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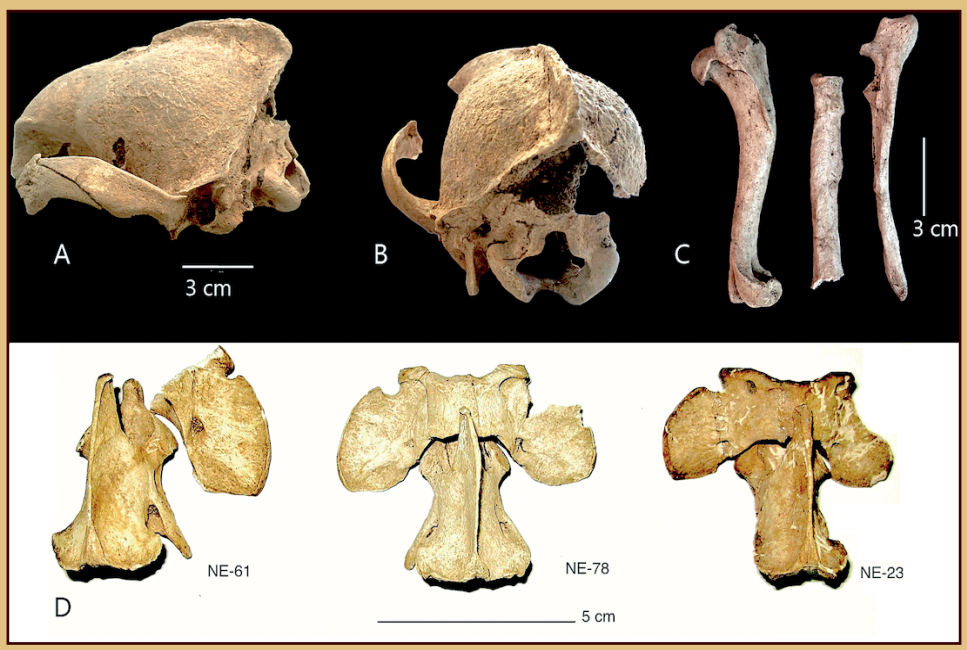

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FRONTISPIECE: A y B: restos craneales del ejemplar NE 78. C: húmero (vista lateral), radio (vista posterior) y ulna (vista lateral). D: atlas y axis de los tres perros de la necrópolis de Empúries.

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Archaeofauna 32(1) (2023): 161-177

A combined approach to reconstructing livestock management in Iron Age north-eastern Iberia: estimating the season of death and palaeodiet using cementochronology and dental micro- and mesowear analyses

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ABSTRACT: Two major settlements were established in the Empordà region (north-eastern Iberian Peninsula) in the Iron Age (6th-2nd centuries BC), 15 km from each other: the Greek colony of Empúries and the Iberian city of Ullastret. This coexistence of two different ethnic entities in the same region – and the same environment – presents an opportunity to shed light on the variability of livestock practices in these settlements, as well as their relationship with the environment. For this purpose, in addition to traditional zooarchaeological approaches, we reconstructed the animal palaeodiet and seasonality of death using three different proxies: dental meso- and microwear analyses, and cementum analysis. The results of the study, conducted on caprine and bovine teeth from both sites, support the hypothesis proposed in previous works, namely that the environment was exploited differently depending on livestock species. Caprinae (sheep and goats) were fed in marginal areas and less suitable areas for agriculture while, in contrast, cattle grazed on rich grassland and/or in wetland areas. The combination of cementochronology and dental microwear suggests a lower consumption of grasses in summer for Caprinae and cattle. Seasonality results show that Caprinae were mainly slaughtered during spring and summer.

KEYWORDS: PALAEODIET, PALAEOENVIRONMENT, SEASONALITY, EMPÚRIES, ULLASTRET, NORTH-EASTERN IBERIAN PENINSULA

RESUMEN: En la región del Empordà (noreste de la Península Ibérica) se establecieron dos importantes asentamientos, situados a 15 km el uno del otro, en la Edad del Hierro (s. VI-II a.C): la colonia griega de Empúries y la ciudad ibérica de Ullastret. La coexistencia de dos

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entidades étnicas diferentes en la misma región –y en un mismo entorno– hace que nos preguntemos por la variabilidad de las prácticas ganaderas en estos asentamientos, así como su relación con el entorno. Para ello, además del análisis zooarqueológico tradicional, hemos reconstruido la paleodieta de los animales y la estacionalidad de muerte. Para ello, se han combinado tres proxies: el análisis del meso- y microdesgaste dental, y la cementocronología. Los análisis realizados en dientes de caprinos y bovinos de los yacimientos de Empúries y Ullastret (s. VI-IV a.C.) apoyan la hipótesis propuesta en trabajos anteriores sobre el uso diferente del medio según las especies: los caprinos (ovejas y cabras) se alimentaron en áreas marginales y menos aptas para la agricultura. Por el contrario, el ganado vacuno se alimentó en pastos y en zonas húmedas. La combinación entre la cementocronología y el microdesgaste sugiere un consumo menor de herbáceas en los meses de verano. Y en cuanto a la estacionalidad, los resultados han mostrado que los caprinos fueron principalmente sacrificados entre los meses de primavera y verano.

PALABRAS CLAVE: PALEODIETA, PALEOAMBIENTE, ESTACIONALIDAD, EMPÚRIES, ULLASTRET, NORESTE DE LA PENÍNSULA IBÉRICA

INTRODUCTION

The Greek *emporion* of Empúries (L'Escala, Girona) was established in the region of Empordà, on the Mediterranean coast of the north-eastern Iberian Peninsula, in the early 6th century BC (Aquilué *et al.*, 1999; Santos *et al.*, 2013). At Empúries, the economy mainly focused on trade with Iberian populations and other Mediterranean peoples. At the same time, agriculture developed significantly in the surrounding areas (e.g., Asensio *et al.*, 2002), generating a series of specific settlements named "silo champs" by archaeologists. The Greek pottery recovered from these sites shows that they were closely related to Empúries. This Greek presence in the Empordà region influenced local populations, as shown by the agglomeration of Ullastret, located 15 km away (Santos & De Prado, 2020). The urban planning of this latter city was developed as early as the 6th century BC. The architecture shows Greek influences and archaeological excavations uncovered a significant number of Greek pottery imports (Codina *et al.*, 2015; Santos & De Prado, 2020). All of this makes Ullastret one of the most important indigenous sites in the northeast of the Iberian Peninsula (Martin *et al.*, 2010; Codina & De Prado, 2021).

