frontiers | Frontiers in Environmental Archaeology

TYPE Original Research
PUBLISHED 11 December 2023
DOI 10.3389/fearc.2023.1309907

OPEN ACCESS

EDITED BY
Lídia Colominas,
Institut Català d'Arqueologia Clàssica, Spain

REVIEWED BY
Leïa Mion,
Cardiff University, United Kingdom
Francesco Carrer,
Newcastle University, United Kingdom
Rosalind Gillis,
Deutsches Archäologisches Institut, Germany

*CORRESPONDENCE
Vanessa Navarrete
✉ vanessa.navarreteb@gmail.com

RECEIVED 08 October 2023
ACCEPTED 20 November 2023
PUBLISHED 11 December 2023

CITATION
Navarrete V, Viñerta A, Clemente-Conte I, Gassiot E, Rey Lanaspa J and Saña M (2023) Early husbandry practices in highland areas during the Neolithic: the case of Coro Trasito cave (Huesca, Spain).
Front. Environ. Archaeol. 2:1309907.
doi: 10.3389/fearc.2023.1309907

Early husbandry practices in highland areas during the Neolithic: the case of Coro Trasito cave (Huesca, Spain)

Vanessa Navarrete[1,2]*, Angel Viñerta[3], Ignacio Clemente-Conte[4], Ermengol Gassiot[5], Javier Rey Lanaspa[6] and Maria Saña[3,7]

[1]Herança Cultural, Estudos e Salvaguarda (HERCULES) Laboratory, Universidade de Évora, Évora, Portugal, [2]Associate Laboratory for Research and Innovation in Heritage, Arts, Sustainability and Territory, Évora, Portugal, [3]Laboratori d'Arqueozoologia, Departament de Prehistòria, Universitat Autònoma de Barcelona, Barcelona, Spain, [4]Grupo de Arqueología de las Dinámicas Sociales, Institución Milá y Fontanals de Estudios en Humanidades del Consejo Superior de Investigaciones Científicas, Barcelona, Spain, [5]Grup d'Arqueologia de l'Alta Muntanya (GAAM), Departament de Prehistòria, Universitat Autònoma de Barcelona, Barcelona, Spain, [6]Dirección General de Patrimonio Cultural, Gobierno de Aragón, Zaragoza, Spain, [7]EarlyFoods, Institut de Ciència i Tecnologia Ambientals, Universitat Autònoma de Barcelona, Barcelona, Spain

Research on animal management strategies in high mountain areas during the early Neolithic (5,700–4,500 cal BC) has been conditioned by the presumption that human occupations in highland areas had a prominent seasonal character and the economic practices focused mainly on the exploitation of wild resources. The results obtained in the framework of research developed recently on settlement dynamics during the early Neolithic in the highland areas indicate the existence of relatively permanent occupations and the exploitation of domestic resources. Regarding livestock, the role of caprine transhumance in highland areas has been highlighted traditionally, conferring a marginal role to husbandry activities and emphasizing principally the temporary maintenance of herds of sheep and goats. In this study, we use the archaeozoological data and $\delta^{13}C$ and $\delta^{15}N$ stable isotopes composition of the faunal bones collagen to characterize the husbandry practices in Coro Trasito cave (Huesca, Spain). The results obtained demonstrated the presence of diverse herd foddering strategies within husbandry practices characterized by taxonomic diversity and multipurpose exploitation suggests that during the Neolithic, Coro Trasito cave played a more complex role than sheepfold. Moreover, the presence of the four main domestic species indicates the adaptation of herds of Coro Trasito to the cave environment, flocks with diverse dietary needs and reproductive behaviors. The results are discussed with an integrated analysis of the data related to animal management strategies in highland areas (more than 1,500 m. asl) during the early Neolithic, in particular in the central Pyrenees area. This study offers new elements to study the complexity of neolithization processes in the central Pyrenees and how these areas were quickly integrated into a broader economic system.

KEYWORDS

central Pyrenees, $\delta^{13}C$ and $\delta^{15}N$ isotopes, livestock practices, animal management, Iberian Peninsula

1 Introduction

The study of animal management strategies in high mountain regions of the Iberian Peninsula during the Early Neolithic (c. 5,700–4,500 cal BC) has been influenced by the assumption that settlements in these areas were primarily seasonal. This assumption has linked the settlements to pastoral or transhumant activities from the beginning of the Neolithic, emphasizing the role of caprine transhumance in highland areas (Martín et al., 2010; Rojo-Guerra et al., 2013, 2014; Lancelotti et al., 2014; Tornero et al., 2018; Tejedor-Rodríguez et al., 2021). However, new research as well as the discovery of new archaeological sites have revealed a wide range of situations, evidencing many complex mixed farming models involving interactions between plant and animal herding (Ebersbach, 2010; Antolín et al., 2018; Villalba-Mouco et al., 2018; Sierra et al., 2019; Gassiot et al., 2021, 2022). In Iberian Pyrenees, Antolín et al. (2018) demonstrate that the settlement dynamics during the Early Neolithic could have been characterized by relatively permanent occupations and the exploitation of domestic resources. Clear evidence of permanent activity at the mountain sites would include agriculture practices, along with other practices linked to medium-to-long-term strategies, such as the storage of plant-based products (Antolín et al., 2017). Regarding livestock, the presence of the four main domestic species (*Bos taurus, Sus domesticus, Ovis aries*, and *Capra hircus*) has been evidenced in the archaeological sites located above 900 m in the Iberian Pyrenees during the Neolithic (with the exception of the Zatoya site: Antolín et al., 2018, p. 88). In the sites where domesticates have been identified, various uses and exploitations of these animals have also been documented (Viñerta, 2015; Antolín et al., 2018; Sierra et al., 2019; Viñerta and Saña, 2019).

