Journal of Archaeological Science: Reports 67 (2025) 105376

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep

Review of the techno-economic trends from Cova de les Cendres and Coves de Santa Maira, Spain. The central Iberian Mediterranean area during the Tardiglacial and Early Postglacial☆

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ARTICLE INFO

Keywords:
Upper Magdalenian
Epipalaeolithic
Central Iberian Mediterranean
Lithic technology
Subsistence strategies

ABSTRACT

This paper investigates the continuity and transformation of lithic production and subsistence strategies during the Late Pleistocene–Holocene transition in the central Iberian Mediterranean region. The analysis of Magdalenian and Epipalaeolithic assemblages from key sites such as Cova de les Cedres and Cova de Santa Maira reveals a sustained technological and subsistence pattern characterised by specialised hunting and lithic production systems. The lithic assemblages from these periods demonstrate minimal changes, with a focus on bladelet production with the final objective to obtain armatures. The exploitation of red deer and Iberian ibex, along with an abundant consumption of leporids, constitutes the core subsistence strategy, with slight geographical variation in taxonomic preference. The diversification of prey towards the Epipalaeolithic, coupled with a stable occupation pattern and reduced mobility, highlights a broader ecological adaptation. Overall, the results underscore a high degree of homogeneity in lithic and subsistence practices, suggesting a unified cultural tradition across the region.

1. Introduction

The end of the Pleistocene in Europe, following the Last Glacial Maximum, and the transition to the Holocene was a period marked by environmental and cultural changes (Aura et al., 1998; Carrión Marco, 2005; Carrión et al., 2010). However, the southern regions of Europe were less impacted by glacial masses, allowing human populations to thrive in a diverse range of ecosystems. The Iberian Peninsula stands out as one of these regions, boasting a rich collection of sites showing human occupation from the Late Pleistocene to the Holocene (Aura et al., 2011; Villaverde et al., 2012). This extensive record enables the analysis of the cultural evolution of these hunter-gatherer populations during a pivotal moment of transition.

This paper focuses on the central region of the Iberian Mediterranean (between 41° and 38° latitude) due to its geographical and archaeological features. This area is outside the influence of glaciers and has moderate altitudes, with rivers and ravines that could facilitate contact between inland and coastal areas (Barton et al., 2013; Villaverde et al., 1998). Although assemblages have been studied from technological, ecological, and economic perspectives, the relationship between the hinterland and coastal landscapes has not been thoroughly explored.

The study of the various assemblages from the Pleistocene–Holocene transition has led to various proposals for naming these archaeological units (Fortea, 1973; Aura, 1995; Aura et al., 2011; Román, 2012; Román and Domingo, 2020). Several chronocultural episodes have been identified and defined in this territory between approximately 16.2 to 10 thousand years cal. BP. These include the Upper Magdalenian (UM), the Final Upper Magdalenian (FUM), the Microlaminar Epipalaeolithic (ME), and the Sauveterroid Epipalaeolithic (SE). In addition, it is worth noting that in many instances human occupations have persisted on the same sites over time.

Among the complete list of archaeological sites (see Casabó, 2004; Morales Pérez, 2015; Real, 2021; Vadillo Conesa, 2018), only a few provide absolute dating and offer insights into the techno-economic

☆ This article is part of a special issue entitled: 'SW EUROPE UPPER PALAEO' published in Journal of Archaeological Science: Reports.

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https://doi.org/10.1016/j.jasrep.2025.105376
Received 1 February 2025; Received in revised form 22 July 2025; Accepted 28 August 2025
Available online 11 September 2025

trends of hunter-gatherer human groups in the region, as well as the relationships between inland and coastal ecosystems (Fig. 1). These include Cova Matutano, Cova dels Blaus, Tossal de la Roca, Coves de Santa Maira (SM), and Cova de les Cendres (CC) (Aura et al., 2009; Cacho et al., 1995; Martínez Valle, 1996; Olària, 1999; Olària et al., 1981; Villaverde et al., 2012). In terms of technological studies, SM and CC have data that enable a comprehensive understanding of the operational chain (Roman, 2004, 2015; Vadillo Conesa, 2018). The other sites, while they offer elements for discussion, do not have recent associated studies. With regard to diet, the abovementioned studies provide data on taxonomic composition, anatomical representation, and ages at death. However, it should be noted that only CC and SM offer an updated taphonomic analysis. The primary data from these two sites, regarding lithic industry and faunal remains, come from recent excavations. The use of similar methodologies for analysing materials from both sites allows for easier comparison (Morales Pérez, 2015; Real, 2021).

Throughout the late 20th century and early 21st century, several studies were conducted to evaluate the technological and subsistence characteristics of human groups transitioning from the end of the Upper Palaeolithic to the Holocene (Aura et al., 1998, 2009; Villaverde and Martínez Valle, 1995; Villaverde et al., 1998). However, in the current context of recent excavations and common methodologies, it is relevant to review the ideas proposed in these studies. Moreover, two sites in different locations, SM (inland) and CC (coastal), have not yet been directly compared.

Within this research framework, the present work is of substantial research interest for several reasons. To date, no combined lithic technology/economy proposal has been made for this Late Pleistocene/Early Holocene episode in the central Iberian Mediterranean region. Furthermore, despite the existence of several sites, few of them are able to provide techno-economic data in the same place. On the other hand, the data obtained at CC and SM sites, both on lithic industry and faunal remains, come from recent excavations that were carried out using similar methodologies, which facilitates their comparison.

From this perspective, the main objective of this paper is to review the techno-economic trends from these two sites located in different environments, comparing their similarities and differences. It focuses on lithic and faunal remains from the UM and Epipaleolithic sequences of SM (inland) and CC (coastal), which are crucial in constructing the regional sequence. Ultimately, the aim of this paper is to develop a regional model for the end of the Pleistocene and the beginning of the Holocene based on the analysis of lithic production systems and subsistence patterns.

2. Materials and methods

The results of the analysis of the study of the lithic industry, macro and mesofauna remains from the UM and Epipaleolithic levels of Cova de les Cendres (CC) and Coves de Santa Maira (SM) have been used to carry out this synthesis.

Fig. 1. Location of the Iberian Mediterranean central region sites mentioned in the text. Upper Magdalenian: Cova Matutano (1), Cova dels Blaus (2), Cova de les Cendres (5). Upper Magdalenian and Epipaleolithic: Tossal de la Roca (3), Coves de Santa Maira (4).

2.1. Cova de les Cendres

CC is a large cave located in Teulada-Moraira (Alicante, Spain) next to the coast at an altitude of 60 masl. However, in the Palaeolithic the distance would be between 10–15 km, leaving a wide area in front of it, including meadow, lagoon and dunes (Real et al., 2022). The interior of the cavity, has an extension of more than 600 m^2, but at present the part that remains visible consists of a surface of 30 by 50 m. The rest of the cavity is still inaccessible today due to an important process of sediment clogging that obstructs the access. The excavation surface was divided into two sectors, A and B, with an extension of 19 m^2, in addition to a test pit of 2.5 m^2. Thirteen sedimentological and chronological levels were defined (Villaverde et al., 2019), including level XVII with occupations of an as yet undetermined chronology, Aurignacian (XVID, XVIC), Gravettian (XVIB, XVIA, XV), Solutrean (XIV, XIII), and Magdalenian (XIIB, XIIA, XI, X, IX). In the present work, we are focusing in levels XI and IX, with dates that place them in: the UM between 16.2–15.5 ky cal BP; and the FUM between 15.2–14.1 ky cal BP (Villaverde et al., 2012) (Fig. 2).