The palaeoenvironment of the Empordà region was characterized by the proliferation of wetlands, predominantly small lagoons and ponds. Palaeonvironmental data highlight a maximum rise in sea level during the Iron Age, leading to the spread of marshy areas and salt pans (Ejarque *et al.*, 2016). Wooded areas were also widespread, with abundant scrubs and holm oaks (Montaner *et al.*, 2014; Castanyer *et al.*, 2016; Ejarque *et al.*, 2022). The reduction of forest mass indicates progressive deforestation during the Iron Age (e.g., Riera & Esteban, 1994; Piqué, 2002), linked to an increase in arable land (López *et al.*, 2011).

The presence of fortified and walled cities, as in the case of Ullastret, and the emergence of local elites, suggests increased social differentiation in Iron Age times (Asensio *et al.*, 1998; Sanmartí, 2004; Sanmartí & Santacana, 2005). This is supported by the presence of warrior equipment, weapons and prestige grave goods at the necropolises of Empúries (Almagro, 1953) and Puig de Serra (Serra de Daró-Ullastret).

The political, social and economic context had an impact on herding practices. However, herding practices are still not fully understood in the north-eastern Iberian Peninsula (e.g., Albizuri, 2018; Valenzuela-Lamas *et al.*, 2018). Territorialisation and an increase in cultivated areas probably led to a reduction in grazing areas and, consequently, to risks of animal malnutrition, as suggested by Valenzuela-Lamas & Albarella (2017). Several authors have postulated that agriculture and animal husbandry were in competition with each other (Valenzuela, 2008; Colominas, 2009). Colominas *et al.* (2011) proposed the hypothesis of differential management of the environment and grazing areas according to the stockbreeding species in the Empordà region. More specifically, they suggest that Caprinae (sheep and goats), which have a flexible diet, were kept in wooded areas or in scrublands. Cattle generally need more water and fresh pastu-

res than Caprinae and would thus have been kept in grassland and wetland areas. This hypothesis has also been put forward for the neighbouring region of Languedoc in France (Nieto-Espinet *et al.*, 2020a).

The reconstruction of the animal diet can shed some light on this debate. However, studies of the animal diet are scarce for such areas (e.g., Gallego-Valle *et al.*, 2017; Ibáñez *et al.*, 2020). Here, we aim to provide new data on the palaeodiet of livestock species from Ullastret and Empúries. To this end, we used two methods to obtain relevant economic as well as environmental information at different time scales: dental mesowear (i.e., the diet of the last years of the animal's life) and dental microwear (i.e., diet of the last weeks of the animal's life) analyses. These proxies can also distinguish different intra- and inter-species feeding strategies. The seasonality of pastoral practices is a key element for reconstructing herding practices, but is still poorly known. Cementochronology can potentially shed light on this grey area since it provides information on the season of death through the study of incremental growth marks in the cementum. In addition, the combination of dental microwear analysis and cementochronology can characterize the type of diets in relation to the season of death. Here, we studied the cementochronology of livestock species from both sites.

In this work, we present the (1) dental microwear analysis, (2) dental mesowear analysis, (3) cementum analysis, and (4) zooarchaeological analysis (i.e., taxonomical representation and mortality profiles) of unpublished assemblages from Ullastret and Empúries. This multiproxy approach aims to provide new data to enhance our understanding of the economic role of animal husbandry and landscape use in Iron Age Empordà.

MATERIALS AND METHODS

The archaeological sites

The faunal samples come from two Iron Age sites in the Empordà region in Spain: Ullastret (Girona) and Empúries (L'Escala, Girona) (Figure 1). Empúries (from the Greek *emporion*) consisted

FIGURE 1
Location of Empúries and Ullastret in the northeast of the Iberian Peninsula.

of two settlements: Palaiapolis ('the old town' in Greek) founded around 580 BC on a semi-island, and Neapolis ('the new town' in Greek) founded around 525-500 BC (Aquilué *et al.*, 1999; Santos *et al.*, 2013; Castanyer *et al.*, 2015). The studied faunal remains derive from phases IIId and IIIe of Palaiapolis, henceforth Empúries B, dated to the early Iron Age I (550-450 BC), and from habitation B in square 21 at Neapolis. Faunal remains from the late Iron Age I (450-325 BC), henceforth Empúries C, come from two assemblages from Neapolis: Stratigraphic Units (SU) 5016 and 6204. SU 5016 (400-375 BC) is located in the northern part of the Temenos and yielded a significant number of culinary pottery sherds (Sanmartí, 1988; Delgado *et al.*, 2020). SU 6204 is a large deposit of pottery and faunal remains located in the northern sector of the temple of *Asklepeion*, dedicated to *Asklepios,* located in the south of the city.

The archaeological site of Ullastret is an Iberian city located just 15 km south of Empúries. The site consists of two fortified complexes separated by a palaeo-pond: Puig de Sant Andreu, located on a small hill (50 m. a.s.l.), and Illa d'en Reixac, located on a plain and surrounded by the same palaeo-pond. This 'binary' settlement, with a total area of almost 15 ha during the 4th century B.C, is the most complex indigenous settlement in the northeast of the Iberian Peninsula (Martin *et al.*, 1999, 2010). Faunal remains dated to the late Iron Age I (550-450 BC, phase Ullastret II/III) were found in the levels of *insula* 7 of Illa d'en Reixac (Martin *et al.*, 1999). The early Iron Age II material (phase Ullastret IV/V phase) comes from the *insulae* 7 and 5 of Illa d'en Reixac.

Zooarchaeological study

The reference collection housed at the ASM/UMR5140 laboratory (CNRS, Montpellier) and various atlases and catalogues of comparison (Pales & Lambert, 1971; Schmid, 1972; Barone, 1976; Boessneck, 1980; Helmer, 2000; Halstead *et al.*, 2002; Wilkens, 2002; Zeder & Pilaar, 2009; Zeder & Lapham, 2010) were used for the anatomical and taxonomical identification of the remains. When the taxon could not be determined, bones were classified according to body mass categories, taking into account the faunal spectrum of the assemblage and age. In this work, 'large-sized' mammals (<150 kg) include adult cattle (*Bos taurus*), red deer (*Cervus elaphus*) and equids (*Equus* sp.); 'medium-sized' (15-100 kg) include immature cattle, equids and red deer, as well as adult sheep (*Ovis aries*), goats (*Capra hircus*), suid (*Sus* sp.) and dog (*Canis familiaris*); and finally, 'small-sized' animals (>15 kg) comprise immature sheep, goat, pig, dog, small carnivores and lagomorphs. Age-at-death was estimated on the basis of the degree of epiphysation and tooth eruption and wear (Payne, 1973; Grant, 1982; Gardeisen, 1997). The number of identified specimens (NISP), the minimum number of elements (MNE) and the minimum number of individuals (MNI) (Lyman, 1994) were calculated to assess the integrity of the assemblage. Mortality profiles were constructed using the Bayesian method established by Valenzuela-Lamas & Pozo-Soler (2011) and interpreted according to the zootechnical models of animal production strategies described by several authors (Stein, 1987; Helmer & Vigne, 2004; Blaise, 2005; Helmer *et al.*, 2005, 2007). A total of 3525 faunal remains from Empúries (N= 2012) and Ullastret (N= 1513) were analysed (Table 1).