Recent research about the Neolithisation process and the socioeconomic dynamics trends of the Neolithic in the central Pyrenees has revealed livestock management practices in the surrounding areas of the Neolithic settlements documented at altitudes ranging from 1,400 to 1,800 m asl (Clemente-Conte et al., 2014; Antolín et al., 2018; Gassiot et al., 2018, 2022; Obea et al., 2021). Sites such as Coro Trasito cave, Cueva Lóbrica, Els Trocs, and Cova del Sardo demonstrate well-established human communities engaged in agricultural and husbandry activities by the end of the sixth millennium and the beginning of the fifth millennium cal BC (Clemente-Conte et al., 2014; Gassiot et al., 2018, 2022). Activities related to local deforestation were observed at Els Trocs and Cova del Sardo. These activities included the clearing of vegetation and the presence of species associated with anthropic action. This suggests activities associated with local grazing and agriculture (Gassiot et al., 2012, 2022; Uría, 2013; Rodríguez-Antón, 2020). However, the scenario is more complex. While Els Trocs and Cova del Sardo document the main domesticates, it is characterized as an occupation closely linked to the seasonal exploitation of caprines (Navarrete and Saña, 2013; Rojo-Guerra et al., 2013, 2014; Gassiot et al., 2018), while Coro Trasito reflects a diverse and complex economic spectrum (Clemente-Conte et al., 2016; Viñerta and Saña, 2019). Additionally in Cova del Sardo and Coro Trasito provide evidence of dairy consumption (Tarifa, 2019).

In this context, settling in mountain regions may not exclude greater permanence and/or more intensive management of these areas. It can involve specialized husbandry practices, leading to the simultaneous management of domesticates, different productive purposes and specific feeding practices. These strategies can encompass activities within the local grazing areas, through mobility strategies, or involve the provision of forage. Considering that each domesticate exhibits distinct requirements and behaviors, a combination of planning and control mechanisms becomes essential to ensure the wellbeing and reproduction of the herds. Although more works address this problem in the Iberian Peninsula (Navarrete et al., 2017, 2019; Tornero et al., 2018; Sierra et al., 2019; Martin et al., 2021; Navarrete et al., Accepted; Tejedor-Rodríguez et al., 2021), there is still a gap in information on animal management strategies during the Neolithic in mountain areas, and the characterization of grazing areas, foraging strategies, and the relation of the herds with the environmental characteristics of the area, the type of site and the use of the settlement. The combined use of archaeozoological and stable isotope analysis can provide us with the keys to the study of pastoral management strategies (Madgwick et al., 2012; Balasse et al., 2016; Navarrete et al., 2017, Accepted).

The main objective of this research is to characterize husbandry practices at the Coro Trasito site during the early Neolithic, emphasizing the management strategies of domesticates. Using archaeozoological and stable carbon and nitrogen isotope analysis in bulk collagen, we will evaluate the animal ecology, herd management and feeding strategies implemented in Coro Trasito. The results will also be discussed within the framework of the neolithisation models proposed for the Iberian Peninsula and, especially, for the central area of the Pyrenees.

2 Coro Trasito (Tella-Sin, Huesca)

Coro Trasito is a large cave located on the southern slope of the Sierra de Las Tucas in Tella-Sin, Huesca, Spain, at 1,540 m a.s.l (Figure 1). This cave has an entrance that is 30.2 m long and 4.4 m high, with a maximum depth of 16.4 m (Clemente-Conte et al., 2014). According to the climatic classification of J. Papadakis, the site is located on the border of the cold temperate and humid Patagonian climate (MAPAMA, 1996), with an average temperature of 7.3°C (Ninyerola et al., 2005). The site is located in a current area of moors and heathland (CORINE Land Cover, 2018). Between the highest areas of the Sierra de Las Tucas and the cave, natural grasslands provide grazing access for livestock during the summer. Below the cave mouth, there are slopes suitable for cultivation and with historic terraces. Adjacent to these historic terraces are mixed forests and coniferous forests (CORINE Land Cover, 2018).

Although the cave was documented in the 1970's, it was not until 2011 that systematic archaeological work began with a test pit (2011 and 2013) in order to evaluate the archaeological sequence and, since 2014, an excavation in extension (Figure 2). The first survey carried out in 2011 and 2013 uncovered antrophic occupations from the early Neolithic (5,320–4,365 cal BC), during the second half of the Second Millennium cal BC (1,430–1,130 cal

