2)	24(19)	10(7)	5(2)	171(64)	21	102(54)	9(9)	4(4)	5(5)	5(3)	2279	2684

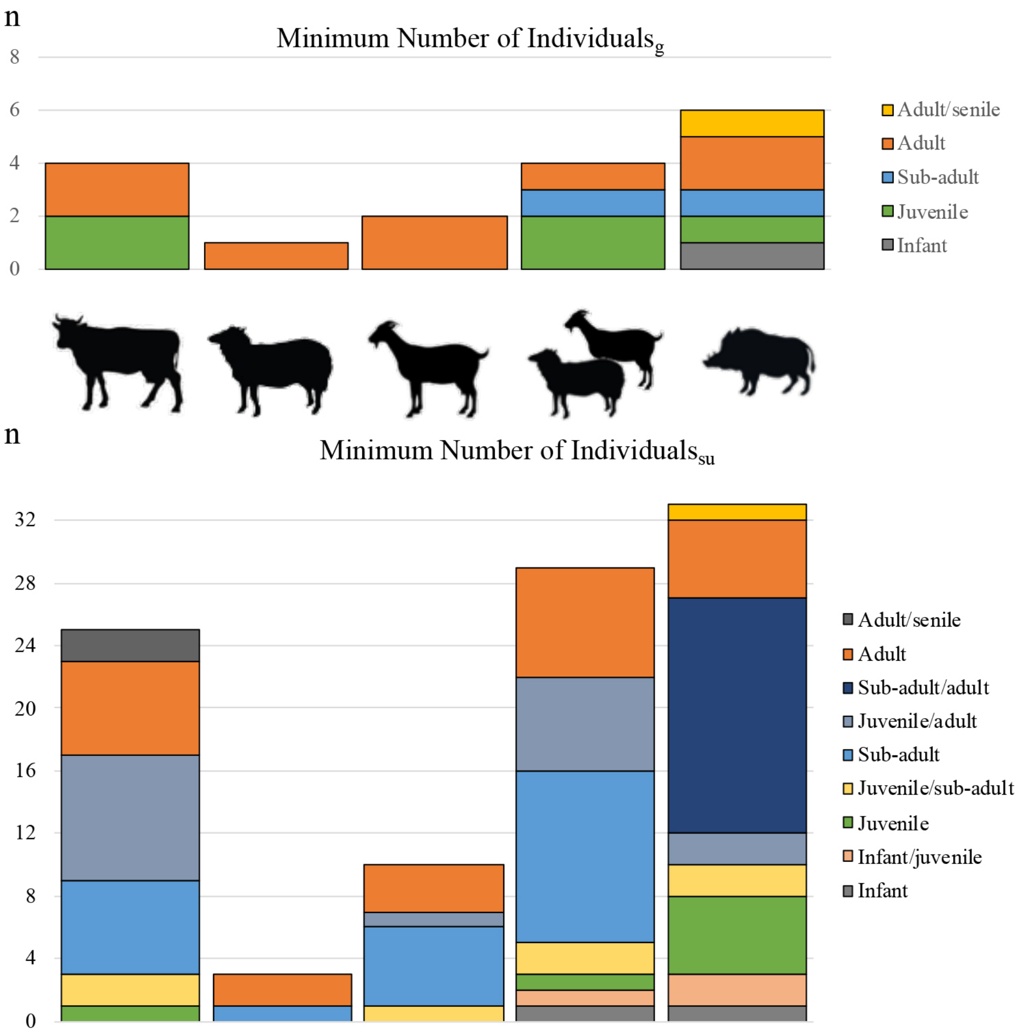

Figure 4. Minimum Number of Individuals (MNIg and MNIsu) estimate for Outeiro do Circo.

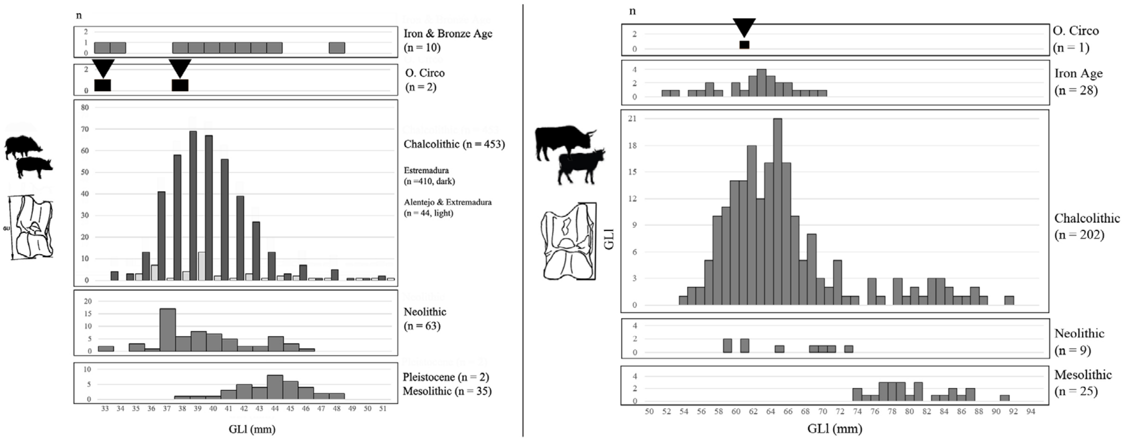

Figure 5. Histogram of results obtained for the Greatest Lateral length (GLl) of swine and bovine astragalus from the O. Circo site and other Portuguese and adjacent Spanish sites dated to the Pleistocene and Mesolithic (Detry 2007; Valente 2008, 2013), Neolithic (Almeida 2017; Davis *et al.* 2018; Encarnação & Almeida 2017; Almeida *et al.* 2021b), Chalcolithic (Driesch & Boessneck 1976; Cardoso & Detry 2001/2002; Castaños 1992, 1997; Rodríguez-Hidalgo & Cabezas 2011; Davis & Mataloto 2012; Moreno-García 2013; Correia 2015; Moreno-García & Sousa 2015; Aleixo 2018; Davis *et al.* 2018; Detry *et al.* 2020; Almeida *et al.* 2021a; Almeida & Valera 2021; Cardoso *et al.* 2021; Pereiro *et al.* 2021; Almeida *et al.* 2022), Iron and Bronze Age sites (Davis 2006, 2017a; Almeida *et al.* 2020b).