Archaeological site/Proxy	Empúries	Ullastret	Total
Zooarchaeology	2012	1512	3524
Dental mesowear	56	48	104
Dental microwear	58	73	131
Cementum analysis	19	19	38

TABLE 1

Number of specimens analysed by archaeological and site according to the approach in this study.

Dental microwear analysis

Dental microwear analysis was carried out following the method defined by Solounias & Semprebon (2002). The occlusal surface of teeth was carefully cleaned with acetone and then with 96% ethanol (Semprebon *et al.*, 2004). Afterwards, the occlusal surface was moulded using the high-precision polyvinylsiloxane dental impression material Provil Novo Light C.D.2 (Heraeus Kulzer) for the first contact layer, and Putty Blue Eco (Detax) for the supporting layer. These moulds were used to make transparent epoxy resin casts (C.P. Química CPOX P 1069/A – CPEN 1585/B). The epoxy casts were analysed using a stereomicroscope at low magnification (x35). For each tooth, we analysed two different areas of 0.4 mm x 0.4 mm

(0.16 mm^2) and averaged the data on the protoconid and/or hypoconid of the first (M1), second (M2) or third (M3) lower molars, and on the paracone and/or metacone of the upper M1, M2 and/or M3 (Xafis *et al.*, 2017). Analyses were performed on well-preserved enamel surfaces, avoiding taphonomic alterations such as fissures, damaged areas and trampling features (King *et al.*, 1999; El-Zaatari, 2010; Uzunidis *et al.*, 2021). Five microwear variables were recorded: the number of pits (NP), the number of scratches (NS), the presence/absence of gouges (G), the scratch width score (SWS) and the presence/absence of cross scratches (XS). We then generated a bivariate plot graph featuring the total number of scratches and pits using the R Statistical Software (version 3.5.1) and the R code from Rivals (2019). After discarding teeth with taphonomic alterations (King *et al.*, 1999; Rivals *et al.*, 2007; El-Zaatari, 2010; Uzunidis *et al.*, 2021), we analysed a total of 131 caprine and cattle teeth from Empúries (N= 58) and Ullastret (N= 73, Table 1). The teeth sampled for dental microwear come from the faunal remains studied in this work and from other faunal assemblages analysed by other researchers (Aquilué *et al.*, 1999; Albizuri, 2018).

Dental mesowear analysis

The Mesowear Score (MWS) consists in the macroscopic and qualitative analysis of the morphology of the dental cusps located on the buccal side of upper molars and on the lingual side of lower molars (Fortelius & Solounias, 2000; Franz-Odendaal & Kaiser, 2003; Kaiser & Solounias, 2003). Cusp morphology is classified into seven categories, where '0' is characterized by high relief and pointed cusps, corresponding to the least abrasive wear, and '6' is characterized by low relief and flattened (blunt) cusps, corresponding to the most abrasive wear (Rivals *et al.*, 2007). A browser dietary regime varies between a MWS value of 0 to 2.00, a grazer regime between 2.09-5.47, and mixed feeders between 0.40-2.74 (Fortelius & Solounias, 2000; Rivals *et al.*, 2007; Mihlbachler *et al.*, 2011). A total of 104 caprine and cattle teeth from Empúries (N= 56) and Ullastret (N= 48) were included in the analysis (Table 1). The sampled teeth come from the faunal assemblages analysed in this work and from other faunal assemblages studied by other zooarchaeologists (Martin *et al.*, 1999).

Cementum analysis

Dental cementum analysis focuses on the study of incremental growth marks in the cementum of mammalian teeth in order to estimate the age and season at death of the animal (Monks, 1981; Klevezal, 1996; Gourichon, 2004; Naji *et al.*, 2015, 2022). The dual characteristics of cementum are that it develops throughout the animal's life, i.e., from the formation of the root until tooth shedding, and its deposition rate follows an annual cycle (cold and warm seasons) (Azorit *et al.*, 2002). Cementum is a bone tissue deposited on the exterior part of the tooth root, although it can also extend to the enamel (coronal cementum) in hypsodont species (Yamamoto *et al.*, 2010). The primary function of this tissue is to anchor the tooth root to the alveolar bone via periodontal ligaments to hold the crown during occlusion and chewing processes. This research focuses on the acellular extrinsic fibre cementum (henceforth, AC). The AC is characterized by a successive and regular alternation of parallel bands. The biological mechanisms underlying this alternation of cementum increments are still not fully understood, but several studies have shown that they are correlated with seasonal changes and other biochronological processes (Klevezal & Kleinberg, 1967; Grue & Jensen, 1979; Lieberman & Meadow, 1992; Naji *et al.*, 2022). Two types of AC can be distinguished: 'growth zones' (GZ) and 'annuli'. GZ are characterized by fast growth and a low mineralization rate and build up during the warm season. 'Annuli' are characterized by slow growth and a high mineralization rate and form during the cold season (Lieberman, 1994; Gourichon, 2004; Naji *et al.*, 2015, 2022). These bands can be microscopically differentiated on the basis of differences in mineralization rates and sometimes in the orientation of the Sharpey fibres (Stallibrass, 1982; Lieberman, 1994; Rendu, 2007).

Season at death can be estimated by determining whether the last cementum band is an 'annulus' (cold season) or a GZ (warm season) (Burke & Castanet, 1995). The GZ can provide further detail by comparing the relative growth volume of the last deposit to the thickness of the previous complete bands: 'beginning' (0-33.3%), 'middle' (33.3-66.6%) or 'last' (66.6-100%) part of a GZ (Gourichon, 2004; Rendu, 2007; Sánchez-Hernández *et al.*, 2020). The estimation can be approximately related to the respective following seasons: spring, summer and fall (Klevezal, 1996).