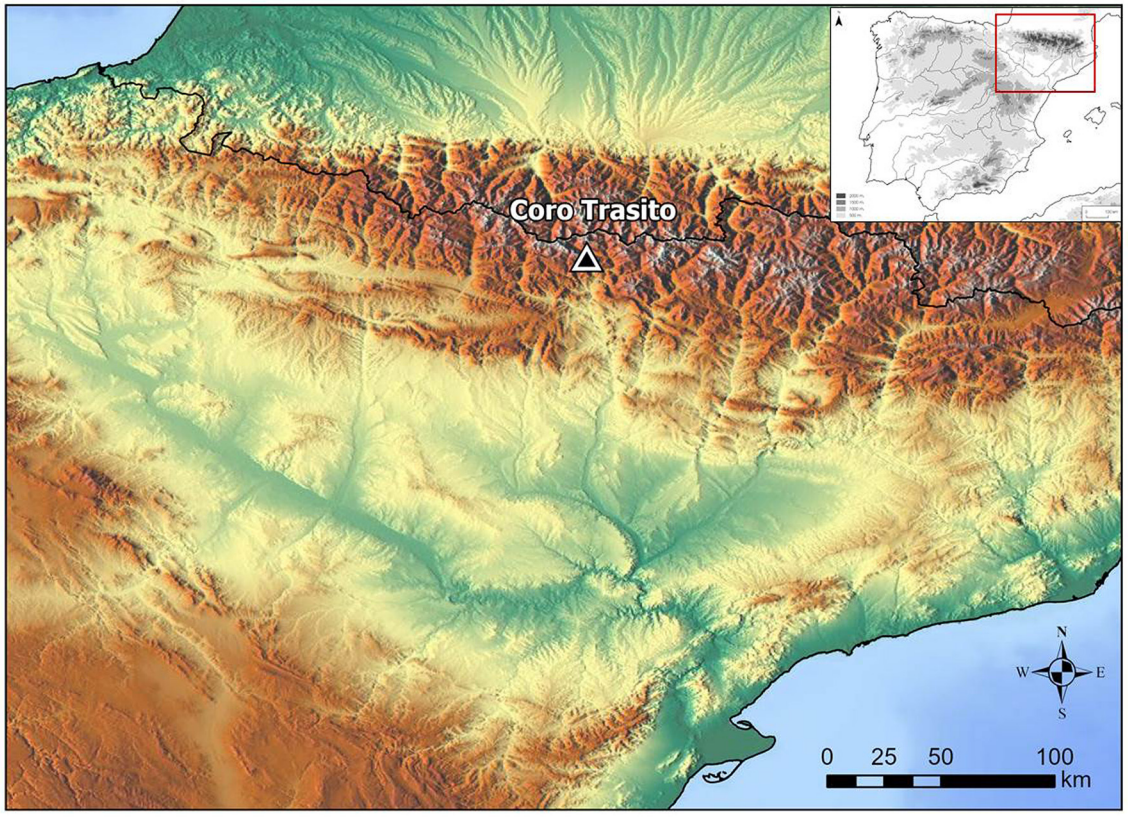

FIGURE 1
Location of Coro Trasito cave (Huesca, Spain).

BC) and, finally, to the Contemporary era (Clemente-Conte et al., 2014, 2016; Gassiot et al., 2018). Regarding Neolithic occupations three phases were identified dating from 5,300–5,000 cal BC, 4,990–4,885 cal BC, and 4,785–4,585 cal BC (Figure 3). The initial phase of cave occupation is characterized by its use as stable for animals. From c. 4,800 cal BC, the presence of domesticates and the use of space for storage in small pits, as well as for habitation and work area was documented (Clemente-Conte et al., 2020). The analysis of archaeological remains suggests the complexity of the occupation dynamics at the site. The predominance of domestic animals remains was recorded, highlighting pigs (*Sus domesticus*) and cattle (*Bos taurus*) in the early layers (Viñerta, 2015). Additionally, the consumption of dairy products is evidenced from the analysis of organic residues (Tarifa, 2019). Carpological remains of naked barley (*Hordeum vulgare var. nudum*) and naked wheat (*Triticum aestivum s.l./durum Desf./turgidum* L.) were recovered (Antolín et al., 2018). The presence of *Bromus* sp., *Polygonum convolvulus*, *Galium aparine*, and *Chenopodium* sp. has also been documented (Antolín et al., 2018). Pollen analysis reveals a high representation of cereals, suggesting the existence of nearby crop fields (Obea et al., 2021). Among the ceramic fragments recovered, both culinary and storage use have been identified (Díaz Bonilla et al., 2016). The presence of tools related to ceramic production indicates the carrying out of various artisanal activities at the site (Clemente-Conte et al., 2016). Furthermore, the presence of a wide range of tools such as grinding stones and sickles, along with storage pits, suggest that Coro Trasito could have functioned as a relatively stable occupation throughout most of the year, rather than being a specialized and seasonal site (Clemente-Conte et al., 2016, 2020; Clemente-Conte and Mazzucco, in press).

3 Materials and methods

3.1 Archaeozoological analysis

A total of 822 faunal remains corresponding to the Neolithic levels from Coro Trasito have been analyzed. Three hundred and twenty faunal remains belong to the occupations dated ca. 5,300–4,900 cal BC (N-I), and 502 faunal remains to those dated ca. 4,900–4,700 cal BC (N-II). In this study, only the remains that have been identified anatomically and taxonomically are presented (NISP_total = 395; NISP_N-I = 194; NISP_N-II = 206), focusing on domestic herds.

The bones were systematically classified both anatomically and taxonomically using the reference collection at the Laboratori d'Arqueozoologia of the Autonomous University of Barcelona (Spain), in addition to several reference manuals. For this study, the archaeozoological analysis has focused on the study of taxonomic representation frequencies and the estimation of the