The study of the Magdalenian levels has been already published (for more details see, e.g., Bel and Villaverde, 2024; Martínez Varea and Badal, 2017; Real, 2020a; Roman, 2004; Román and Villaverde, 2012; Villaverde, 1981; Villaverde et al., 1999, 2010, 2012, 2019).

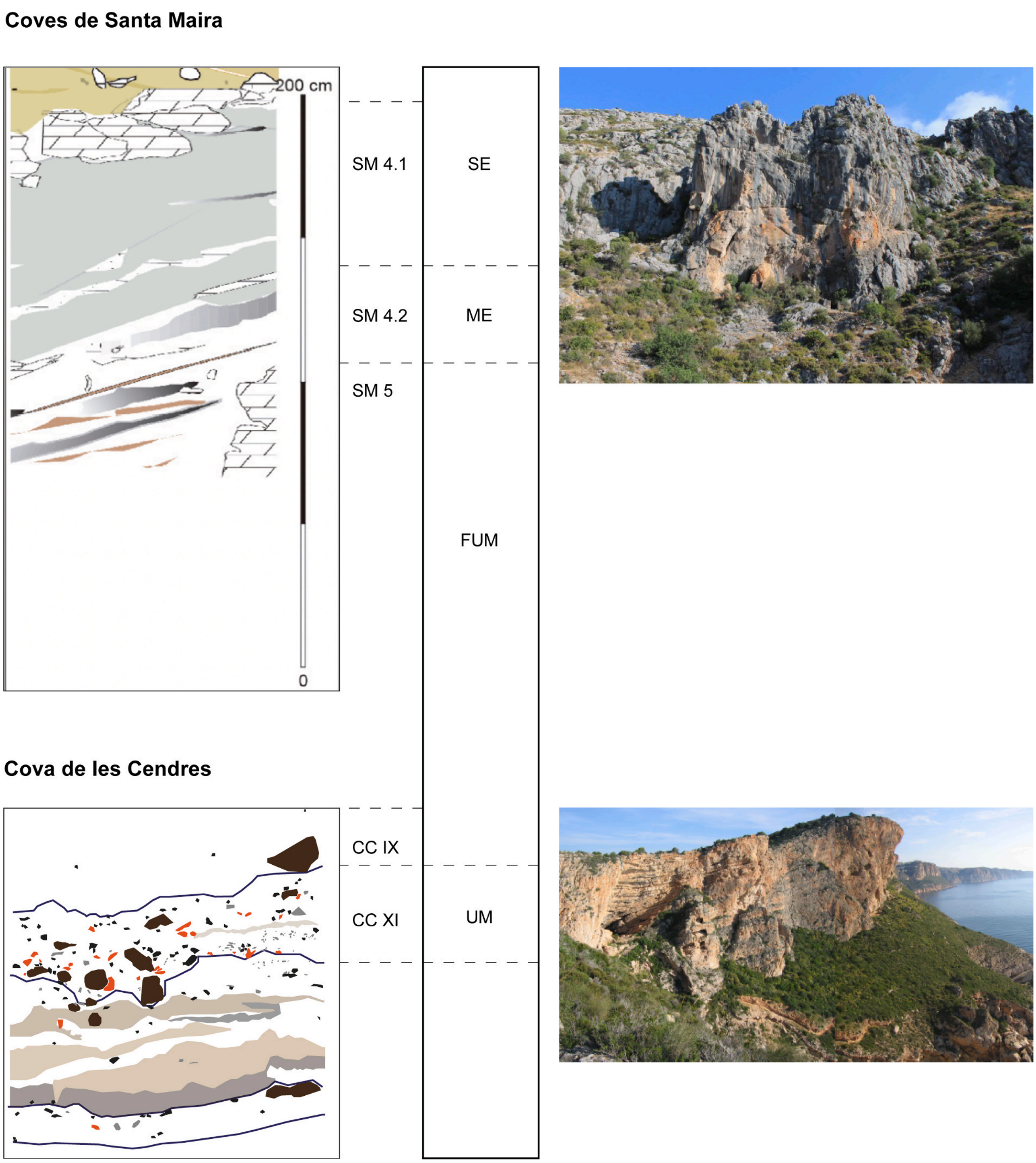

Fig. 2. Stratigraphic sequence of the mentioned levels from Cova de les Cendes and Coves de Santa Maira. Abbreviations: Upper Magdalenian (UM), Final Upper Magdalenian (FUM), Microlaminar Epipalaeolithic (ME) and the Sauveterroid Epipalaeolithic (SE).

2.2. Coves de Santa Maira

SM is located in the municipality of Castell de Castells (province of Alicante, Valencia region) at approximately 600 masl and at a distance of 25–30 km from the current coastline. The archaeological interventions at SM have focused on two sectors: the Corral del Gordo and the Boca Oest (= SM-W). The SM-W archaeological sequence is divided into five major lithostratigraphic units (Aura et al., 2006). Unit SM-5 was deposited at the end of OIS2, during GI-1 and GS-1(15–13 ky cal BP). It contains Magdalenian industries (upper and final). The base of Unit 4 could be related to the end of the Younger Dryas (GS-1), dated to 12.7–11.6 ky cal BP, while the upper sequence corresponds to the Preboreal, dating to 11.1–10.2 ky cal BP (Fig. 2). It contains Epipalaeolithic occupations. In the Radiocarbon dating places the unit 3 at the Boreal (10.2–8.8 ky cal BP). It includes Early Mesolithic materials. Unit SM-2 shows erosional contact over the lower unit. Unit SM-1 has a chaotic appearance with tabular geometry, and it is strongly eroded over the underlying unit. Chalcolithic to the Middle Ages.

The study of the Magdalenian and Epipaleolithic materials has been already published (for more details see, e.g., Aura et al., 2006, 2020; Balcázar-Campo and Aura, 2021; Morales Pérez, 2015; Soler Mayor and Aura, 2021; Vadillo Conesa, 2018; Vadillo Conesa and Aura, 2020; Vadillo Conesa et al., 2019).

2.3. Methods

The lithic assemblage has been analysed from a technological (Inizan et al., 1995; Pelegrin, 2000; Perlés, 1991) and typological perspective (Sonneville-Bordes and Perrot, 1954, 1955, 1956a, 1956b). Several categories have been discriminated based on the objectives for which they were produced, following the operational chain principles.