3. Results

3.1. Anatomy and Taxonomy

The assemblage is composed of a NSP = 2805, of which a NISP = 406 (14.5%) are taxonomically identified Mammalia, NISP = 119 (4.2%) are Mollusca, and NISP = 1 (0.1%) Aves (Tables 2 and 3). A total of 2279 (81.2%) of the remains correspond to indeterminate Mammalia that follow the taxonomic pattern of the identified mammals, with an important number of remains corresponding to WG 2 (n = 812) and the remaining groups being less common. The majority of indeterminate Mammalia are also indeterminate in the WG category (n = 989, 43.4%).

Among the identified sample, within Mammalia, one must emphasize the relevance of caprine for which goats and sheep are specifically identified. The lack of diagnostic features hindered further identifying the remaining specimens ascribed to *Ovis*/*Capra*. A similar situation occurred with the remains of indeterminate herbivores, comprising mostly small isolated tooth fragments that with a certain degree of certainty probably correspond to *Ovis*/*Capra* although we cannot confirm this. The MNI estimate indicates one adult sheep, two adult goats, plus other individuals comprising two juveniles, one sub-adult, and one adult goat/sheep (Figure 4).

Swine are quantitatively important in this collection. The problems associated with the specific identification of swine status and the superimposition in linear biometric data commonly hinder their specific discussion (Albarella *et al.* 2005). This occurs in the assemblage under analysis but the small size of the measurable (Figure 5) and unmeasurable remains seems to point towards smaller individuals, possibly domesticated or hybrid. The MNI estimate demonstrates a spread in the age groups with one infant, one juvenile, one sub-adult, two adults, and one adult/senile.

The small size of the bovine is noteworthy (Figure 5) with a majority of these remains being identified specifically as cattle. The appendicular skeleton is present but an important amount of the fragments corresponds to the cranial body part. The MNI is divided between juvenile and adult individuals.

The red deer is the most commonly used taxa to discuss hunting practices in Iberian Late Prehistory. This species is identified in the assemblage by remains from adult individuals' cranial and appendicular body parts, the latter mainly from the distal portions. Leporids comprise the European wild rabbit, hare and wild rabbit/hare. A lack of smaller bones from the appendicular extremities is noticeable and could be the result of anthropic selection or, maybe more probable, diagenetic attrition and/or recovery bias. The status of equids is problematic because only two remains were recovered: one upper tooth that could relate to *Equus asinus* as previously suggested, and a pelvis fragment (Dias *et al.* 2022). Canids have more remains but these lacked diagnostic data that could eventually allow distinction between dog and wolf.

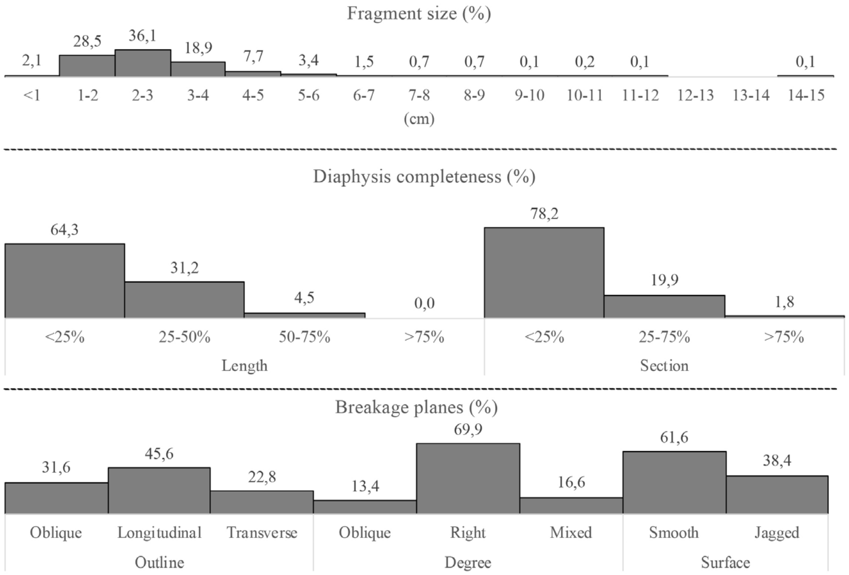

Figure 6. Assessment of breakage per weight group in the assemblage considering fragment size (n = 2805), diaphysis completeness (n = 487), and breakage planes (n = 1160).

Several Mollusca were recovered with a higher frequency of Gastropoda, among which *Rumina decollata* is the more numerous taxa. Bivalvia is comparatively less frequent but comprises a *Scrobicularia plana* and two *Pecten* sp. shell fragments.