A total of 62 thin sections of eight sheep, 15 goat, two unidentified caprine and 13 cattle lower and upper molars were made following the protocol established by Naji *et al.* (2015) (Table 1). The teeth were first extracted from the alveolar bone. Then, the teeth, except the crown, were placed in plastic boxes and covered with transparent epoxy resin (DBF epoxy). A total of three thin sections were cut per root using a slow-speed diamond saw (Buehler IsoMet 1000) in the CEPAM laboratory (CNRS, Nice). After cleaning, the sections were glued (Geofix epoxy) to a glass plate (25x30 mm). The inner face of these sections was mechanically abraded to a thickness of 50-80 µm using a diamond grinding wheel (Buehler PetroThin) and a thin glass coverslip was then glued directly onto the surface of the sample. Thin sections were analysed using a polarizing light microscope at x100 and x200 magnifications. Teeth with taphonomic alterations were discarded (Rendu *et al.*, 2011; Gourichon *et al.*, 2016). The incremental bands, and particularly the last one, were identified using three optical filters: plane-polarized light, cross-polarized light and full-wave retardation plate (λ plate). Microphotographs of the main regions of interest were systemically taken for archiving and further study.

RESULTS

Zooarchaeological data

A total of 1512 faunal remains from Ullastret II/III (550-450 BC) and Ullastret IV/V (450-325 BC) were studied. For the Ullastret II/III phase, 299 remains were analysed, of which 132 (44.1%) were anatomically and taxonomically identified. The most frequent species are Caprinae (*Ovis aries* and *Capra hircus*), followed by pigs (*Sus domesticus*) and cattle (*Bos taurus*) (Figure 2A). To

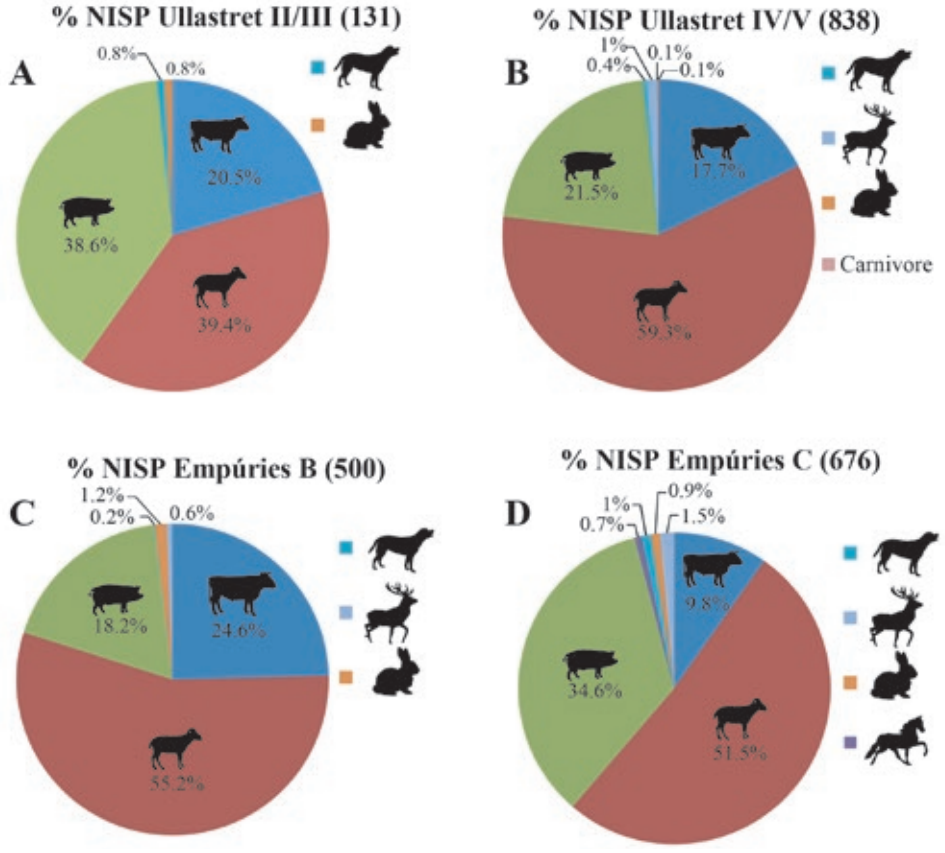

FIGURE 2
Mammal NISP frequencies per period at Ullastret (A and B) and Empúries (C and D).

a lesser extent, dog (*Canis familiaris*) and rabbit (*Oryctolagus cuniculus*) remains were also identified. For the Ullastret IV/V phase, 1213 faunal remains were examined, of which 838 (69%) were identified. Caprinae are the most frequent taxon, followed by pigs and cattle (Figure 2B). Dog, red deer (*Cervus elaphus*), rabbit and an unidentified carnivore were also recovered. The mortality profiles of Caprinae from both phases show that they were mostly slaughtered before the age of 24 months, followed by animals 24-48 months old. According to the zootechnical models currently used in zooarchaeology (cf. section 2.2), this pattern corresponds to flock management strategies focused on meat production. The mortality profile of cattle from Ullastret II/III suggests that slaughtering centred on animals aged 24-48 months, i.e., in the prime of their age and at the meat/weight optimum (Supplementary material). For the second phase (Ullastret IV/V), cattle were mainly slaughtered at 12-24 months old for meat exploitation, and at 48 months old or more in the case of dairy exploitation and the use of animals for traction/ploughing. A total of 2012 faunal remains from the Empúries site were studied. For the Empúries B phase, 500 remains out of 1101 (45.4%) were anatomically and taxonomically identified. The most abundant taxa are Caprinae, followed by cattle and pigs (Figure 2C), and to a lesser extent, dog and rabbit remains. In the Empúries C phase, Caprinae, pig and cattle are the most frequent taxa. Other identified taxa are equids (*Equus* sp.), dog, red deer and rabbit (Figure 2D). The kill-off profiles of Caprinae in both phases (Empúries B and C) indicate a focus on meat production (6-12 and 12-24 months). The slaughtering of individuals at 24-48 and 48-72 months old also reflects milk exploitation. Two culling peaks were observed for cattle at 12-24 and 24-48 months old in Empúries B, indicating mainly meat production. Conversely, in Empúries C, the main peak is observed at 72-96 months old, which may possibly be related to milk production and traction (Supplementary material).

Dental mesowear score

The overall results obtained from the dental mesowear analysis are presented in Figure 3a and Table 2. For Ullastret II/III, sheep and goats were grouped together. In the remaining assemblages, sheep and goats were distinguished. The mesowear score (MWS) of Caprinae from both phases (550-450 BC and 450-325 BC) and sites varies between 1.11 and 2.12. These values indicate a dietary pattern compatible with mixed feeders with a browsing tendency. Only the sheep from Empúries B show values compatible with grazers (MWS= 2.69). Concerning variability between sheep and goats, sheep present a higher MWS than goats. The degree of abrasion is higher for cattle than for Caprinae, varying between 2 and 2.5, indicating a grazing dietary regime. In general, these data suggest the presence of more abrasive particles in resources eaten by cattle than those consumed by Caprinae. Caprine MWS values show higher abrasion in the second phase (450-325 BC) than in the first (550-450 BC), suggesting the consumption of less shrubby plants in the first phase.