The study of the faunal remains followed a classical methodology of

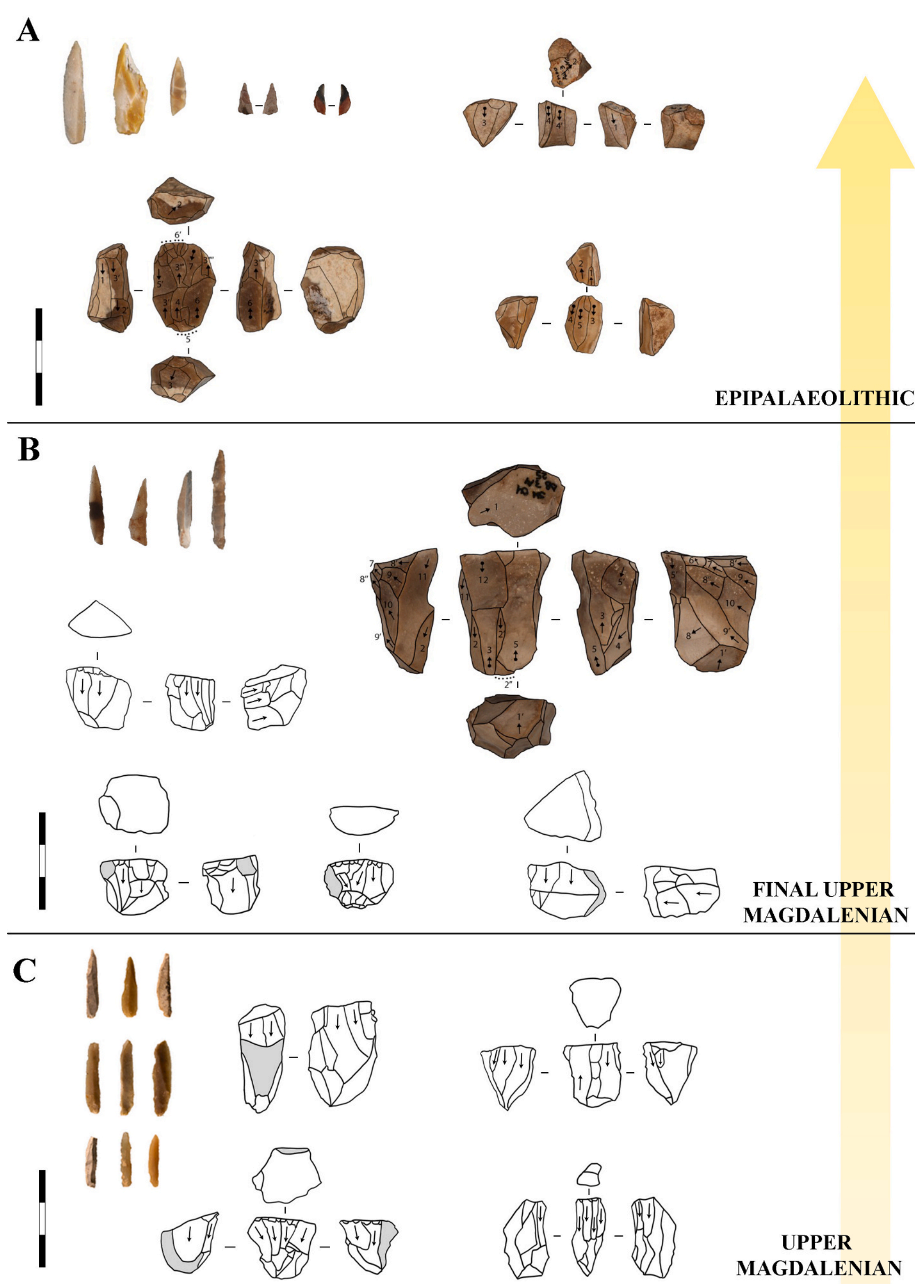

Fig. 3. A. Armatures and cores from Epipalaeolithic levels of SM. B. Photos: armatures and cores from FUM levels of SM; drawings: cores from FUM levels of CC. C. Armatures and cores from UM levels of CC.

zooarchaeological and taphonomic analysis (see references in, e.g., Morales Pérez, 2015; Real, 2021): taxonomic and anatomical identification, age at death and anthropogenic modifications (cut marks, fracture marks, dental marks and thermal alterations), non-anthropogenic modifications (dental marks, digestive corrosion) and diagenetic modifications. Quantification based on number of remains (NR) and number of identified specimens (NISP).

3. Results

3.1. Lithic technology

3.1.1. Cova de les Cendres

The raw materials identified in the Magdalenian levels (UM and FUM) of the CC – mainly flint and chert – can be categorised into two groups. The first group consists of locally sourced materials, which are typically of medium quality. The second group includes materials of the Serreta and Mariola varieties (Molina, 2015), recovered from Oligocene deposits in the Serra de Mariola area (Villaverde et al., 1999), approximately 50 km away from the cavity. These materials are of very good quality and are primarily used for producing blades, bladelets, and backed tools.

The lithic technology of the UM and FUM levels of CC is so similar that it is difficult to differentiate between them based solely on lithic technological data (Fig. 3. B, C) (Román, 2004; Román, 2015). The original raw material is small in size, which probably determines both the process and objectives of the lithic production from the initial stages. The reduction schemes for the production of bladelets clearly dominate. Many of them are carried out on thick flake cores that result in short-lived and low-productivity exploitations. Only in some cases does the process begin with the aim of obtaining blades, which are generally short and wide (averaging approximately 25– 30 mm in length and 9–10 mm in width), before quickly transitioning to the exploitation of bladelets (averaging 15 mm in length and 5.5 mm in width). The pieces chosen for the production of retouched tools are slightly larger than average in size. While there are no specific flake exploitation schemes in place, the flakes that are produced during the preparation and maintenance processes are used to create certain domestic retouched tools such as burins, denticulates, and end-scrapers).

The core reduction schemes that are developed involve primarily frontal, semi-enveloping, or thick flake edge techniques (similar to a burin-like core). The cores are prepared through simple operations, with minimal initial preparation leading to significant material loss. Only high quality raw materials can support the development of more complex schemes, such as semi-enveloping and even enveloping schemes, which utilise crêtes or semi-crêtes to create cores with pyramidal morphologies. Similarly, in certain cores made from high-quality raw materials, some extractions are carried out with different orientations before abandonment, in order to fully complete them (orthogonal cores).

Knapping direction is typically unipolar in most cases, with only a few instances of bipolar exploitation. The latter usually occurs during maintenance actions on the main knapping surface from the opposite striking platform. In addition, the striking platform undergoes more maintenance through the removal of tablets or semi-tablets, as well as the abrasion of the core overhang.

The entire system of lithic production is focused on obtaining microlaminar supports of small, fairly standardised dimensions. The ultimate objective is to produce backed bladelets (Fig. 3. C), many of which are marginal backed bladelets or bladelets with fine direct retouch (Bel and Villaverde, 2024; Villaverde et al., 2012). These bladelets are sometimes pointed and used as part of projectiles or as lateral armature for composite tools.

Microlaminar tools are followed at a considerable distance by end-scrapers, burins, and pieces with retouched edges. These pieces were mainly manufactured on flakes, and in some cases on blades or laminar flakes. The rest of the typological groups appear in lower percentages, such as splintered pieces, notches and denticulate flakes, and truncations.

3.1.2. Coves de Santa Maira

Three phases (FUM, ME, and SE) are included in this work. In all of them (Vadillo Conesa, 2018; Vadillo Conesa and Aura, 2020), most of the lithic materials identified consist of a type of fine- or medium-grained flint from the Upper Cretaceous, specifically Mariola flint (Molina, 2015), which is found in conglomerates in the surrounding area. The second most abundant type in the three phases is Ypresian flint, known as Serreta (Molina, 2015), which originates from a regional outcrop approximately 30 km from the site. The initial volumes are of small dimensions. The average dimensions of the volumes tested are 35.82 mm in length, 30.64 mm in width, and 18.94 mm in thickness. Nodules, flakes, or fragments have been identified in the volumes exploited. Overall, there appears to be minimal focus on tasks related to the initial stages of exploitation.

In the FUM, we find flat, regular, rectilinear laminar blanks, as well as carinated laminar blanks. In the Epipalaeolithic phases, flat, small, rectilinear laminar blanks and carinated, regular, rectilinear pieces are also present. While the production of blanks of various sizes is only associated with integrated exploitations in the FUM, integrated *chaînes opératoires* coexist with differentiated production systems in the ME. This means that blanks of different dimensions result from different exploitations. No integrated *chaînes opératoires* have been distinguished in the SE; only short-lived production systems that did not generate blanks of different dimensions.