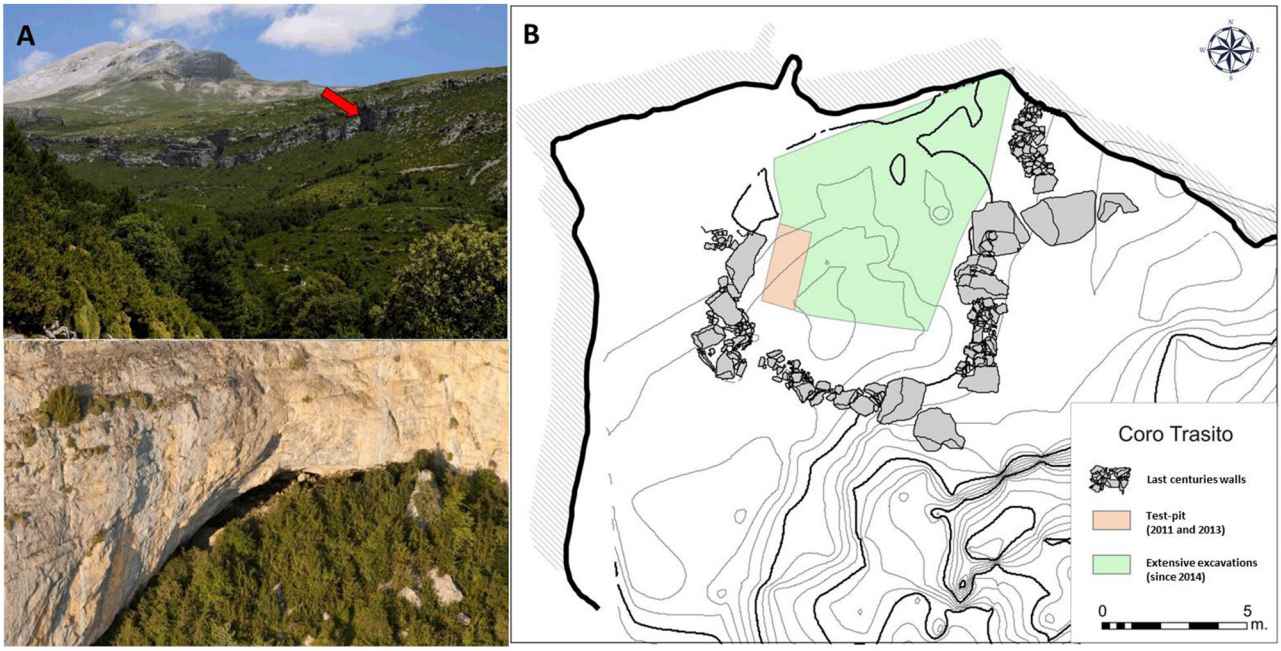

FIGURE 2
(A) Above: Image of the southern slope of Sierra de Tucas (Huesca, Spain). The arrow indicates Coro Trasito cave. Below: Entrance to Coro Trasito cave. **(B)** Plan view of Coro Trasito cave, showing the location of the 2011 and 2013 test-pit and the area of the extended excavation. The isocotes indicate every 20 cm.

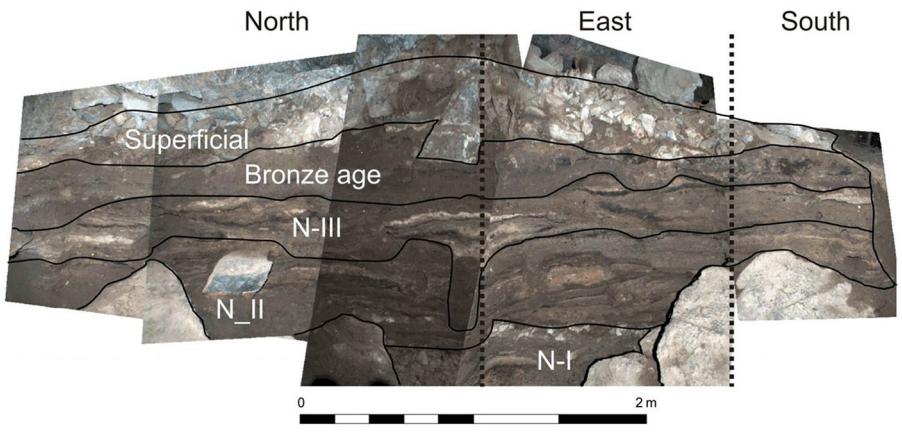

FIGURE 3
North, east and south profiles of the 2011–2013 test-pit of Coro Trasito cave (Huesca, Spain).

age of death. Quantitative assessment of the assemblages was based on the Number of Identified Specimens (NISP) and the Minimum Number of Individuals (MNI). The MNI was calculated by considering the estimated age, anatomical representation and laterality (Lyman, 1994). We estimate the age of the death using a combination of the estimation of stages of tooth wear (Grant, 1982; Payne, 1985, 1987; Jones, 2006; Lemoine et al., 2014), eruption sequences and epiphyseal fusion in postcranial elements (Silver, 1969; Barone, 1976; Amorosi, 1989; Zeder, 2006).

3.2 Carbon and nitrogen analysis

Twenty-one faunal individuals were selected from N-II for stable carbon and nitrogen isotope analysis in bulk collagen. We selected a range of herbivores [$n = 11$, including domestic (*Ovis aries, Capra hircus, Bos taurus*) and wild animals (*Capra pyrenaica, Capreolus capreolus*], omnivores ($n = 9$, *Sus domesticus, Ursus arctos*), and carnivores ($n = 1$, *Vulpes vulpes*). Samples for stable isotope analysis correspond to adult individuals previously determined through archaeozoological analyses (MNI and age

10.3389/fearc.2023.1309907

estimation). The samples included the diaphysis of long bones, maxilla, mandibular diastema and phalanx. Specimens were selected to represent individual animals by sampling the same-sided portion of a specific element. When this was not possible, different specific elements from different archaeological layers, the same level: N-II, were analyzed. The N-I could not be sampled due to its high fragmentation and the thermal alterations of remains resulting from the *fumier* levels.

Collagen extraction and stable isotope analysis were performed at the Laboratori d'Arqueozoologia (Department of Prehistory) and Unitat d'Antropologia Biològica (Department Animal Biology, Plant Biology, and Ecology) at the Autonomous University of Barcelona (Spain). Faunal bone samples were collected with a rotary drill and cleaned to remove contaminating materials. Collagen extraction followed a modified Longin (1971) method (Brown et al., 1988; Richards and Hedges, 1999; Craig et al., 2010). Collagen samples weighing 0.3 mg were subjected to analysis using a Thermo Flash 1,112 elemental analyzer (EA) coupled to a Thermo Delta V Advantage isotope ratio mass spectrometer (IRMS) with a Conflo III interface, at the Institute of Environmental Science and Technology (ICTA-UAB) (Spain). The average analytical error was <0.2‰ (1σ) for $\delta^{15}N$ and <0.1‰ (1σ) for $\delta^{13}C$ as determined from the duplicate analyses of $\delta^{13}C$ and $\delta^{15}N$. As a control, the international laboratory standard IAEA 600 (caffeine) was employed. For $\delta^{13}C$, the Vienna PeeDee Belemnite (V-PDB) was used, while air N_2 (AIR) served as the standard for $\delta^{15}N$. To assess the $\delta^{13}C$ values, one-way ANOVA test ($\alpha = 0.05$) was employed, preceded by the verification of normal distribution through the Shapiro–Wilk test for normality ($\alpha = 0.05$). Thus comparison between the $\delta^{15}N$ values was performed using the Kruskal–Wallis test ($\alpha = 0.05$). All statistical tests were performed using PAST 3.x (Hammer et al., 2001).

TABLE 1 Quantification of domestic species in N-I of Coro Trasito cave (Huesca, Spain).