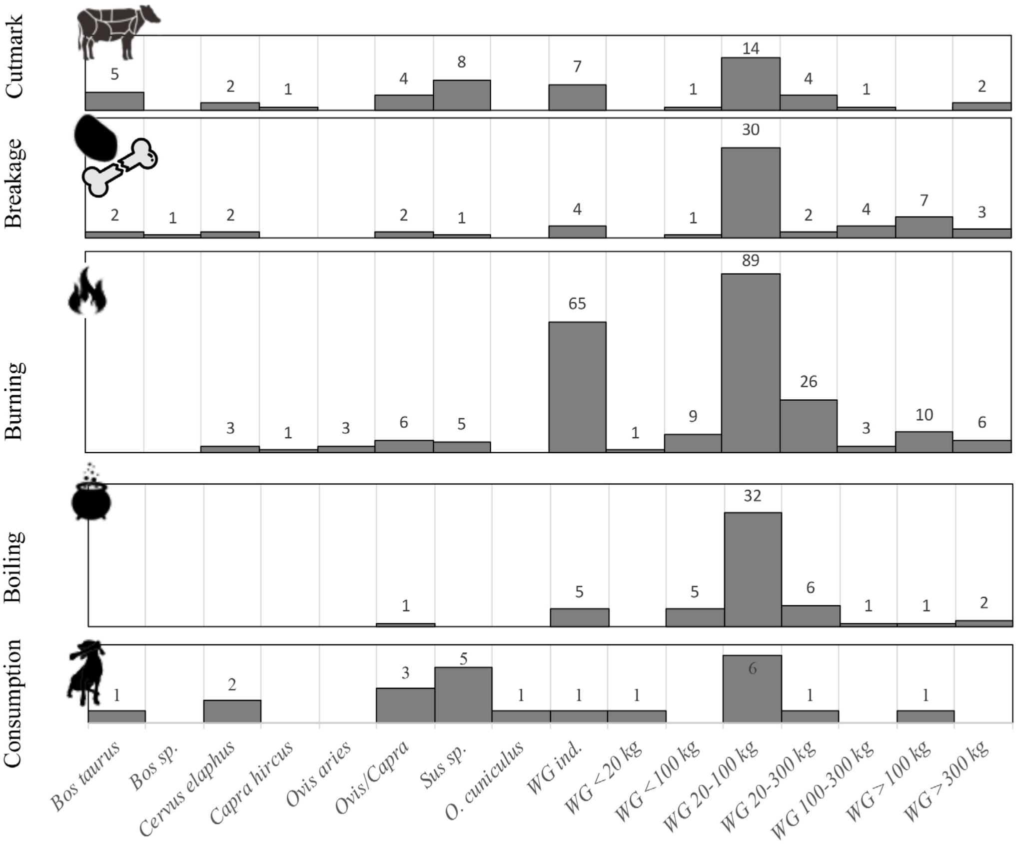

Figure 7. Main taphonomical indicators observed by taxa and weight group (WG).

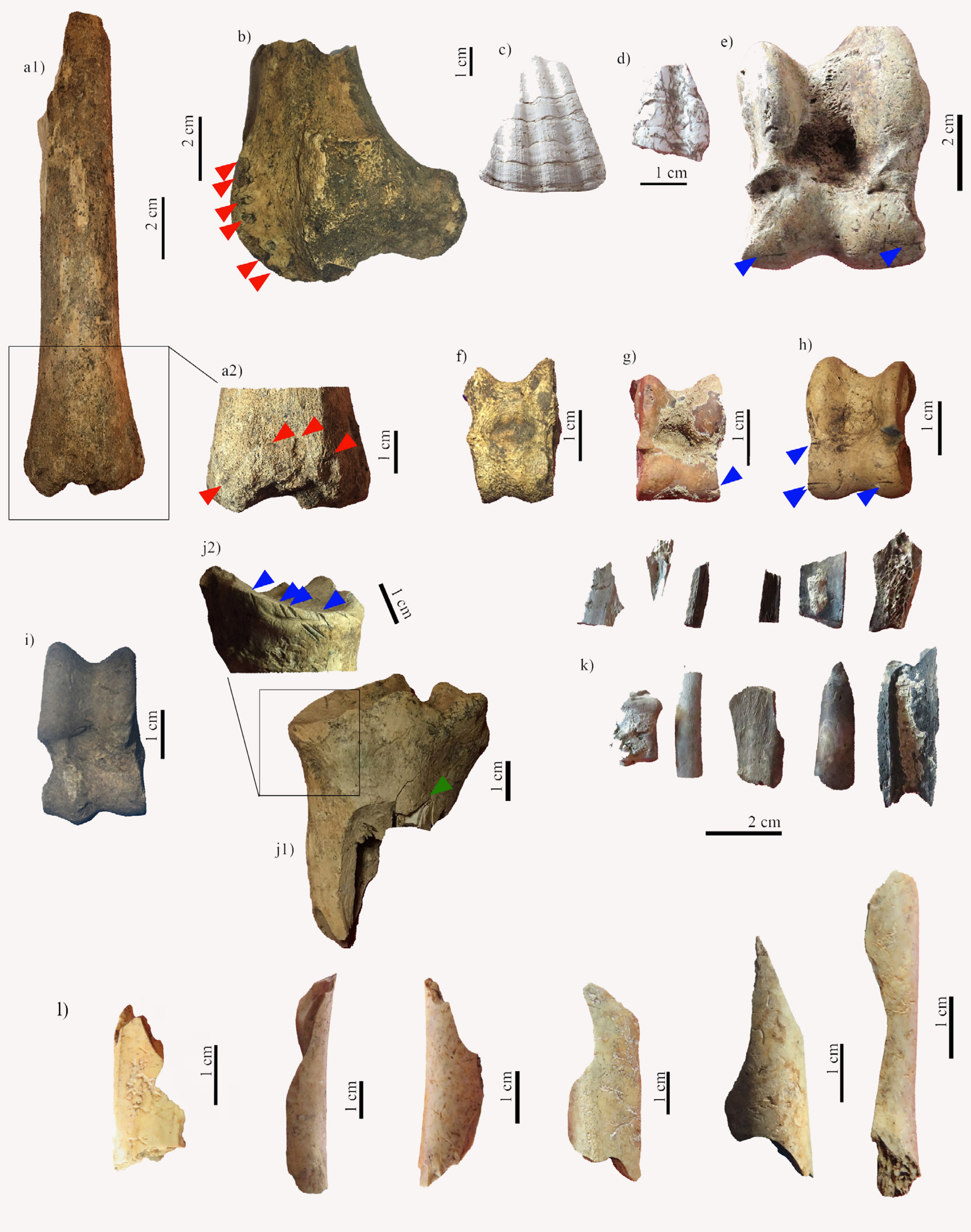

Figure 8. Selection of materials from Outeiro do Circo: carnivore action in a red deer radius (a) and femur (b); two scallop shell fragments (c, d); cattle astragalus with cutmarks (e); astragalus showing digestive damage (f); sheep astragalus with burnt damage (g); goat astragalus with cutmarks (h); astragalus (possibly) from a pig (i); red deer radius with anthropogenic breakage and cutmarks (j); example of bone fragments showing burnt damage in carbonisation and calcination stages (k); example of long bone fragments with fresh and anthropogenic breakage (l).