In all three phases we observe production modalities predominantly focusing on the wide surface of the cores (Fig. 3. A, B). One common feature that appears throughout the sequence is the exploitation of natural edges, from which blanks of various dimensions would have been obtained, as they are related to the use of irregular blocks of volumes. In terms of exploitation dynamics, there is a predominance of unipolar methods and a gradual decline in bipolar methods. Generally, these exploitations would not have been very productive, with the exception of semi-tournant cores. These exploitations would generate blanks of different dimensions, indicating they were integrated exploitations.

The main goal of flint knapping is to obtain laminar blanks. The laminar assemblage can be categorised based on the specific selection during the tool production stage; for example, a width of 8 mm as the dividing line between the blanks chosen for making armatures and those used for creating other tools, such as end-scrapers and truncations. In addition to this selective process, there was a more precise selection of blanks for armatures. Only small laminar blanks were utilised, while for other types of tools, débitage blanks like flakes resulting from the management of the exploitation process were also used. The typometric analysis of blanks does not reveal any significant changes in production systems throughout the sequence. Differences become apparent when we observe retouched tools. Although the width remains very similar, certain nuances can be observed in the diachronic evolution of lengths, revealing a situation in which armatures would have become shorter throughout the course of the Epipalaeolithic. Conversely, other types of tools would have been made from longer laminar blanks. Throughout the sequence, armatures play an important role, making up more than 50 % of the total retouched pieces in the three phases (Fig. 3. A, B). Fragments of backed bladelets make up 75 % of the total. Non-pointed backed bladelets make up between 8 % and 11 % of the armatures, while geometrics increase in presence from 1 % of the total armatures in the FUM and ME to 6.25 % of the total in the SE. There is a progressive increase in the number of end-scrapers, while truncations decrease to the point where they are less frequent than retouched blanks, flakes and blades in the SE. Burins are scarcely represented in the sequence and microburins are present in all episodes, but only in very low percentages.

3.2. Faunal assemblages

3.2.1. Cova de les Cendres

A total of 66,005 remains were analysed across the two Magdalenian levels: (CC XI = 58,552 [UM] and CC IX = 7,453 [FUM]). Taxonomically and/or anatomically, 17,114 and 2,969, respectively, were identified (Table 1) (Real, 2020a). In both levels, leporids are the most common group, accounting for between 87 % and 91 % of the total number of identified remains (Fig. 4. A). The red deer is the next most prevalent species, making up between 5 % and 8 % of the total. The presence of other species of ungulates and carnivores is very low, except for the Iberian ibex, which has somewhat higher quantities, especially in level CC XI. If we exclude the leporids, we can better observe that red deer represent more than 50 % of the remains (Fig. 4. B).

The anatomical representation of the main species (red deer, Iberian ibex and rabbit) indicates the presence of all anatomical groups, although the percentages of the axial skeleton are always lower. In the case of red deer, at level CC IX, the representation is more homogeneous. On the other hand, at level CC XI, there is a greater number of metapodials and phalanges. This could be due to selective transport or to the butchering process and its spatial distribution.

The skeletal remains are well preserved, as indicated by the low levels of diagenetic alteration: 7.8 % (CC XI) and 13.3 % (CC IX), mostly manganese stains and slight concretions. However, the bone assemblage is highly fragmented, with a fragmentation rate of 1.4 among those identified at the two levels.

All stages of butchery have been documented in red deer and leporids on the basis of cut marks. However, there is little evidence in the other species. In the leporids at level CC XI, the abundant cut marks on the forelimb and the zeugopod of the hindlimb could be the result of filleting meat for preservation.

Fractures are systematic and intense in both red deer and leporids. In the red deer, the focus is on the long bones, metapodials and phalanges. However, bones with less medullary content are also fractured, as well as the epiphyses of the long bones. Fractures were caused primarily by percussion and in some cases by bending. In the leporids, the long bones are fractured by bite or bite and flexion, forming cylinders and fragments of diaphysis. Dental impressions are very rare in all groups, although some have been recorded in less dense areas and are sometimes associated with bending fractures. It is only in the leporids at level CC XI that dental marks are more common in the diaphysis or in areas close to the epiphyses.

Finally, thermal alterations affect 11.5 % (CC XI) and 58.4 % (CC IX) of the taphonomically identified and analysed remains. In general, the thermo-alterations affect the entire surface and mainly with brown-black colorations. However, there is a difference between the two levels, since the percentages are much lower at level CC XI: 11.7 % of red deer and 9.5 % of leporids compared to 49.5 % of red deer and 42.3 % of leporids at level CC IX.

3.2.2. Coves de Santa Maira

A total of 19,112 remains were analysed at the three levels (SM 5 = 1,214; SM 4.2 = 3,272; SM 4.1 = 14,626). They were taxonomically and/or anatomically identified in 57.7 %, 61.2 %, and 58 % of cases, respectively (Table 1) (Morales Pérez, 2015). Leporids are the most well represented group at all three levels, with values ranging from 87 % to 92 % (Fig. 4. A). In this instance, the Iberian ibex is the main taxon with values ranging from 0.5 % to 2 %. Other species of ungulates and carnivores are also recorded, although in very small numbers, with the exception of level SM 4.1, where diversity is higher. Excluding leporids, the Iberian ibex accounts for more than 85 % of the remains (Fig. 4. B).

Bones from all anatomical groups are found at all three levels, but the axial skeleton is consistently less well represented, both in Iberian ibex and leporids. The cranial region of the Iberian ibex is always well represented, as are the long bones of the limbs, depending on the level. The entire specimen is well preserved, with minimal calcareous concretions. However, the remains are highly fragmented. Fresh fractures can be seen throughout the skeleton of the Iberian ibex. The marrow in both the long bones and phalanges has been extracted. In addition, there is abundant direct evidence of bone fractures, indicated by notches and some bending, except at level SM5 where it is scarce. Fresh fractures in rabbits are important, as there are abundant fragments of diaphyses or cylinders of long bones. In addition, there are a greater number of direct fractures in the femur and tibia, as well as bites in the stylopodium and zeugopodium.

Cut marks reveal extensive processing of the Iberian ibex, with evidence of skinning, disarticulation, and removal of meat packages. Most of the cut marks are located on the long bones, particularly the diaphyses, but there are also remains of the cranial and axial skeleton. When it comes to leporids, cut marks are also present throughout the

Table 1
Taxonomic composition by site and levels based on NISP and %NISP.