Taxa	NISP	%NISP	MNI*	%MNI
Bos taurus	23	12.6	2 (2 indiv. +24)	9.1
Sus domesticus	17	9.3	2 (2 indiv. 18–21)	9.1
Ovis aries	3	1.7	3 (2 indiv. 18–24 1 indiv. 6–24)	13.6
Capra hircus	4	2.2	2 (2 indiv. 6–24)	9.1
Ovis/Capra	135	74.2	13 (10 indiv 0–3 3 indiv 6–24)	59.1

NISP, Number of Identified Specimens; MNI*, Minimum Number of Individuals with age of death (month).

TABLE 2 Quantification of domestic species in N-II of Coro Trasito cave (Huesca, Spain).

Taxa	NISP	%NISP	MNI*	%MNI
Bos taurus	8	4.4	3 (3 indiv. +24)	17.6
Sus domesticus	26	14.1	6 (6 indiv. 18–21)	35.3
Ovis aries	12	6.5	3 (2 indiv. 12–18 1 indiv. +24)	17.7
Capra hircus	2	1.1	2 (1 indiv. 12–18 1 indiv. +24)	11.7
Ovis/Capra	136	73.9	3 (1 indiv. 0–3 2 indiv. 6–24)	17.7

NISP, Number of Identified Specimens; MNI*, Minimum Number of Individuals with age of death (month).

4 Results

4.1 Archaeozoological analysis

The results of specific variability revealed a slight dominance of domesticates in the early level (N-I). The percentage of domesticates ranged from 93.8% (NISP = 182) in N-I to 89.3% (NISP = 184) in N-II. Wild species in N-I (6.2%, NISP = 12) were represented by *Cervus elephus* (NISP = 5, MNI = 1), *Capreolus capreolus* (NISP = 4, MNI = 1), *Sus scrofa* (NISP = 2, MNI = 1), and *Oryctolagus cuniculus* (NISP = 2, MNI = 1). In N-II (10.7%, NISP = 22) wild species were represented by *Cervus elephus* (NISP = 10, MNI = 1), *Capreolus capreolus* (NISP = 2, MNI = 2), *Capra pyrenaica* (NISP = 2, MNI = 1), *Sus scrofa* (NISP = 1, MNI = 1), *Oryctolagus cuniculus* (NISP = 5, MNI = 1), *Vulpes vulpes* (NISP = 1, MNI = 1), and *Ursus arctos* (NISP = 1, MNI = 1). The results of slaughtering patterns for wild individuals showed specimens over 24 months old.

The composition of the herds was rather mixed in both levels. In N-I, the herds would have been composed of caprines (o/c NISP = 135, MNI = 13; goat NISP = 4, MNI = 2; sheep NISP = 3, MNI = 3), cattle (NISP = 23, MNI = 2), and pig (NISP = 17, MNI = 2) (Table 1). And in N-II, the herds seemed to be composed mainly of caprines (o/c NISP = 136, MNI = 3; sheep NISP = 12, MNI = 3; goat NISP = 2, MNI = 2), pig (NISP = 26, MNI = 6), and cattle (NISP = 8, MNI = 3) (Table 2). If the representation frequencies of domesticates are compared in N-I and N-II, an increase in the relative number of pig remains to cattle can be observed, as well as a higher number of sheep remains compared to goats in N-II. The minimum number of individuals (MNI) for each species in the Neolithic levels is different (MNI_total_N-I = 22; MNI_total_N-II = 17). In N-II, pigs show the highest increase in MNI among domesticates (N-I, MNI_pig = 2; N-II, MNI_pig = 6). Differences in the level of fragmentation within the faunal assemblages could explain the variation in the MNI between N-I and N-II for the *Ovis/Capra*.

Slaughtering patterns were analyzed per taxon. Pigs were killed between 18 and 21 months old; and cattle killed at more than 24 months old. For both levels, sheep and goats presented a rather similar pattern, were also primarily killed at between 6 and 24 months of age in N-I and between 12 and 24 months of age. In the N-I a large proportion of newborn and infantile caprines (41% of MNI) were also recovered (0–3 months of age). This proportion of neonates decreases in N-II (6% of MNI).

Neonate and infantile individuals <3 months of age have not been able to be classified into specific categories due to the high degree of fragmentation of the remains and, in some cases, the absence of identifying features of the species.

4.2 Carbon and nitrogen stable isotopes

Of the 21 samples analyzed, 19 samples exhibited satisfactory C% and N% ranged from 22 to 45% and 11 to 16%, respectively, with C:N ratios ranging from 3.2 to 3.6 and falling within the values proposed by DeNiro (1985), Ambrose (1990), and Van Klinken (1999) for preserved collagen. Although attempted repeatedly, collagen could not be extracted from samples 13 and 14. Data from the stable isotope analysis can be found in Table 3 and Figure 4.

The $\delta^{13}C$ values of the individuals analyzed in Coro Trasito ranged from −20.99 to −18.57‰, average $\delta^{13}C = -20.13$‰ ($n = 19$). The $\delta^{15}N$ values ranged from 6.13 to 2.80‰, average $\delta^{15}N = 4.13$‰ ($n = 19$).

The average $\delta^{13}C$ values of wild herbivores was -20.11 ± 0.17‰ ($n = 3$). When the *Ursus arctos* sample was included with wild herbivores, although it is an omnivorous species its diet is mainly herbivorous, the average $\delta^{13}C$ values for the wild herbivorous-omnivorous species was -20.08 ± 0.15 ‰ ($n = 4$). The average $\delta^{13}C$ values of domestic herbivores was -20.18 ± 0.38‰ ($n = 8$) (Figure 4). Statistical tests showed that there are no significant differences in $\delta^{13}C$ between wild and domestic herbivores ($p > 0.6$) and wild herbivores and domestic herds ($p > 0.5$). Likewise, there are no significant differences in $\delta^{13}C$ between domestic herds ($p > 0.8$).