Dental microwear pattern

A total of 131 goat, sheep and cattle teeth were analysed after discarding specimens with taphonomically altered enamel surfaces.

For the first chronological phase (550-450 BC) of Ullastret and Empúries, the microwear pattern of sheep and goats presents an intermediate number of pits (between 24 and 28) and an intermediate to high number of scratches (16.0-20.5). These data indicate a mixed feeding dietary regime. The average number of scratches is slightly higher in sheep than in goats in both sites (Table 3). Concerning inter-site variability, the dietary regime of sheep and goats tends closer to browsing in Empúries than in Ullastret. Cattle present a lower number

Archaeological site	Sheep			Goat			Caprines			Cattle		
	N	MWS	SD	N	MWS	SD	N	MWS	SD	N	MWS	SD
Ullastret II/III (6th-5th c. BC)	-	-	-	-	-	-	14	1.5	0.85	4	2	0.81
Ullastret IV/V (5th-4th c. BC)	11	2	0.9	4	1.71	1.7	-	-	-	15	2.5	0.99
Empúries B (6th-5th c. BC)	13	2.69	1.7	9	1.11	0.78	-	-	-	19	2.21	1.39
Empúries C (5th-4th c. BC)	8	2.12	1.24	3	2	1	-	-	-	6	2	1.26

TABLE 2

Mesowear score (MWS) analysis of caprines and cattle from Ullastret and Empúries (N= number of specimens; SD= standard deviation).

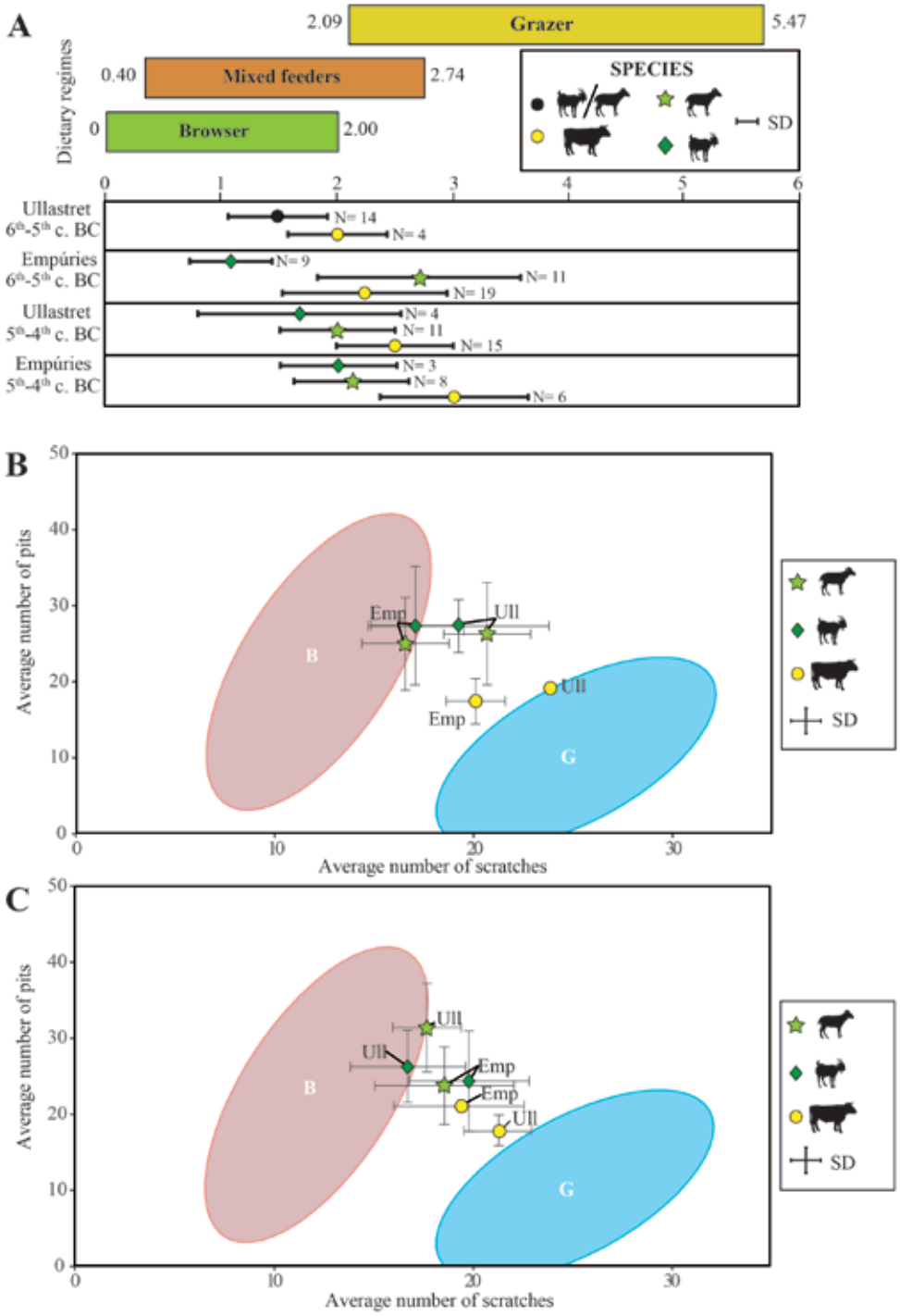

FIGURE 3

A= Dental mesowear results of sheep, goat and cattle; B= Microwear bivariate graph for sheep, goats and cattle from 550-450 BC. Extant data on leaf browsers (B) and grazers (G) from Solounias & Semprebon (2002). C= Microwear bivariate graph for sheep, goats and cattle from 450-325 BC. Extant data on leaf browsers (B) and grazers (G) from Solounias & Semprebon (2002). (Ull= Ullastret; Emp= Empúries; N= number; SD= standard deviation).

Archaeological site	Cattle								Sheep								Goat							
	N	NP	SD	NS	SD	SWS	%XS	%G	N	NP	SD	NS	SD	SWS	%XS	%G	N	NP	SD	NS	SD	SWS	%XS	%G
Ullastret II/III (6th-5th c. BC)	1	15.5	-	18	.	1	100	0	4	26.5	11	20.5	3.3	0.8	80	0	7	28.2	5.2	18.6	4.4	0.7	40	0
Ullastret IV/V (5th-4th c. BC)	32	19.2	5.8	21.8	4.7	0.9	60	0	15	28.9	8	18.5	3.5	0.7	10	0	14	24.1	8.9	16.7	5.7	0.4	10	0
Empúries B (6th-5th c. BC)	22	16.5	4	19.6	3.4	0.9	30	0	12	25.8	10.4	18.1	5.2	0.8	30	0	7	26.5	10.8	17.1	4	0.9	10	0
Empúries C (5th-4th c. BC)	11	22.3	8.4	20.9	5.8	1.2	80	0	8	23.6	7.2	18.8	4.9	0.8	10	12.5	8	24.3	9.5	19.8	4.2	0.6	10	0

TABLE 3

Summary of dental microwear pattern of cattle, sheep and goats from Ullastret and Empúries (N= number of specimens, NP= number of pits; SD= deviation standard; NS= number of scratches; SWS= scratch width score; %XS= presence of more than four cross scratches; %G= presence of gouges).

of pits (15.5-19.2) and a slightly higher number of scratches (18-21.8) than Caprinae.