	CC XI NISP	%NISP	CC IX NISP	%NISP	SM 5 NISP	%NISP	SM 4.2 NISP	%NISP	SM 4.1 NISP	%NISP
DETERMINATE	**16,669**	**97.53**	**2709**	**91.24**	**701**	**57.74**	**2004**	**61.25**	**8479**	**57.97**
Equus ferus	23	0.14	3	0.11						
Artiodactyla					3	0.43			2	0.02
Cervidae	31	0.19	20	0.74					1	0.01
C. capreolus	1	0.01	2	0.07					5	0.06
Cervus elaphus	920	5.52	109	4.02	4	0.57	6	0.30	93	1.10
Bos primigenius	2	0.01		0.00					2	0.02
Caprinae					77	10.98	148	7.39	585	6.90
Capra pyrenaica	241	1.45	26	0.96	29	4.14	149	7.44	678	8.00
R. rupicapra									14	0.17
Ovis/Capra									1	0.01
Sus scrofa	4	0.02	2	0.07			4	0.20	25	0.29
Carnivora	7	0.04	1	0.04			1	0.05		
Canidae									1	0.01
Cuon alpinus									1	0.01
Vulpes vulpes	3	0.02	1	0.04					12	0.14
Felinae	7	0.04	0	0.00						0.00
Felis silvestris	11	0.07	0	0.00					1	0.01
Lynx pardina	84	0.50	7	0.26					7	0.08
Leporidae	15,008	90.04	2468	91.10	588	83.88	1696	84.63	7048	83.12
Birds	327	1.96	231	8.53						
Erinaceus									3	0.04
INDETERMINATE	**620**	**3.60**	**260**	**8.80**	**513**	**42.26**	**1268**	**38.75**	**6147**	**42.03**
TOTAL	**17,091**		**2969**		**1214**		**3272**		**14,626**	

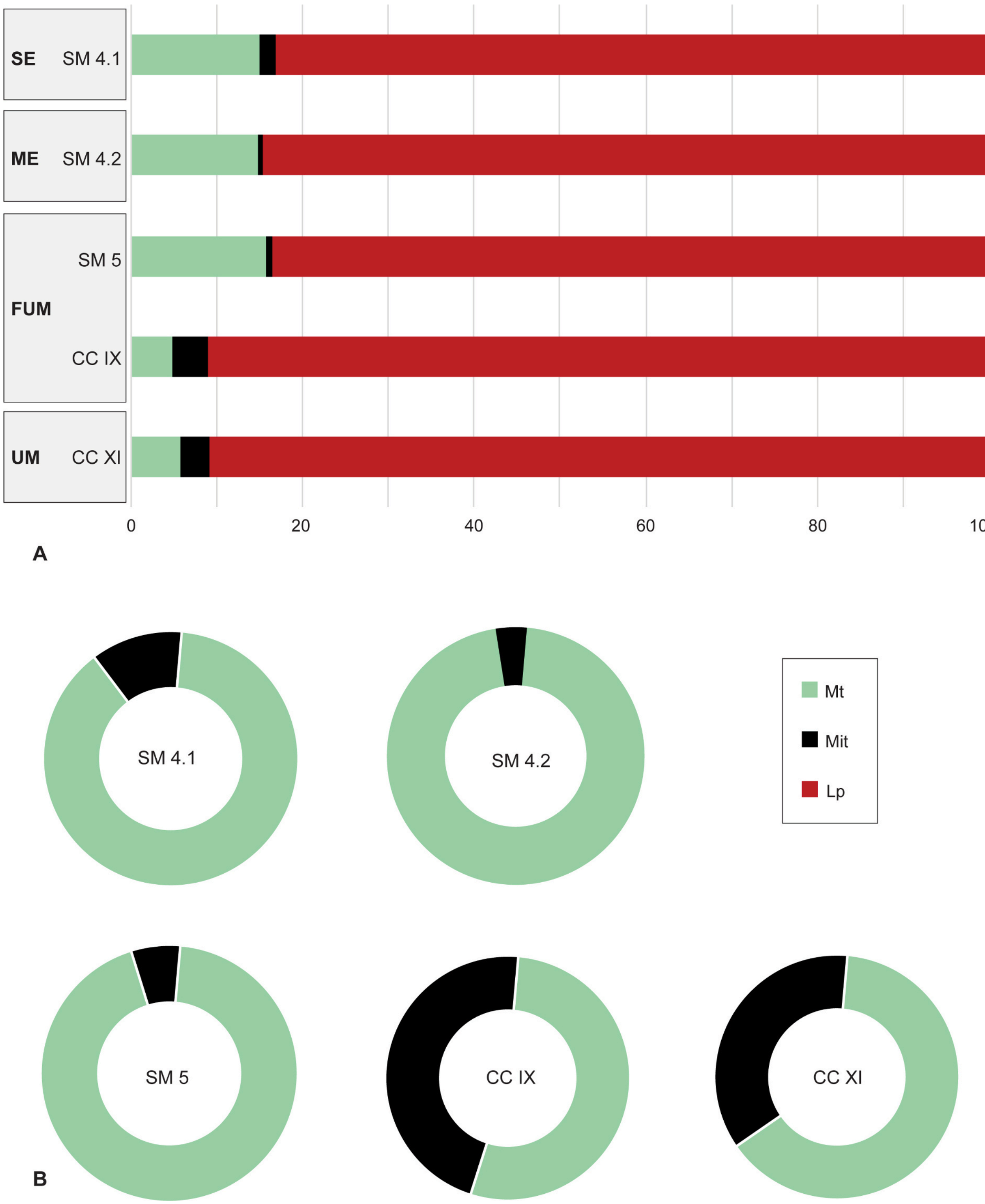

Fig. 4. A. Proportion between taxonomic groups (%NISP) define in the text: Mt (Main taxon), Mit (Minority taxa), Lp (Leporids). B. Proportion between the Mt in grey and Mit in black. Abbreviations: Upper Magdalenian (UM), Final Upper Magdalenian (FUM), Microlaminar Epipalaeolithic (ME) and the Sauveterroid Epipalaeolithic (SE).

skeleton, with a notable concentration on the scapula, humerus, femur, and tibia. These marks indicate the removal of flesh for preservation, and their frequency is higher at level SM 5. Thermal alterations are observed in 41.7 % to 49.3 % of the mesofauna at level SM 4.1 and in 39.9 % to 33.2 % of the leporids. These percentages decrease to 35.1 % and 22.4 % at level SM 4.2 and to 35.7 % and 27.6 % in level SM 5. Overall, level 2 (brown-black) is the most prevalent, followed by level 1 (brown).

4. Discussion

4.1. *Lithic production systems*

In the central Iberian Mediterranean region (Region of Valencia) there is limited information available on the production systems in sites with Magdalenian and Epipalaeolithic levels co-existing. Apart from SM, it is only in Tossal de la Roca and Cova Matutano that these two periods can be studied together.

Between the FUM of CC and the end of the Epipalaeolithic of SM there are numerous elements that reveal a continuity in terms of lithic production systems. In the initial phases of exploitation at both sites throughout these periods there is minimal investment in the initial conditioning of the volumes. The small size of the available raw material probably influences this situation. In addition, both sites feature exploitations that yield few products, alongside others that are more productive. This dual situation is also documented at levels III and II of the internal area of Tossal de la Roca, associated with the UM (Cacho and Martos, 2004) and Cova Matutano (Domènech, 1990, 1998). Similar to CC, there is a distinct production system for lithic exploitation depending on the quality of the raw materials. The exploitation of higher quality raw materials involves a higher level of complexity in the preparation and maintenance of the cores. By contrast, raw materials that are less suitable for knapping are typically exploited using simpler techniques (Román, 2015; Vadillo Conesa, 2018).

The objective in all cases is the production of blade and microblade blanks, without any evidence of exploitation for obtaining flakes found at any of the sites. The presence of flake negatives in certain cores recovered at CC and Tossal de la Roca has been linked to behaviour associated with extensive use of the raw material. It appears that towards the end of the Magdalenian, integrated production was evident, resulting in blade products of varying sizes. This practice gradually disappeared during the Epipalaeolithic, with distinct productions being identified. The prevalence of unipolar bladelet exploitations is a common characteristic at both sites and throughout all episodes, including the UM of Tossal de la Roca and Matutano.