3.2. Taphonomy

The assemblage is highly fractured and fragmented, with around 31% having < 2 cm of maximum size, and 63% between 2 and 5 cm. Other larger remains exist but are rare (Figure 6). The analysis of diaphysis completeness further reinforces this with a higher relevance of diaphysis fragments with < 25% of their original length and section (Figure 6). Remains with > 75% of their original length are non-existent and only 1.8% show > 75% of their section preserved. The analysis of breakage planes seems elucidative concerning the type of predominant breakage in the collection. Longitudinal outlines are abundant with some number of transverse outlines as well. Right degrees are predominant in almost 70% of the cases analysed but jagged surfaces are only observed in 38% of the sample. Adding to this, complete remains are uncommon and correspond to bones from the extremities – carpal or tarsal bones (n = 8, 6.4%), phalanges (n =9, 7.1%), metatarsals (n = 1, 0.8%) –, isolated teeth (n = 22, 17.5%), and mostly gastropods shells (n = 86, 68.3%).

Taphonomical indicators of butchering, processing and consumption were observed (Tables 4, 5 and 6). Cutmarks are present in 49 remains, incisions (n = 39), chop marks (n = 6), incisions+chop marks (n = 3) and the complete sectioning of the bone (n = 1), registered mainly in long bones, astragalus, and ribs (Table 5). These occur in taxonomically identified bones from swine, caprine, red deer and cattle, being more common in taxonomically indeterminate remains (Figures 7 and 8). Activities related to skin removal, evisceration, dismemberment and segmentation of the post-cranial axial skeleton were inferred based on cutmarks morphology and location.

Anthropogenic breakage is found in the shape of impact notches (n = 26), cortical extractions (n = 14), percussion cones (n = 8), and other stigmas (n = 15) such as adhering flakes, fissures and possible counterblows. These indicators are almost exclusively found in long bones (n = 51). They were registered in swine, caprine, red deer, and bovine, but are more frequent in remains only identified to WG, mainly of 20-100 kg.

Burning is the most common indicator observed (Table 6). It appears generally in taxonomically indeterminate remains being frequent in WG 2, WG 2/3, and WG indeterminate. The burnt bones are anatomically diverse but indeterminate fragments, indeterminate long and flat bones are more numerous. Among identifiable body parts, ribs and astragalus are prevalent. Degrees 1 (n = 12, 5.1%), 2 (n = 65, 27.4%), 3 (n = 69, 29.1%), 4 (n = 30, 12.7%), and 5 (n = 22, 9.3%) are present. Double colouration is common, namely in degrees 2/3 (n = 33, 13.9%), 2/5 (n = 1, 0.4%), 3/4 (n = 2, 0.8%), 3/5 (n = 1, 0.4%), and 4/5 (n = 2, 0.8%). Possible boiling is found in long bones, indeterminate flat bones, indeterminate bones, and one rib. In the exception of one caprine bone, boiling is circumscribed to taxonomically indeterminate bones with WG 2 corresponding to 59%.

Consumption indicators include digested bones (n = 3), one caprine shaft cylinder (n = 1), and bones with tooth marks (n = 20). The morphologies registered are furrowing (n = 6), pits (n =9), punctures (n = 3), and notches (n = 5). Swine scapula, indeterminate long bones, and determinate long bones from rabbit, red deer, caprine and cattle are the most common bones altered.

The measurements obtained in pits and punctures are presented in Table 7 and were compared with published actualistic and experimental data (Figure 9). The wide 95% CI and small sample hinder comparisons. However, some aspects are noteworthy: a clear separation from the different human samples for cortical/thin cortical measurements with some similarities in cancellous tissue; parallels with the size of tooth marks made by both swine and canids, especially the width in cancellous tissue and width and length in cortical/thin cortical tissues, but with the high mean being more similar to swine, as is clearer in the length in cancellous tissue.

Taphonomical indicators related to the sedimentary environment are observable but predominantly show early stages of alteration (Tables 4 and 8). Chemical corrosion and hydric abrasions are scarce. The relative abundance of weathering and vermiculations is comparatively higher than concretions and manganese oxides but early degrees 1 and 2 are >76% of the affected sample in all cases.

Table 4. Main taphonomical indicators from the Outeiro do Circo assemblage. For the indicators identified with an *, the % values were calculated without considering Aves, Mollusca, and Mammalia isolated teeth independently of their preservation.

indicators	**n**	**%**
artifact	2	0.1
*cutmarks	49	2.0
*anthropogenic breakage	58	2.3
*burnt	227	9.1
*consumption marks	24	1.0
*boiling	54	2.2
weathering	401	14.3
vermiculations	755	26.9
chemical corrosion	5	0.2
concretion	101	3.6
manganese oxides	175	6.2
hydric abrasion	1	0.04
recent breakage	949	33.8
complete remains	126	4.5

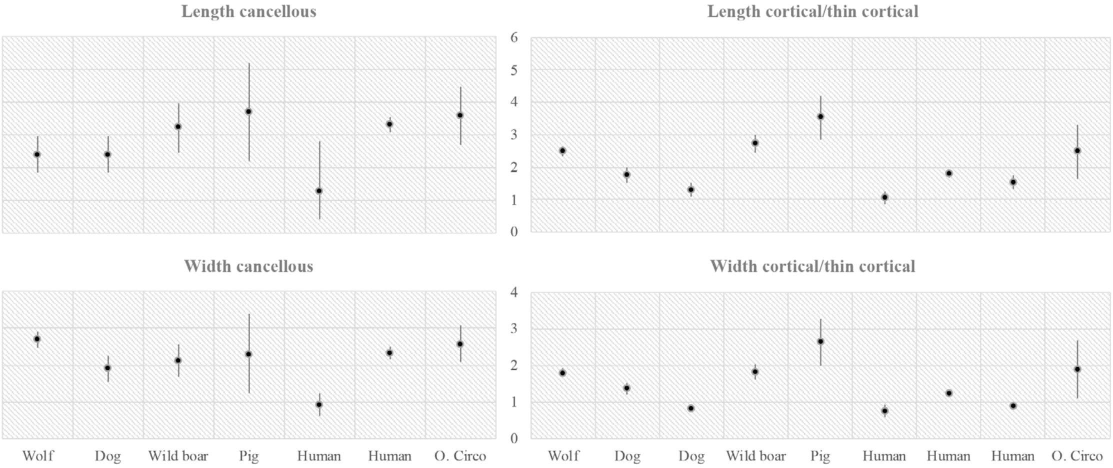

Figure 9. Comparison of results (in mm) obtained for the maximum length and width of pits/punctures recorded according to the type of bone tissue (after Andrés *et al.* 2012; Saladié 2009; Saladié *et al.* 2013; Delaney-Rivera *et al.* 2009). The values presented are the mean and CI of 95%.