The average $\delta^{15}N$ values of wild herbivores was 3.60 ± 0.11‰ ($n = 3$), and 3.61 ± 0.09‰ with *Ursus arctos* ($n = 4$). The average $\delta^{15}N$ values of domestic herbivores was 4.28 ± 1.08‰ ($n = 8$). Statistical tests showed that there are no significant differences in $\delta^{15}N$ between wild and domestic herbivores ($p > 0.26$) and wild herbivores and domestic herds ($p > 0.27$). Among herds, only the $\delta^{15}N$ values were significantly different between cattle and goat ($p = 0.008$). Cattle were ^{15}N-enriched by 2.3‰ compared to the goat. Although there are no significant differences between wild herbivores and herds, wild herbivores were ^{15}N-enriched by 0.37‰ compared to pigs, 0.58‰ compared to sheep and 1.64‰ compared to cattle. Surprisingly, goats have a depletion of −0.67‰ compared to wild herbivores (Figure 5).

Carnivores were only represented by one specimen (*Vulpes vulpes*). The $\delta^{13}C$ value was −18.57‰, and the $\delta^{15}N$ value was 5.94‰.

5 Discussion

The results obtained from archaeozoological and isotopic analysis of Coro Trasito emphasizes the role of domestic animals in the highland areas and the complexity of the Neolithisation process in the central Pyrenees, where livestock and agriculture may have played roles different from those traditionally assumed for medium and high mountain areas (Antolín et al., 2018; Tornero et al., 2018; Sierra et al., 2019; Alt et al., 2020; Gassiot et al., 2021, 2022; Palomo et al., 2022). The importance of domesticates in early Neolithic layers of Coro Trasito is reinforced by the presence of the four main domestic species and a diversified husbandry strategy. The exploitation of caprines played a central role in the husbandry practices. Sheep flocks acquired progressively greater economic importance, as demonstrated by their increase during the N-II. The relative abundance of animal remains from neonate and infantile age, in N-I, could indicate the use of the cave as a stabling and/or breeding area. Martín et al. (2016) clarify that herders usually prefer to separate pregnant females from the rest of the herd to minimize risks during calving periods. In addition, excavations carried out in Coro Trasito have documented clearly stratified deposits of *fumier* (Clemente-Conte et al., 2014, 2016; Gassiot et al., 2018). Additionally, the presence of remains of infantile animals in N-I and N-II could also be related to dairy exploitation (Helmer, 1992). The analysis of the pottery waste from Coro Trasito shows how some of the Neolithic containers were used for dairy products (Tarifa, 2019). Furthermore, the documentation at Coro Trasito of the agriculture practices (Antolín and Jacomet, 2015; Antolín et al., 2018), supports the full development of practices such as agriculture and livestock in high mountain areas during the early Neolithic, leaving behind the character of traditionally granted marginal territory.

The breeding and maintenance of four different animal species, with diverse dietary requirements and reproductive behaviors, demonstrates an adaptation of herds to the cave environment. The wide availability of essential natural resources, including water and a wide variety of animal and plant resources, present in the various ecosystems (river valleys and forests) in the area, allowed the human communities that lived in Coro Trasito cave to exploit various ecosystems in the immediate surroundings. This is demonstrated by the archaeozoological results with the diversity of wild and domestic species exploited and the results of the carbon and nitrogen stable isotopes analyzed in bone collagen. The herbivore $\delta^{13}C$ values suggest a terrestrial environment dominated by open C3-plants (De Niro and Epstein, 1978; O'Leary, 1988). The low variation and little dispersion in the $\delta^{13}C$ values of herbivores and omnivores (amplitude of 1.67‰) and the non-existence of significant differences between the specimens analyzed, could indicate that the feeding areas of the Coro Trasito herds are similar between them.

The $\delta^{15}N$ values increase due to arid conditions or vary depending on soil type and manuring effect (Ambrose and Norr, 1993; Handley et al., 1999). The $\delta^{15}N$ values documented in wild herbivores are low and very little variable compared to sheep, pigs and cattle herds. Goat herds have lower $\delta^{15}N$ values than wild herbivores. The low $\delta^{15}N$ values in the goats may indicate grazing in an environment less impacted by humans, for example on soils that had not been used for agricultural practices or areas with less aridity.

In contrast, sheep have a different isotopic signature than goats. According to studies by Hodgson et al. (1991) and Dumont (1997), sheep are more readily including non-herbaceous plants into their diet. But Müldner et al. (2014) suggest that incorporating herbaceous or non-herbaceous plants into their diet seldom leads to discernible isotopic differences between the species in temperate C_3 environments. Three hypotheses could potentially account for the

10.3389/fearc.2023.1309907

TABLE 3 Results from isotopic analysis of faunal samples from level N-II of Coro Trasito cave (Huesca, Spain).

Specimen ID	Layer	Taxon	Element	Laterality	%C	%N	δ13C (‰)	δ15N (‰)	C:N
1	3007	*Ovis aries*	Radius	Right	37.69	13.71	−20.07	3.86	3.2
3	3005	*Ovis aries*	Tibia	Right	38.76	14.08	−20.23	3.93	3.2
12	3006	*Ovis aries*	Humerus	Left	39.66	14.15	−20.78	4.78	3.3
2	N-II	*Capra hircus*	Radius	Left	37.42	13.57	−19.96	2.80	3.2
4	3006	*Capra hircus*	Mandible	Right	37.00	13.36	−20.00	3.08	3.2
5	N-II	*Bos taurus*	First phalanx	Left	37.51	13.58	−20.73	4.62	3.2
6	3005	*Bos taurus*	Radius	Left	37.79	13.66	−19.86	5.01	3.2
7	3006	*Bos taurus*	Metacarpus	Right	36.36	13.23	−19.81	6.13	3.2
8	N-II	*Ursus arctos*	Maxilla	Right	40.64	14.70	−20.00	3.63	3.2
9	3004	*Capreolus capreolus*	Humerus	Left	37.08	13.43	−20.04	3.61	3.2
10	3004	*Capreolus capreolus*	Humerus	Left	33.01	11.92	−19.97	3.71	3.2
11	3006	*Capra pyrenaica*	Humerus	Right	32.37	11.69	−20.30	3.49	3.2
13	3007	*Sus domesticus*	Scapula	Left	-	-	-	-	-
14	3004	*Sus domesticus*	Second phalanx	Right	-	-	-	-	-
15	3003	*Sus domesticus*	Metacarpus	Left	40.73	14.76	−19.91	4.97	3.2
16	N-II	*Sus domesticus*	First phalanx	Right	40.67	14.59	−19.32	2.85	3.2
17	3006	*Sus domesticus*	Maxilla	Left	40.26	14.49	−20.64	4.34	3.2
18	3005	*Sus domesticus*	Metatarsus	Left	40.37	14.67	−20.40	3.74	3.2
19	3003	*Sus domesticus*	Metacarpus	Left	38.79	14.11	−20.99	3.65	3.2
20	N-II	*Sus domesticus*	Humerus	Left	39.66	14.29	−20.80	4.32	3.2
21	3007	*Vulpes vulpes*	Fibula	Left	42.97	15.65	−18.57	5.94	3.2