For the second period (450-325 BC), Caprinae present an intermediate number of pits (23.0-26.5) and an intermediate to high number of scratches (18-20). This dental microwear pattern is compatible with a mixed dietary regime. Caprinae from Empúries show a higher number of scratches than those from Ullastret. Cattle teeth bear a higher number of scratches (between 21 and 22) and a lower number of pits (19-22) than Caprinae.

Seasonal pattern

A total of 14 caprine and five cattle teeth were analysed. Mixed cementum was found in the upper part of the roots of all teeth, and it was thus difficult to identify and study optimal regions of acellular cementum. In this regard, the presence of cementocytes throughout the cementum layer was observed in 14 specimens. For three caprine teeth from the first phase of Ullastret (550-450 BC), the last cementum deposit shows the beginning of a GZ, suggesting slaughtering in spring. In another caprine tooth, a half-thick GZ (*ca*. summer) was identified. For Empúries, the nature of the last cementum increment is variable: one individual with the beginning of a GZ (*ca*. spring), a second with a half-thick GZ (*ca*. summer), and another with an almost-complete GZ (*ca*. fall). In the case of cattle (Figure 4), one specimen from Ullastret shows the beginning of a GZ, one from Ullastret a middle GZ, and another a final annulus. For the second period (450-325 BC), the cementum analysis of caprine teeth from Ullastret shows slaughtering in the middle (N=2) and at the beginning (N=1) of the warm season. Observations at Empúries are also variable: two Caprinae were killed in summer and two others during the cold season (winter). The two analysed cattle specimens from Ullastret indicate that one was slaughtered in the middle of the warm season (*ca*. summer) and the second at the end of this period (*ca*. fall).

Combination of dental cementum and microwear data

It was possible to combine the data from dental microwear and cementum analyses for 14 teeth: five sheep, seven goats and two cattle. The results, presented in Table 4, show a lower number of scratches in summer (middle of the warm season) compared to the other seasons.

	Warm season			Cold season
	Early (N=6)	Middle (N=6)	Late (N=1)	(N=2)
Number of scratches	19.1	12.3	19	22.5

TABLE 4

Summary of the combination between dental microwear and cementum analysis. The average of the number of scratches according the season of death is indicated (N= number of specimens).

DISCUSSION

The zooarchaeological analysis showed that Caprinae were the most abundant animals in the two studied settlements, in keeping with trends observed in other sites from the same chronological and geographical context (e.g., Colominas, 2009, 2013; Albizuri *et al.*, 2010; López *et al.*, 2011). At Ullastret, pigs are well represented in both periods,

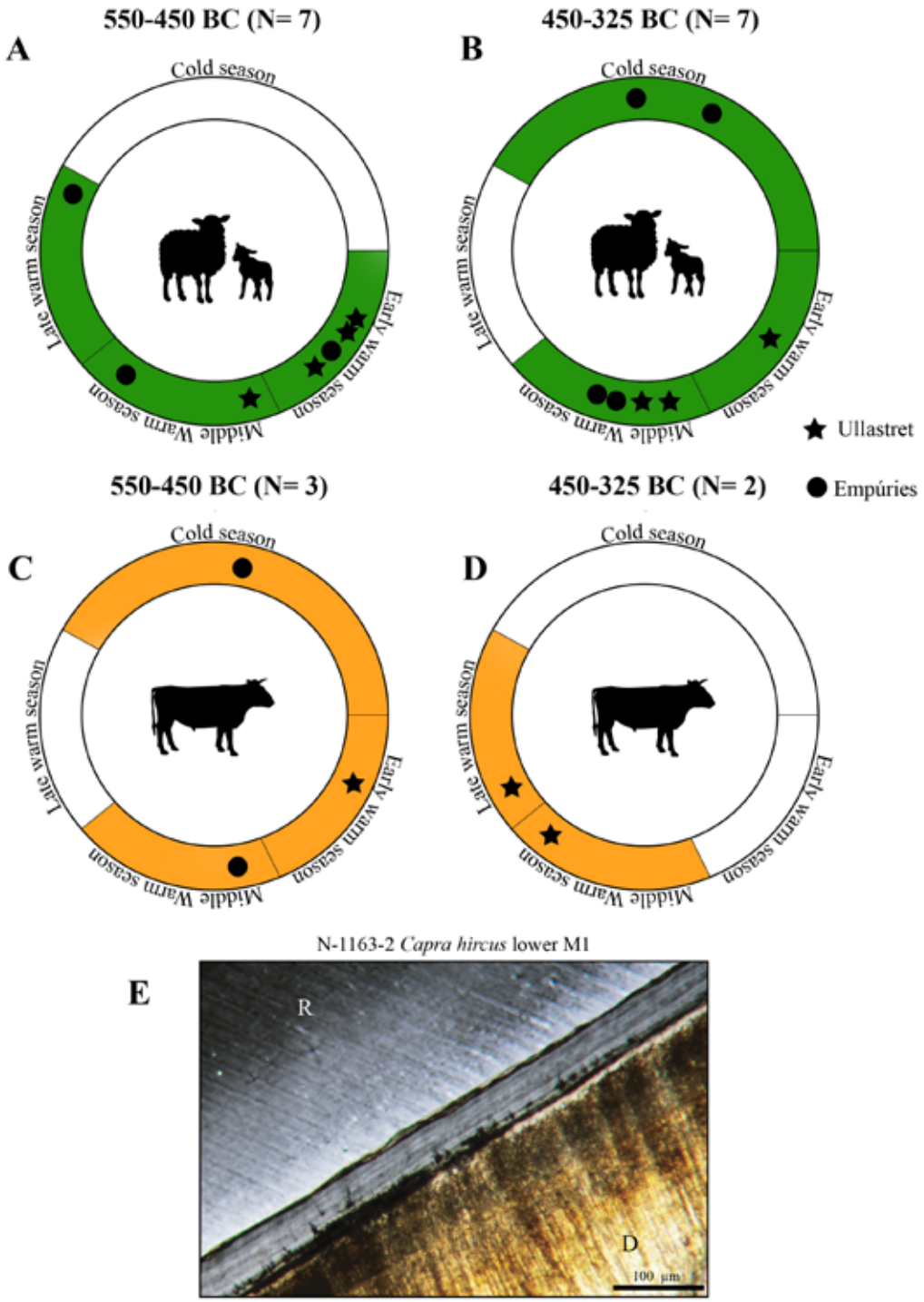

FIGURE 4

A, B, C and D= Schematic representation of the seasonality of caprine slaughtering and teeth from Empúries and Ullastret (550-450 BC and 450-325 BC). E= Microphotograph of a longitudinal section of goat tooth showing growth zones and annuli deposits (R= resin, D= dentin, N= number).