Table 5. Absolute values of cutmarks, anthropogenic breakage, tooth marks & digestion per mammalian body part and species. BT = *Bos taurus*, B = *Bos* sp., CEE = *Cervus elaphus*, CH = *Capra hircus*, OA = *Ovis aries*, OC = *Ovis*/*Capra*, S = *Sus* sp., ORC = *Oryctolagus cuniculus*, IND = Indeterminate.

	Cutmarks								**Anthropogenic breakage**								**Tooth marks & digestion**							
	BT	**CEE**	**CH**	**OC**	**S**	**IND**	**n**	**%**	**BT**	**B**	**CEE**	**OC**	**S**	**IND**	**n**	**%**	**BT**	**CEE**	**OC**	**S**	**ORC**	**IND**	**n**	**%**
axial cranial skeleton																								
horn core/antler																								
cranium (maxilla)						1	1	2.0																
mandible	1				1		2	4.1		1	1				2	3.4			1				1	4.3
axial post-cranial skeleton																								
vertebra						2	2	4.1														1	1	4.3
rib						5	5	10.2																
appendicular skeleton																								
scapula					2		2	4.1												4			4	17.4
humerus													1	1	2	3.4					1		1	4.3
radius		1		1			2	4.1			1	2			3	5.2		1	1				2	8.7
ulna																								
metacarpal																								
pelvis				1		1	2	4.1																
femur				2		2	4	8.2						1	1	1.7		1					1	4.3
patella																								
tibia					1		1	2.0																
fibula																								
metatarsal	1				1		2	4.1	1						1	1.7	1						1	4.3
astragalus	1	1	1		2		5	10.2														1	1	4.3
calcaneus	1				1		2	4.1																
metapodial														1	1	1.7								
carpal/tarsal																				1			1	4.3

	Cutmarks								**Anthropogenic breakage**								**Tooth marks & digestion**							
	BT	**CEE**	**CH**	**OC**	**S**	**IND**	**n**	**%**	**BT**	**B**	**CEE**	**OC**	**S**	**IND**	**n**	**%**	**BT**	**CEE**	**OC**	**S**	**ORC**	**IND**	**n**	**%**
phalange 1	1						1	2.0																
phalange 2									1						1	1.7								
phalange 3																								
phalange																								
Other																								
long bone						10	10	20.4						43	43	74.1						8	8	34.8
flat bone						7	7	14.3						2	2	3.4						2	2	8.7
indeterminate						1	1	2.0						2	2	3.4								
total	5	2	1	4	8	29	49	100	2	1	2	2	1	50	58	100	1	2	2	5	1	12	23	100

Table 6. Absolute values of burning and boiling per mammalian body part and species. BT = *Bos taurus*, B = *Bos* sp., CEE = *Cervus elaphus*, CH = *Capra hircus*, OA = *Ovis aries*, OC = *Ovis*/*Capra*, S = *Sus* sp., ORC = *Oryctolagus cuniculus*, IND = Indeterminate.

	Burning damage								**Boiling**			
	CEE	**CH**	**OA**	**OC**	**S**	**IND**	**n**	**%**	**OC**	**IND**	**n**	**%**
axial cranial skeleton												
horn core/antler												
cranium (maxilla)												
mandible												
axial post-cranial skeleton												
vertebra						2	2	0.9				
rib						12	12	5.3		1	1	1.9
appendicular skeleton												
scapula				1	2		3	1.3				
humerus									1	1	2	3.8
radius				3			3	1.3				
ulna												
metacarpal												
pelvis												
femur										1	1	1.9
patella												
tibia												
fibula												
metatarsal												
astragalus	2	1	3	1			7	3.1				
calcaneus				1			1	0.4				
metapodial										1	1	1.9
carpal/tarsal												
phalange 1												
phalange 2	1				2		3	1.3				
phalange 3					1		1	0.4				
phalange												
other												
long bone						112	112	49.3		31	31	58.5
flat bone						21	21	9.3		12	12	22.6
indeterminate bone						62	62	27.3		5	5	9.4
total	3	1	3	6	5	209	227	100	1	52	53	100

Table 7. Descriptive statistics for the length and width (in mm) of pits and punctures on cortical/thin cortical and cancellous tissues recorded on taxonomically identified and indeterminate remains identified to weight group (SD = standard deviation, C.I. = confidence interval).