$\delta^{15}N$ values observed in the sheep of Coro Trasito. Considering the significant presence of neonate and infantile individuals recovered in Coro Trasito cave, the animal feeding practices could play an important role in ensuring the nutritional wellbeing of the mother, which is essential for the survival of the lambs (Mellor and Stafford, 2004). It has been documented that the cereals were manipulated inside or in close proximity to the cave (Antolín et al., 2018; Obea et al., 2021), which could indicate the consumption of agricultural remains by the flocks. The impact of animal dung on plant $\delta^{15}N$ values varies significantly and is influenced by factors such as the manuring rate and the type of fertilizer used (Fraser et al., 2011; Szpak, 2014). Firstly, $\delta^{15}N$ values for Coro Trasito sheep could reflect the consumption of agricultural surpluses, such as crop stubble. Secondly, the $\delta^{15}N$ values could indicate that the sheep flocks had the opportunity to graze in the manured fields. Thirdly, the enrichment of $\delta^{15}N$ values could be due to feeding in a closed place such as a stable. In Coro Trasito, the fumier levels and the presence of neonates inside the cave have been interpreted as the cave serving as a stable for caprines (Viñerta and Saña, 2019; Clemente-Conte et al., 2020).

The cattle in the analyzed sample exhibit the highest $\delta^{15}N$ values. This enrichment in $\delta^{15}N$ may be attributed, similar to sheep, to factors like access to cultivated fields or the provision of surplus crops as forage. Furthermore, Bogaard et al. (2007, 2013) document that grains contain higher values of $\delta^{15}N$ than manured cereal straws. Unfortunately, due to the extensive fragmentation of faunal remains, it has been impossible to conduct analyses on bone pathologies in the extremities of the studied cattle individuals. These analyses would have been useful to characterize tasks related to activities such as field maintenance. The archaeobotanical record of Coro Trasito suggests the presence of agricultural practices in the vicinity of the cave during the Neolithic period (Clemente-Conte et al., 2016; Antolín et al., 2018; Obea et al., 2021). The abundance of cereals and the existence of adventitious plants in an area previously densely forested imply the presence of small-scale crop fields near the cave (Clemente-Conte et al., 2016; Obea et al., 2021). Several lines of evidence support this hypothesis, including high pollen counts from both cereals and adventitious plants, the discovery of straw from both free-threshing and non-free-threshing cereals, and the carpological record of cereals at various stages of processing for consumption, indicating that cereals were manipulated inside or in close proximity to the cave (Antolín et al., 2018; Obea et al., 2021). Additionally, the discovery of multiple storage pits inside the cave indicates that the storage of plant products, such as cereals, might

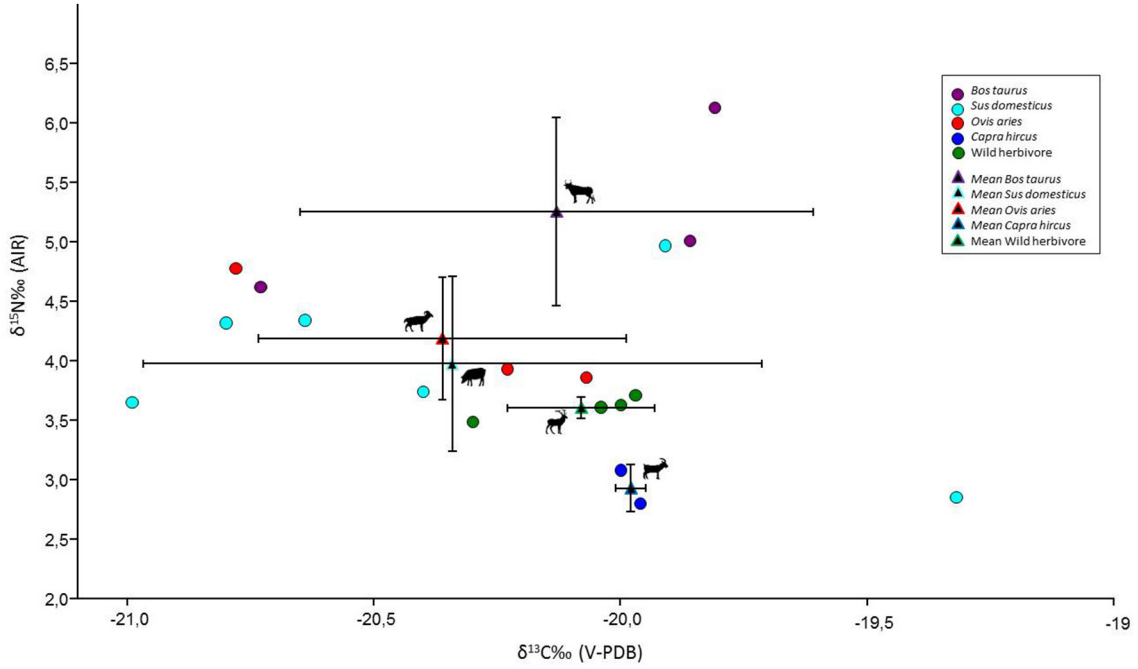

FIGURE 4
Bone collagen $\delta^{13}C$ and $\delta^{15}N$ values compared to the mean $\delta^{13}C$ and $\delta^{15}N$ values $\pm$ 1σ s.d for each taxon from the faunal remains recovered at level N-II of Coro Trasito cave (Huesca, Spain).