The main objectives of both the Magdalenian and Epipalaeolithic exploitations are focused on acquiring bladelets that will serve as armatures, forming part of composite tools. In the SE of SM, there is a unique element present among the armatures, known as pygmy geometrics, which are not found in other episodes (Aura, 2001; Vadillo Conesa, 2018). However, other types of tools, including burins, truncations, and end-scrapers, have also been recovered. These have been fashioned on the laminar lamellar supports of larger dimensions, and sometimes shaped on flakes generated in the exploitation processes.

4.2. *Subsistence patterns*

The faunal assemblages from the central area of the Mediterranean region demonstrate notable similarities thought the UM and Epipaleolithic periods, regardless of the geographical location of the site. The taxonomic spectrum indicates consistent patterns that have already been addressed in previous studies (Aura et al., 2002a, 2009; Morales Pérez, 2015; Pérez Ripoll and Martínez Valle, 2001; Real, 2020a; Villaverde and Martínez Valle, 1995; Villaverde et al., 1998, 2012), with the following characteristics (presented in Table 2). First, there is a

Table 2
Taxonomic data from the sites mentioned in the text.

SITE	Location	LEVEL	PERIOD	NISP	Mt taxa	% NISP	Mit taxa	% NISP	Lp % NISP	REFERENCES
Cova de les Cendres	coastal	IX	FUM	2709	red deer	4.1 %	Iberian ibex, wild boar, roe deer, horse, fox, lynx	2.3 %	93.5 %	Real, 2021
		XI	UM	16,494	red deer	5.6 %	Iberian ibex, wild boar, roe deer, horse, auroch, fox, lynx, wild cat	2.5 %	91.8 %	
Cova Matutano	coastal	IIb-Ia	ME	252	red deer	21.1 %	Iberian ibex, hedgehog, carnivors, horse	6.2 %	72.7 %	Olària, 1999; Olària et al., 1981
		Sect.1 N5	UM	7586	red deer	2.8 %	Iberian ibex, chamois, roe deer, horse, carnivors, hedgehog	2.1 %	95.1 %	
		Sect.2 N4	UM	2020	red deer	8.9 %	Iberian ibex, wild boar, horse, auroch, lobo	1.5 %	89.1 %	
		Sect.1 N3	UM	2545	red deer	8.4 %	Iberian ibex/chamois/roe deer, horse, carnivors, hedgehog	3.5 %	88.1 %	
		Sect.2 N3	UM	2237	red deer	12.2 %	Iberian ibex, auroch, chamois, wild boar, horse	1.8 %	86.0 %	
		Sect.3B	UM	896	red deer	2.0 %	Iberian ibex, chamois, roe deer, hedgehog	2.0 %	96.0 %	
		Sect3. C	UM	973	red deer	6.0 %	Iberian ibex, chamois, roe deer, auroch, mustelids, lynx, hedgehog	8.0 %	86.0 %	
Tossal de la Roca	interior	I (sect. int)	ME	1439	Iberian ibex	12.5 %	red deer, wild boar, chamois, auroch/horse, lynx	3.1 %	81.1 %	Cacho et al., 2001, 1995
		II (sect. int)	FUM	453	Iberian ibex	29.5 %	red deer, wild boar	5.8 %	64.7 %	
		III (sect. int)	UM	768	Iberian ibex	18.8 %	red deer, wild boar, hedgehog	2.6 %	79.3 %	
		IV (sect. int)	UM	732	Iberian ibex	4.6 %	red deer, wild cat	2,6%	92.8 %	
Coves de Santa Maira	interior	SM-4.1a	SE	1397	Iberian ibex	17.0 %	red deer, wild boar, carnivors, hedgehog	1.7 %	84.6 %	Morales Pérez, 2015
		SM-4.1b	SE	3756	Iberian ibex	14.7 %	red deer, roe deer, wild boar, lynx	1.7 %	85.9 %	
		SM-4.1c	SE	994	Iberian ibex	12.9 %	red deer, wild boar, chamois, lynx, roe deer, fox, wild cat, auroch	1.2 %	83.6 %	
		SM-4.2	ME	1268	Iberian ibex	14.8 %	red deer, fox, chamois, wild boar, hedgehog, lynx, cuon	0.6 %	79.7 %	
		SM-5	FUM	513	Iberian ibex	15.1 %	red deer	0.6 %	83.9 %	
Cova dels Blaus	coastal	III-I	ME	2577	red deer	8.2 %	hedgehog, chamois, wild boar, fox, auroch, horse, lynx, Iberian ibex	4.8 %	86.9 %	Martínez Valle, 1996
		IV	M	1676	red deer	6.6 %	Iberian ibex, chamois, wild boar, horse, lynx, hedgehog	3.6 %	89.3 %	
		V	M	1221	red deer	4.0 %	chamois, wild boar, horse, lynx, wild cat, hedgehog	3.5 %	92.5 %	

specialisation in hunting ungulates, focusing on two medium-sized species, namely red deer and Iberian ibex (Main taxon = Mt). Second, this specialised hunting is complemented by the consumption of other ungulate and carnivore taxa, though the quantities are minimal (Minor Taxa = Mit). Third, there is a systematic and abundant exploitation of leporids, which make up over 80 % of the total bone remains (Leporids = Lp). This distribution pattern is evident in the results of both CC and SM studies, as well as in other nearby sites and throughout the sequence (Table 2; Fig. 5).

Regarding the Mt, there is a variation depending on the location of the site. In this case, a chronological constant is observed at each site, although it varies between them. Red deer are hunted in areas between 0 and 400 m above sea level, on coastal plains, or near the coast (CC, Cova Matutano, Cova dels Blaus). The Iberian ibex, on the other hand, is prominent in sites located above 400 m above sea level, in inland and/or mountainous areas crossed by valleys (Tossal de la Roca, SM). The percentage of the Mt fluctuates between 2 % and 20 % (Figs. 5 and 6), higher in the interior sites, and with an extreme value at Tossal de la Roca level II (29 %) (Cacho et al., 1995). The Mit include ungulates such as wild boar, roe deer and chamois, as well as two large species, namely horse and auroch. Regarding carnivores, the remains correspond primarily to lynx and fox, but there is also evidence of wild cat, wolf, cuon, mustelids, and in the case of CC, marine carnivores. Their percentages indicate a mean of 3 % (Figs. 5 and 6). At the coastal sites, there is a slight increase in the number of Mt and Mit and a slight decrease in the number of leporids. At the inland sites, there is an uneven trend among the assemblages, with some cases breaking the general pattern. For example, at level II in Tossal de la Roca, the number of leporids is lower. On the other hand, SM exhibits the same pattern as the coastal sites. However, the relationship between the two groups differs significantly between CC and SM. In CC, the proportion of Mit is between 30 % and 45 %, whereas in SM it is only 12 % at the end of the Epipalaeolithic. In addition, the number of species is an important indicator of diversification, as it provides information on the emergence of new taxa. The number of species increases towards the Epipalaeolithic, as evidenced in level SM4.1 of SM.