	N	mean	SD	C.I.+95%	C.I.-95%	min	max	95%CI
length cortical	18	2.48	0.86	3.32	1.64	1.21	4.03	0.84
length cancellous	14	3.57	1.10	4.45	2.69	2.44	6.62	0.88
width cortical	18	1.90	0.82	2.70	1.09	0.75	3.25	0.81
width cancellous	14	2.58	0.64	3.09	2.07	2.44	4.22	0.51

Table 8. Other taphonomical indicators according to the degrees of alteration registered. Weathering follows Behrensmeyer (1978), vermiculations, concretion and manganese oxide according to Almeida (2017).

	degree 1	degree 2	degree 3	degree 4
weathering	56.6	26.9	13.7	2.7
vermiculations	64.9	23.2	10.3	1.6
concretion	44.6	31.7	15.8	7.9
manganese oxides	42.3	37.7	17.1	2.9

4. Discussion

4.1. The Outeiro do Circo Late Bronze Age faunal record

Previous works allowed for preliminary insights into the exploitation of animal resources in the Outeiro do Circo during the LBA. Dias *et al.* (2022) indicated a similar abundance of caprine and bovine, followed by swine and red deer (NISP = 80), with kill-off patterns suggesting the acquisition of primary and secondary products. Later, Almeida *et al.* (2020) published the zooarchaeological and taphonomical analysis of a small sample with a clear prevalence of caprine, followed by swine and bovine, with other taxa being scarce (NISP = 94). Besides an initial comparison at the regional scale, the kill-off patterns further reinforced previous suggestions of exploitation, and the taphonomical information allowed for an initial characterization of butchery practices and secondary access by a carnivore. The comparison with the previous work by Dias *et al.* (2022) was hindered by differences in methodologies and data collection. Here we present the results for the entirety of the Outeiro do Circo assemblage (NISP = 526) following the same methodological framework, thus allowing for a sustained comparison of data. This is important, especially from a taphonomical perspective. Moreover, to reinforce the chronological framework, we obtained two new absolute dates for the most relevant contexts with fauna, namely the pit/silo from sector 3, and the wall from sector 8, which demonstrate "contemporaneity" between different samples. The acquisition of a more robust set of absolute dates for the site is ongoing, with new results expected to be obtained in the near future. For the time being, the four absolute dates previously mentioned are consistent among themselves and with the LBA archaeological materials recovered in the different trench pits. As such, the faunal materials are considered informative of the animal palaeoeconomy of the site during the transition from the second to the first millennium BCE. A continuation of archaeological works in other areas of this large settlement is needed to better understand the possible differences in the intra-site anatomic, taxonomic or taphonomic profiles.

The Outeiro do Circo mammal assemblage shows a clear predominance of caprine followed by swine that has a parallel in the taxonomically indeterminate predominance of WG 2 (20-100 kg). This is obvious in terms of NISP and MNE values, but less relevant if MNI estimates are considered, with swine having a similar number of individuals. In the few cases where a separation between goat and sheep was achieved, the latter are less numerous. Caprine has a majority of adult individuals, still, at least two juveniles and one adult are present. Swine have a generally small size suggesting that they would correspond to pigs or hybrids, with larger animals, for example with the size of Chalcolithic (presumable) wild boar being absent. Swine kill-off patterns are interesting since all age categories from infant to adult/senile individuals are present. This could be hinting at their status with the hunting of younger individuals probably not being a common practice.

Bovines are the third most numerous animals, followed by red deer, leporids, and the scarce equids and canids' bones and teeth. Bovines seem to correspond to domesticated cattle, with a complete absence of larger individuals that could be related to aurochs. Their kill-off patterns with juveniles and adults could relate to the acquisition of primary and also secondary products. Altogether, domesticated animals are more numerous independently of the quantification estimate used and hunting practices are complementary.

Mollusca has an important number of shell fragments. Bivalvia is less prevalent than Gastropoda with one fragment of peppery furrow shell and two scallops registered. These species are known to have been used for culinary and non-culinary practices in Southwestern Iberian Late Prehistory; they could have been consumed due to their bromatological value or part of existing interaction and circulation networks (Coelho 2006, 2008, 2013; Soares 2013; Valera & André 2016/2017). Scallops shells have been found in different interior sites, with authors relating its presence mostly to the circulation of the shell because it is the convex shell that is commonly found – as happens in Outeiro do Circo. The gastropods comprise mainly decollate and other snails with no meaningful bromatological value with around 74% of these gastropod shells complete. As previously suggested, we interpret these gastropods as intrusive in the archaeological record.

Overall, the assemblage is highly fractured and fragmented as demonstrated by fragment size, diaphysis and section completeness. Breakage plane analysis suggests that fresh bone breakage is greatly superimposed by dry breakage; the former is attested by the existence of anthropogenic breakage that together with the presence of cutmarks demonstrates the processing of animal body parts. Culinary practices in the form of boiling seem to have occurred but these indicators are not common in the collection. Possible boiling is more frequent in long and flat bone fragments of indeterminate animals with <100 kg suggesting their use in stews with small animal portions.

Burning deserves some further consideration. Indeterminate and appendicular fragments (less axial) of different animal sizes can relate to the grilling of appendicular portions. Nonetheless, the incidence of carbonization and calcination (66%) might relate to other activities, such as the post-consumption feeding of fire with animal extremities. This is inferred for a large number of burnt remains with small sizes that probably result from these activities, even if prior ones could have also occurred.

Consumption indicators are of interest even if not common in the assemblage. Regarding tooth mark size, recent studies dealing with morphometric approaches to tooth marks indicate that their measurements are not very accurate if using digital callipers with a 1mm of error since these can result in measurement bias (Yravedra *et al.* 2019; Toledo *et al.* 2020; Courtenay *et al.* 2021a, 2021b). Still, the lack of morphometric analysis of swine tooth marks hinders an approximation of their access and modification of remains. In our study, this tentative approximation is needed, so tooth mark size was considered as a way to also compare results with swine tooth marks. In the Outeiro do Circo sample, one cannot completely discard the possibility that some shallow and smaller tooth marks could result from human chewing (Saladié 2009; Saladié *et al.* 2013), mainly in the case of smaller-weight animals. Swine could also have been involved in the consumption and modification of elements as the size of tooth marks in cancellous tissues might suggest. However, if we consider that the typical scores resulting from swine consumption (Saladié 2009) are absent, we can disregard it as the main modifier of faunal remains. Large canids are another possibility but tooth marks size differences are evident. Several aspects can influence tooth mark size and some are not accountable for this type of analysis. Nevertheless, we must consider the archaeological and taphonomical evidence: the variability of types of feeding behaviour indicators (furrowing, pits, punctures, notches, digestion, shaft cylinders), and the type of archaeological context (large walled settlement) together are suggestive of a large canid, possibly of a domesticated status. Its action is scarce in large-game such as bovines and cervids but more widespread in small animals between 20-100 kg. In a certain way, this mimics anthropogenic BSM but corresponds to secondary access. Other smaller animals such as leporids lack taphonomical indicators that could allow for a sustained assessment of the agent(s) involved in the accumulation and/or modification of remains.