while at Empúries, an increase in the frequency of pigs was observed during the Iron Age II phase (450-325 BC) compared to the previous period (550-450 BC). This trend was also observed in the north-eastern Iberian Peninsula (e.g., Valenzuela-Lamas, 2008; Colominas, 2009; Nieto-Espinet, 2012, 2020a, 2020b; Colominas *et al.*, 2017), and in neighbouring regions (Gardeisen, 2010; Colominas *et al.*, 2017). The increase in arable land in that time (e.g., Asensio *et al.*, 2002) could explain the increase in pigs, as they do not require grazing lands and are not in competition with agriculture. Higher frequencies of this taxon could also be explained by an increase in urbanisation and intensive meat production (Valenzuela-Lamas, 2008; Colominas, 2013; Nieto-Espinet *et al.*, 2020a).

The mortality profiles of Caprinae reflect a mixed production of milk and meat at the two studied sites and periods. A focus on adult individuals was observed in other Iron Age sites in Catalonia and Languedoc (Valenzuela-Lamas, 2008; Albesso *et al.*, 2013; Nieto-Espinet *et al.*, 2020a; Jiménez-Manchón, 2020; Jiménez-Manchón *et al.*, 2020). The slaughtering of adult specimens could be linked to the exploitation of secondary products, such as wool and milk. In this respect, archaeological evidence, such as the finding of *pondera* (measure of weight), in these sites demonstrates the use of wool and related activities (Castro Cruel, 1985). However, mortality profiles do not follow a single trend, as they vary depending on settlement types and the chronological period. Thus, at Mas Castellar de Pontós, located in the Empordà region (Colominas, 2009), or La Ramasse in Languedoc (Jiménez-Manchón, 2020), adults are predominant, while in *Lattara,* young specimens are more frequent (Jiménez-Manchón, 2020; Nieto-Espinet *et al.*, 2020a, 2020b).

Higher variability is observed among cattle. In the first phase (550-450 BC), milk and meat production are balanced in Empúries, as at the same period in *Lattara* (Languedoc, France) (Nieto-Espinet *et al.*, 2020a). In Ullastret, slaughtering focused on fully-grown animals (24-48 months), as in la Monédière (Languedoc, France) (Nieto-Espinet *et al.*, 2020a). In the second period (450-325 BC), the mortality profiles of both studied sites show an increase in adult individuals, suggesting a greater exploitation of secondary products, such as milk, or the use of animals for traction/ploughing. These data suggest the use of cattle for dairy products, in addition to Caprinae, to the detriment of high-quality meat. This trend has also been observed in other Iron Age sites in Catalonia and Languedoc (e.g., Valenzuela-Lamas, 2008; Nieto-Espinet *et al.*, 2020a). Pottery sherds found in Iron Age sites in the neighbouring region of Languedoc may possibly be related to milk production (Py, 1993). Pigs were slaughtered to obtain tender meat (12-18 months) and maximum meat/fat yields (18-36 months). A higher number of animals older than 36 months were only observed in the first phase of Ullastret (550-450 BC).

The dental micro- and mesowear analyses results revealed the overall dietary patterns of sheep, goat and cattle at the Empúries and Ullastret sites during the Iron Age. In general, they show that sheep and goats were mixed feeders with a tendency to browse. This suggests a diet rich in eudicotyledonous plants, shrubs and bushes, with a reduced consumption of graminaceous plants. This type of diet has been recorded in sheep and goats in the Bronze Age Balearic Islands (Valenzuela-Suau *et al.*, 2022), and in the Iberian Peninsula during the Roman (Gallego-Valle *et al.*, 2017), Iron Age (Jiménez-Manchón *et al.*, 2019) and Neolithic periods (Sierra *et al.*, 2021). The diet of sheep from Ullastret and Empúries was slightly more abrasive than that of goats, perhaps due to a sheep preference for herbaceous plants (e.g., Martínez, 2002). This trend has been identified in various archaeological contexts using stable isotopes (e.g., Balasse, 2002) and dental microwear analyses (Ibáñez *et al.*, 2020). Unlike Caprinae, cattle present a grazing dietary regime, compatible with a diet rich in grasses. These data suggest pasturing on meadows and/or in less wooded areas. The available palaeoenvironmental data describe a landscape dominated by grasslands with the existence of wooded areas. The results obtained from dental meso- and microwear analyses support the hypothesis put forward by Colominas *et al.* (2011) regarding landscape use and husbandry practices. They postulate that Caprinae, characterized by a more flexible diet than cattle, would have fed in wooded areas less suitable for agriculture. In contrast, cattle require more fresh pastures than Caprinae, and probably fed in grassland areas. However, the consumption of grasses in the form of fodder by cattle cannot be ruled out, although this type of diet is difficult to identify with dental microwear analyses (Gallego-Valle *et al.*, 2020). No evidence of animal pens, where animals can be fodder fed, has been found in Ullastret and Empúries. However, such practices have been

recognized in other Iron Age sites from Catalonia (Jiménez-Manchón *et al.*, 2020) and cannot be excluded.

The results obtained from the dental mesowear analysis show that Caprinae and cattle consumed less woody plants in the second phase (450-325 BC) than in the first phase (550-450 BC). This scenario is consistent with the progressive reduction of the forest mass documented by palaeoenvironmental studies in the north-eastern Iberian Peninsula (e.g., Riera & Esteban, 1994; Piqué, 2002).

Using a combination of dental microwear and cementum analyses, we characterized the type of animal diet and the season of death. The number of scratches, a parameter used to discriminate between browsing and grazing diets (Solounias & Semprebon, 2002), is lower in the middle of the warm season than in other seasons. This implies a higher consumption of eudicots in summer, due to (1) a reduced availability of grasses in this season (Drogoul *et al.*, 2004); or (2) additional leguminous fodder supply. This latter strategy has been documented in Iron Age sites in nearby geographical contexts (e.g., Bouby & Rouas, 2005; Alagich *et al.*, 2018). Another explanation (3) could be that herds were moved to nearby wooded areas, as attested by palaeoenvironmental data (Montaner *et al.*, 2014; Castanyer *et al.*, 2016; Ejarque *et al.*, 2022). This latter explanation could be related to a system of summer pastures.