Finally, the proportion of leporids remains more consistent throughout the sequence than the percentage of Mt and Mit (Figs. 5 and 6). The only exception is at Tossal de la Roca level II, where it reaches only 65 %. Despite the trend towards diversification resulting from the growth and utilisation of the Mediterranean forest, the significance of rabbits in the diet does not decrease significantly. It was not until the Mesolithic that the diet became much more diverse, leading to a significant decrease (30–40 %) in the presence of rabbits (Aura et al., 2009;

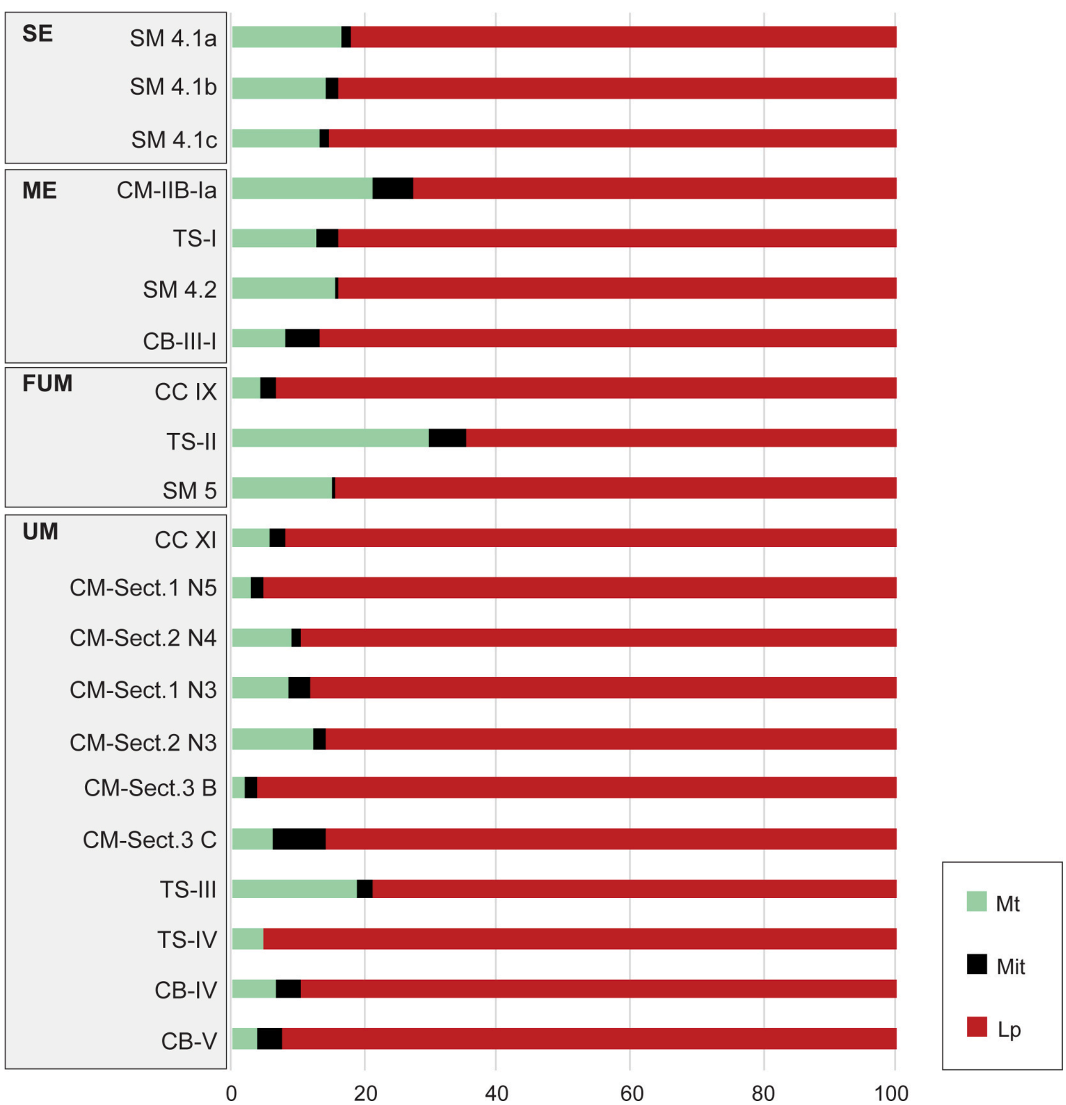

Fig. 5. Proportion of the taxonomic groups (%NISP) define in the text: Mt (Main taxon), Mit (Minority taxa), Lp (Leporids) by site: Santa Maira (SM), Cova Matutano (CM), Tossal de la Roca (TS), Cova dels Blaus (CB), Cova de les Cendres (CC). Abbreviations: Upper Magdalenian (UM), Final Upper Magdalenian (FUM), Microlaminar Epipalaeolithic (ME) and the Sauveterroid Epipalaeolithic (SE).

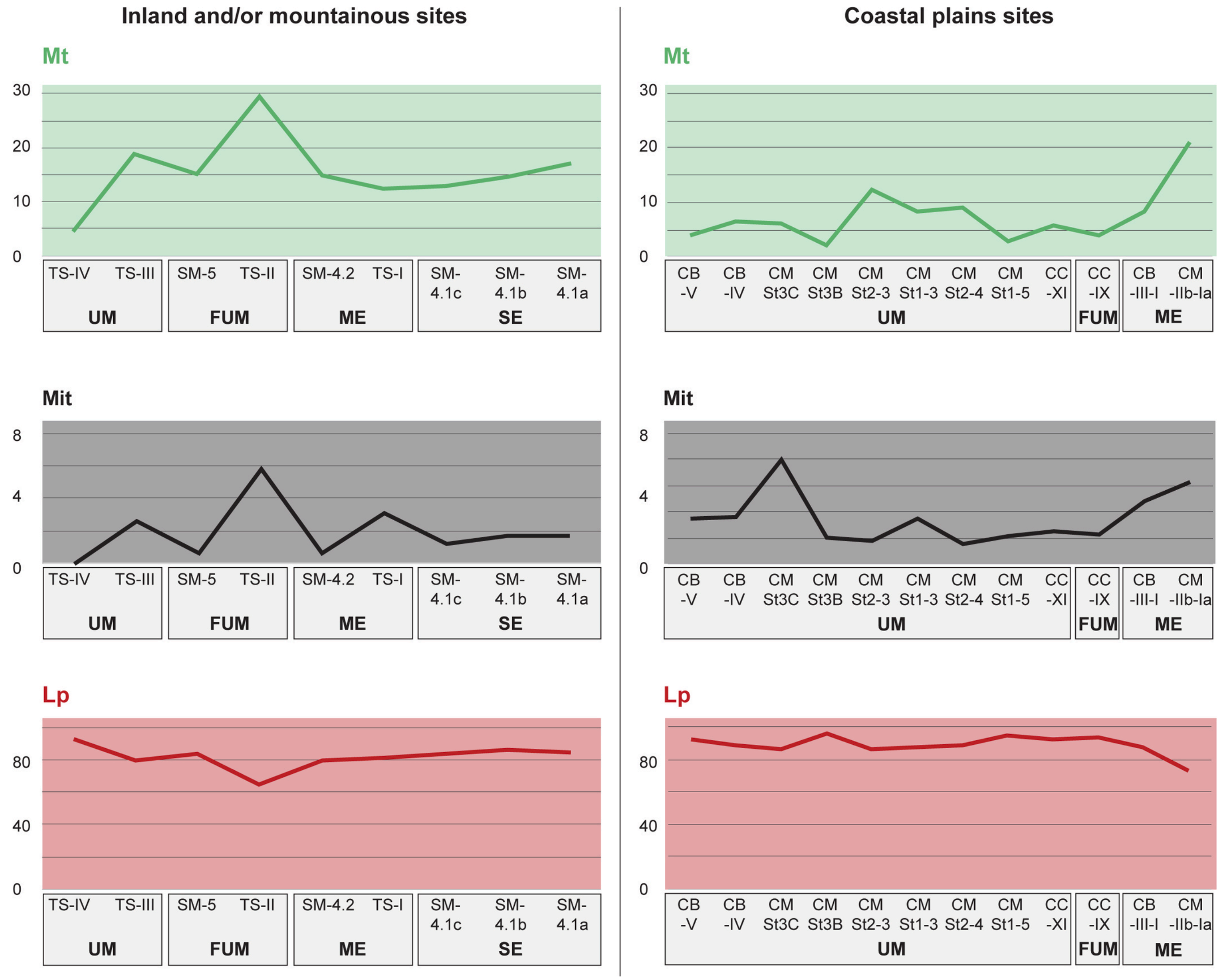

Fig. 6. Evolution of the taxonomic groups (%NISP) define in the text: Mt (Main taxon), Mit (Minority taxa), Lp (Leporids) by sites and geographical location. Sites: Santa Maira (SM), Cova Matutano (CM), Tossal de la Roca (TS), Cova dels Blaus (CB), Cova de les Cendres (CC).