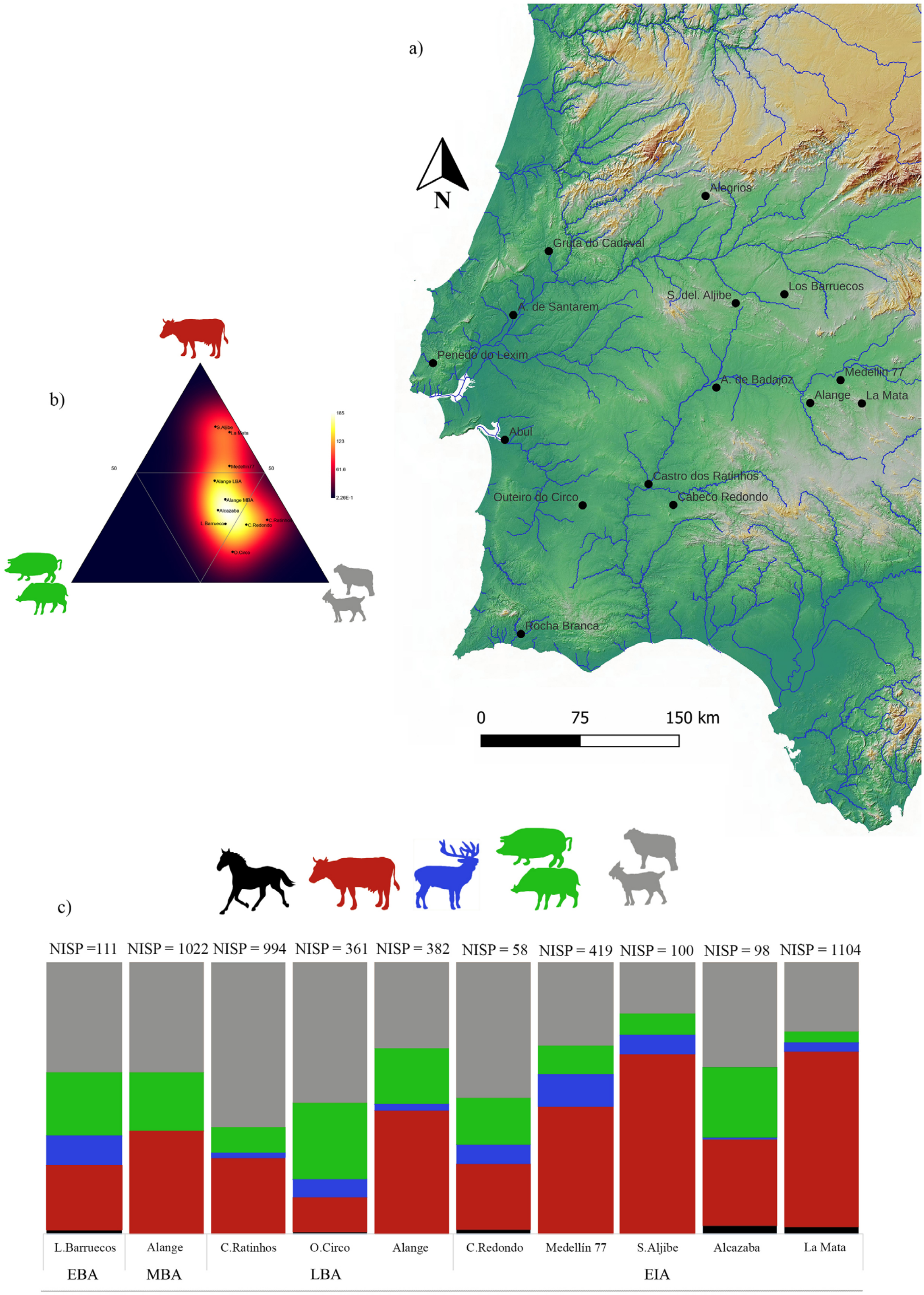

Figure 10. Location of the Outeiro do Circo and other sites with faunal assemblages mentioned in the text (a); ternary plot considering values for bovine, swine and caprine (b); stacked bar graph with the relative abundance of equids, bovine, cervids swine and caprine (c). Hypsometry and hillshade after Servicio de Cartografía de la Universidad Autónoma de Madrid; altimetry after IGN Spain, IGN France, SRTM and others; and hydrography after DGT Portugal and CNIG Spain. Faunal data is based on Castaños (1998a, 1998b, 1999, 2004), Liesau & García (2010), Cardoso & Soares (2013) and Morales (1977).

Finally, BSMs related to the depositional environment were not observed in the majority of the assemblage. Only weathering and root etching have frequencies >14% and both are predominantly in early degrees of alteration. This suggests that even if an important part of the assemblage was deposited in the upper stratigraphical horizons where roots normally appear, the sedimentation was fast or at least the re-exposition of remains was not important. If one considers that the majority of the remains were recovered from the top levels of the sector 8 wall, we can admit that their sedimentation was fast due to them being used in the wall-infilling matrix.

4.2. The data from a wider perspective

The Outeiro do Circo faunal assemblage is noteworthy from a regional and supra-regional perspective (Figure 10). In accordance with previous synthesis focusing on the Bronze and Iron ages (Cardoso 1996), the number of assemblages from domestic contexts in Southwestern Iberia is not only scarce for the LBA, but for all of the Bronze Age. This situation differs significantly from what occurred during the Chalcolithic (~3000-2000 BCE) when the predominance of swine and caprine in the Portuguese Estremadura, swine in the Alentejo, and caprine in Spanish Extremadura is generally attested (Valente & Carvalho 2014; Almeida & Valera 2021). A rise in hunting is starting to be noticed in the Alentejo towards the end of the Chalcolithic (~2400-2000 BCE) (Almeida & Valera 2021), with red deer being numerous throughout the Extremadura Chalcolithic (Castaños 1992, 1997).