Regarding the seasonality of animal slaughtering, cementum analysis on caprine teeth showed that the last deposit most frequently indicated the beginning of a growth zone (*ca*. spring) in the first period studied (550-450 BC) and the middle of a growth zone in the second phase (*ca*. summer). In both phases, slaughtering in winter or fall is scarce. Our results suggest that adult Caprinae were preferentially slaughtered in the spring and summer months but we must remain cautious due to the small number of samples. The lower availability of grasses and reduced grass intake in summer (Drogoul *et al.*, 2014), confirmed by the dental microwear analysis (see section 3.5), could have prompted shepherds to slaughter adult Caprinae in spring/summer. In addition, this time frame would have been propitious to sheep shearing. For cattle, slaughtering took place all year round. However, the number of specimens analysed is even smaller than for Caprinae. These hypotheses therefore need to be tested in future studies.

CONCLUSIONS

In this paper, we presented a multiproxy approach (zooarchaeology, dental micro- and mesowear analyses, cementochronology) applied to two Iron Age sites (Empúries and Ullastret) located in the northeast Iberian Peninsula.

Dental wear analyses suggest that sheep and goats were fed in an environment dominated by shrubs and bushes in both studied periods (550-450 BC and 450-325 BC) and sites, while cattle mainly grazed in grasslands. This scenario is compatible with the hypotheses proposed in previous works: shepherds would have been forced to lead Caprinae to marginal areas less suitable for agriculture. The results are also consistent with feeding on eroded landscapes. Increased woodland clearance and land degradation in the region at that time have been documented by palaeoenvironmental studies (Riera & Esteban, 1994; Piqué, 2002).

In this study, cementum analyses on sheep, goat and cattle teeth provided valuable information on the seasonality of husbandry practices. Caprinae were mostly slaughtered in spring and summer. Combined cementum and microwear analyses revealed a lower consumption of grasses in summer than during the rest of the year. This could be the result of environmental/climatic factors or linked to the human control of feeding places or practices (fodder procurement).

The results obtained in this work support the hypotheses put forward in previous works. Competition between agriculture and livestock, as well as the socio-economic context, impacted livestock management and landscape use. The multiproxy approach presented here shows that animal feeding strategies, grazing areas and the season of livestock slaughtering were probably adapted to this context. This paper demonstrates how the application of this multiproxy approach can offer new perspectives and lines of research on livestock management and landscape use in Late Prehistory, which cannot be attained with traditional zooarchaeological studies.

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SUPPLEMENTARY MATERIAL

See supplementary material at https://revistas.uam.es/archaeofauna/article/view/archaeofauna32.1_010

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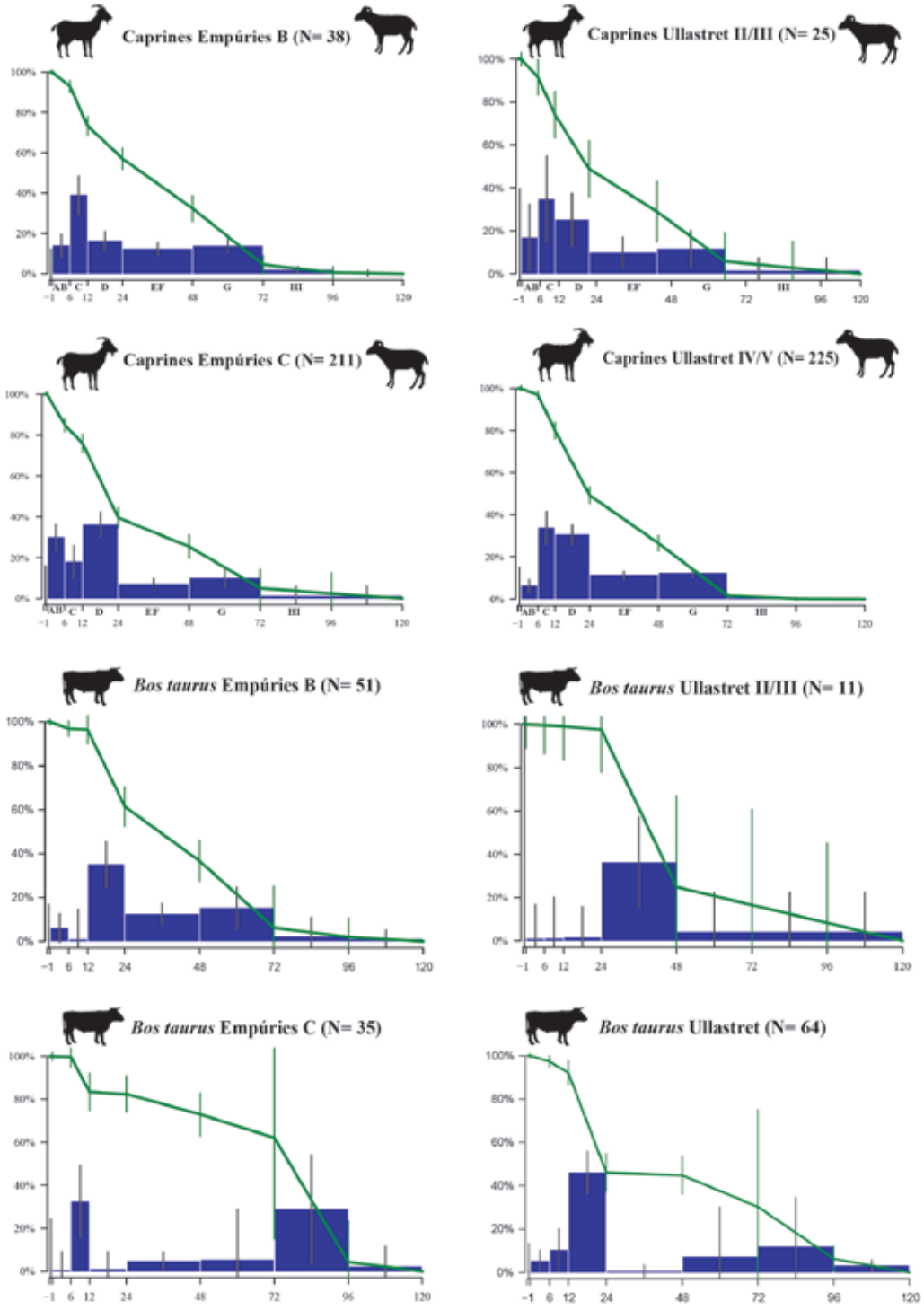

Mortality profiles of cattle and caprines at Empúries B and C, and Ullastret II/III and IV/V

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