Fernández-López de Pablo et al., 2015; Lloveras et al., 2021; Real et al., 2024). The diversification of the diet during this period includes not only ungulate and carnivore species, but also species related to the marine environment such as molluscs, fish, birds, and marine mammals (Aura, 2019; Aura et al., 2016). From the Magdalenian period onwards, there was an increase in the use of marine resources, especially in southern areas of the Mediterranean. Coastal sites such as the Cueva de Nerja offer well-preserved assemblages of these resources (Álvarez-Fernández et al., 2014, 2022; Aura et al., 2002b; Morales et al., 2019). However, evidence of these resources is also found, albeit to a lesser extent, in inland sites such as SM or in plains such as CC. Even though CC is now located on the coast, it was separated from the site by a marine regression of 10–15 km at that time. In these sites, evidences suggest the use of animals for diet as well as non-bramatological purposes (Martínez Valle, 1996; Monterrosa, 2023; Soler Mayor, 2001). This does not just reflect the consumption of marine resources at these sites, but also indicates a connection between remote or inland areas and coastal regions.

An analysis of the exploitation of these species reveals that both red deer and Iberian ibex were transported whole to the sites, and were processed to include all stages and the consumption of all their resources, including meat, marrow, and potentially fat from joints after cooking. Intensive use was made of each individual specimen, as evidenced by the systematic fracturing of not only long bones with marrow, but also phalanges and carpals/tarsus. It is possible that fire was used to facilitate breaking of bones, roasting of meat, and cooking of fatty epiphyseal fragments (Real, 2020b; Morales Pérez, 2015). The use of teeth is documented to aid in breaking thinly packed areas and nibbling on meaty parts. In the case of carnivores, such as lynx in CC and red fox in SM, both have been subject to anthropic exploitation (Real et al., 2017, 2024a). Percussion, bending, and biting were used in processing and consumption. Leporids, as prey, were hunted in large quantities – primarily adults, due to their size. Human groups consumed the meat and fractured the long bones with the highest marrow content – the humerus, femur, and tibia – in order to access the marrow. Both lithic tools and manual bending, biting or biting/flexing were used for peeling, disarticulation, defleshing and fracture (Pérez Ripoll and Villaverde, 2015; Real, 2020c). In some cases, at CC and SM, bones with a large number of cut marks were identified. These marks could be related to the preservation of meat through smoking or sun-drying techniques, as shown by a current experimental programme (Real et al., 2025).

5. Conclusion

The archaeological evidence from the central Mediterranean region of the Iberian Peninsula reveals a remarkable continuity in the techno-economic behaviors of hunter-gatherer groups during the Late Upper Palaeolithic and Epipalaeolithic, though the assemblages have been classified under various nomenclatures (Aura, 1995; Fortea, 1973; Román, 2012; Román and Domingo, 2020). This pattern is particularly evident in the consistent strategies employed in both lithic production and subsistence practices across key sites such as Cova de les Cendres and Coves de Sant Maira.

In terms of lithic production, the data point to a shared operational framework centered on the manufacture of bladelets for use in composite tools, a technological objective that remains stable from the Upper Magdalenian through to the late Epipalaeolithic. The recurrent use of unipolar and straightforward core reduction techniques, modulated only by the quality of the available raw materials, suggests that functional efficiency outweighed typological variability. The limited investment in core preparation and the pragmatic adaptation to raw material constraints reflect a production system geared towards expediency and continuity rather than innovation. These shared features across sites and chronological phases underline a stable technological tradition with minimal structural change over time.

This technological stability is mirrored in the subsistence strategies, that exhibit stable patterns in mammal exploitation over time. The faunal assemblages consistently reveal a diet dominated by leporids and by medium-sized ungulates—red deer and Iberian ibex—whose relative prevalence is determined more by site topography than by chronological factors. The systematic exploitation of all anatomical parts, including low-utility elements such as phalanges and tarsals, indicates a high degree of resource intensification. Moreover, the growing presence of minor taxa points to an incipient trend toward dietary diversification, likely influenced by broader ecological shifts, such as afforestation, during the Tardiglacial and Early Holocene. This pattern of continuity in subsistence practices persists until the advent of the Mesolithic.

Beyond techno-economic homogeneity, the region also evidences continuous human occupation throughout the Upper Palaeolithic and into the Early Holocene, and even since the Middle Palaeolithic (Real et al., 2022). This long-term settlement stability is likely facilitated by the area's diverse biotopes and its favourable geography, including the short distances between coastal plains and interior mountain ranges. The marine transgression during the Late Glacial period further shortened these distances, potentially intensifying interregional connectivity. The ecological duality of mountain/plain and water/land environments remains key to understanding settlement patterns and site distribution. This geographic proximity and the convergence of lithic and faunal data supports the hypothesis of reduced residential mobility and longer, more stable occupations. This is evidenced by the use of local raw materials, exhaustive processing of faunal remains, and the absence of significant occupational hiatuses used by other predators in the studied sites. The emergence of site-specific elements, such as pygmy geometrics in Santa maira, or increased faunal diversity in later Epipalaeolithic levels, suggests local adaptations within a broadly uniform cultural and economic matrix.

In sum, the integration of lithic and faunal analyses reveals a resilient and flexible human system that responded to environmental changes not through radical cultural shifts, but through the steady adaptation of well-established technological and subsistence practices. These findings highlight the value of integrated, diachronic analyses in understanding the long-term stability and subtle transformations of prehistoric lifeways in Mediterranean Iberia.

CRediT authorship contribution statement

Cristina Real: Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Margarita Vadillo Conesa:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Data curation, Conceptualization. **J. Emili Aura:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Juan Vicente Morales:** Methodology. **Dídac Román:** Writing – review & editing, Writing – original draft, Supervision, Formal analysis, Data curation. **Valentín Villaverde:** Writing – review & editing, Supervision.

Declaration of Competing Interest

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

Acknowledgement

This paper has been funded by CIGE/2023/5 project "¿Snack o menú? Exploración de las técnicas de aprovechamiento y conservación de pequeñas presas por neandertales y humanos modernos" by Generalitat Valenciana, and PROMETEO project "The Great Deglaciation: climate change and social dynamics in the Late Paleolithic and Mesolithic period in the Iberian Mediterranean region", (CIPROM2021/036) by Generalitat Valenciana, Direcció General de Ciència I Investigació, Conselleria d'Educació, Universitats i Ocupació.

Data availability

Data will be made available on request.

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