The Early Bronze Age of Los Barruecos (Castaños 1998a) and the Middle Bronze Age of Alange (Castaños 1998b) are worth mentioning: both have a predominance of caprine and bovine, followed by swine, with red deer being scarce in both sites, even if with a higher percentage in Los Barruecos. Out of our main regional focus, other LBA assemblages are found in surrounding areas such as the Penedo do Lexim settlement (Davis & Moreno-García 2007) showing the importance of caprine and swine, while in the Cadaval cave layer B (Almeida 2010) caprine are by far the most numerous group, probably related to the specialized nature of this site's occupation and the higher altitude ecology of the site. Even if they are generally smaller assemblages (<100 NISP), the Beira Baixa zooarchaeological data is also worth mentioning, especially the LBA from Alegrios (Vilaça 1992) with a predominance of domesticated animals in an assemblage dominated by caprine, followed by bovine and swine (Antunes 1992).

In the Alentejo, where Outeiro do Circo is located, caprine are prevalent, followed by bovine in Castro dos Ratinhos (Liesau & García 2010) and swine in Outeiro do Circo. Red deer hunting is scarce in both sites, especially in Ratinhos. Red deer is also not common in the Spanish Extremadura sites where bovine and caprine are more frequent and followed by swine. Early Iron Age sites are more numerous and show a higher relevance of caprine in Cabeço Redondo (Cardoso & Soares 2013), or of bovine in Medellín 77 (Morales 1977), Sierra del Aljibe (Castaños 1999) and La Mata (Castaños 2004). Alcazaba de Badajoz (Castaños 1998a) has similar values for bovine and caprine, and higher relevance for swine with red deer hunting being almost absent. Other EIA sites located in the surrounding regions, such as Rocha Branca and Abul, closer to the coast, or Alcáçova de Santarém further north, show a predominance of cattle or caprine, with equids having relevant values in Rocha Branca, and red deer being comparatively less abundant (Cardoso 1993, 1996).

Even if small differences are evident between chronologies and sites, a tendency towards the higher relevance of herding, as opposed to hunting strategies, is evidenced. The different proportions observed between the main species among these sites might relate to differences in the type of sites, chronology and other archaeological and environmental characteristics. The prevalence of caprine in Cadaval seems to relate to the specialized nature of this occupation (higher altitude cave used as corral?) and the type of ecological conditions of the Estremadura Limestone Massif, while Penedo do Lexim is mostly based on swine, possibly due to it being a larger settlement. A predominance of caprine herding occurs in other LBA sites such as Alegrios and both Outeiro do Circo and Castro de Ratinhos. In the case of Alegrios and other Beira Baixa sites the easier adaptation of caprine to regional poorer soils and rocky areas seems important (Cardoso 1996). Further analysis is needed for Outeiro do Circo and Castro de Ratinhos aiming to understand mobility patterns since the high values for caprine could to some extent related to a more mobile exploration of the landscape.

The Extremadura sites have a comparatively higher relevance of bovine during the LBA (Alange) and especially in the EIA. The relevance of hunting in Extremadura is both higher and lower during EIA in comparison to the Bronze Age depending on the sites under analysis. In Medellín 77, for example, the higher availability of large game such as red deer could be related to ecological and environmental factors favouring availability or other socio-cultural aspects. The appearance of equids in these sites is also noteworthy. Equid remains are found in higher numbers in Chalcolithic sites in the Alentejo (Almeida & Valera 2021) and Extremadura in comparison to the Portuguese Estremadura. Their prevalence decreases during the Bronze Age, probably hinting at different management and exploitation of these species. The growth in the relevance of red deer hunting in the Chalcolithic (and to a lesser extent the presence of equids) in Southern Portugal and Extremadura could relate to the availability, i.e., the presence of these species in surrounding biotopes. Some "cultural traditions" can also be involved in the small differences among assemblages both synchronically and diachronically. The increase in hunting that seems to have occurred in the Portuguese Alentejo during the transition from the Chalcolithic to the EBA is of interest due to possible socio-cultural and environmental factors (Almeida & Valera 2021), but it remains to be clearly understood what happens after this that led to a change from swine-dominated assemblages to caprine dominated ones, and to a scenario of very low hunting during the LBA. To what extent these changes relate to environmental and ecological influences and/or socio-cultural decisions is currently unclear.

5. Conclusions

The characterization of the Southwestern Iberia Late Bronze Age is something that is being attempted for decades. An increasing amount of data, mainly related to the number of sites and the material culture, is allowing for a better understanding of this important period of human history. Still, some problems seem to persist, especially if we try and discuss the palaeoeconomical aspects of these groups and the different strategies for the exploitation and management of herds.

In this paper, we focused on the zooarchaeological and taphonomical characterization of the complete faunal assemblage recovered in Outeiro do Circo between 2008 and 2021. This data was discussed within a reinforced chronological framework by the acquisition of two new absolute dates that reinforce the Late Bronze Age chronology of different sectors in the settlement. Results allowed us to characterize the consumption patterns of this community, greatly dependent on domesticated animals, mostly caprine and swine, but also on the bovine. Not only primary but also the exploitation of secondary processes is inferred. Hunting practices of mostly red deer but possibly some wild boar and leporids were merely complementary. Butchery, processing and consumption taphonomical indicators were registered in the assemblage, as well as the important influence of post-depositional processes. The secondary access to remains by a large canid, possibly a domesticated dog, is attested.

Wild species percentages are in contrast with what was occurring in the region by the end of the Chalcolithic and the transition to the Early Bronze Age where hunting increased. Data related to the Early and Middle Bronze Ages are poorly understood or completely absent. Nonetheless, the Late Bronze Age record of Outeiro do Circo and other regional and supra-regional archaeological records seem to show the increasing relevance of agro-pastoralism in Southwestern Iberia. Exogenous shells hint at the existence of exchange networks although their characteristics are far from understood. The continuity of field research and the acquisition of animal diet and mobility information by means of isotope analysis are being prepared, thus more data will be available in forthcoming years.

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