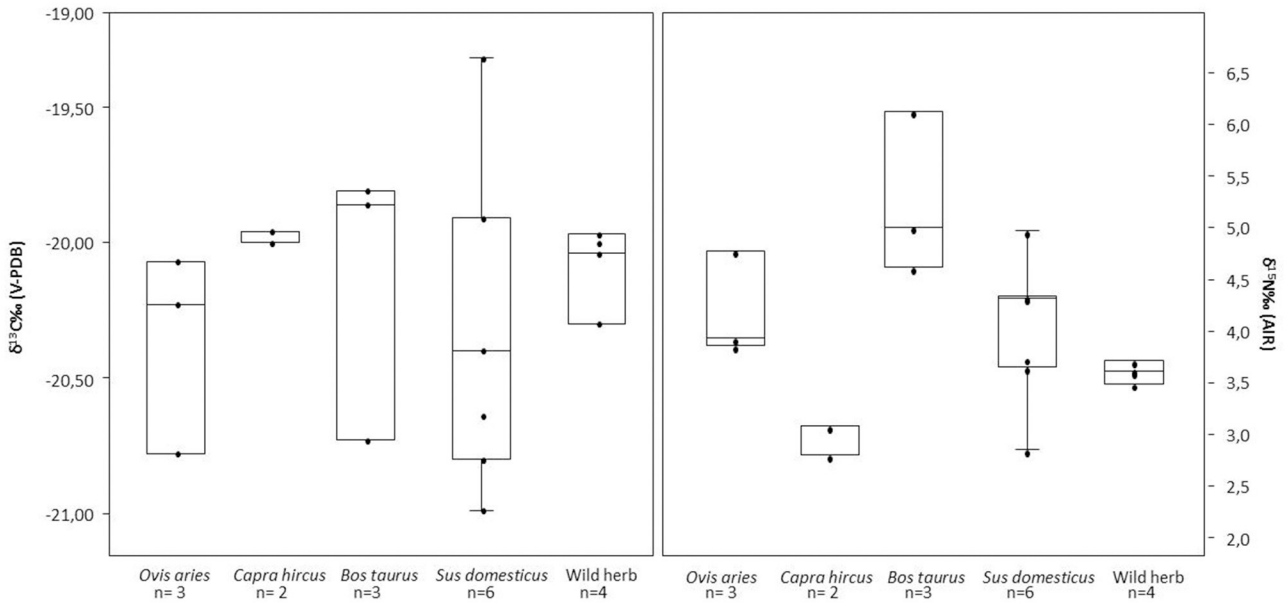

FIGURE 5
Box plot $\delta^{13}C$ and $\delta^{15}N$ values from faunal remains recovered at level N-II of Coro Trasito cave (Huesca, Spain).

have played a significant role in the subsistence strategies at Coro Trasito (Gassiot et al., 2018). Lithic tools were also recovered that show the processing of the cereal, both in harvesting and grinding (Clemente-Conte et al., 2016).

Finally, the $\delta^{13}C$ values of the pigs present the broadest range of variation compared to the other specimens analyzed. This variability in $\delta^{13}C$ values suggests access to a broader range of plant resources compared to the other flocks. This could imply that they were free to roam in forested environments in addition to the use of the same landscape areas for grazing. Furthermore, the $\delta^{15}N$ values indicate that pigs primarily consumed plant-based products, with values close to wild herbivores, although also of sheep. The

variability in $\delta^{15}N$ values could be explained by access to products as by-products of crop production, such as cereals and/or legumes. Alternatively, this variability could be related to the variation in the amount of animal protein ingested (Hamilton and Thomas, 2012). For example, the pigs' diet could have included worms, insects, or small animals, as well as human food waste such as garbage or the discarding of animal remains from butchery activities. Similar interpretations have been proposed for prehistoric pigs that were potentially raised within extensive herd management systems, characterized by semi-free to free-range regimes with plant-based diets for the Central Pyrenees (Villalba-Mouco et al., 2018) and Northeast of the Iberian Peninsula (Navarrete et al., 2017). In addition, the mortality profiles documented in Coro Trasito, where pigs are slaughtered at around 18 and 21 months of age, closely resemble those seen in traditional agricultural societies with extensive systems (Hadjikoumis, 2012).

The increase in MNI of pigs in N-II could suggest a greater interest in pig production. The decrease in subadult caprine individuals and the increase in infantile individuals may indicate greater use of derived products such as milk. Pigs could cover the food needs that until now had been met by caprines. This change in the composition of flocks during the Neolithic has also been documented in the Can Sadurní cave (Saña et al., 2015). The significant increase in the number of pig specimens and access to a broader range of plant resources documented by stable isotope analysis may be related to the adaptability of this species to different environmental conditions. It is important to note that pigs have a high reproduction rate and can adapt to different husbandry strategies, making them a versatile source of meat and other products such as fat or marrow (Crosby, 1986). Furthermore, the use of other pig by-products, such as fat, has been recorded in Coro Trasito. Tarifa (2019) reports a range of n-alkanoic acids (fatty acids) that are attributable to a source of non-ruminant adipose fat and related to pig fat in 7 of the 19 ceramic containers analyzed.

Finally, the presence of the four main domestic species is documented in Coro Trasito and the results of MNI analysis show that the size of each flock would be composed of a few individuals of each species. This type of flocks with few individuals is also documented in the Cova del Sardo (Navarrete and Saña, 2013) and Cova Colomera (Martín and Oms, 2021) sites.

6 Conclusion

The study of highland areas such as the mountainous zone of the Pyrenees has brought new and important data about the dynamics of neolithisation process, particularly focusing on economic practices. Husbandry practices played an essential role in the economic strategies of Coro Trasito during the early Neolithic.

The presence of diverse herd foddering strategies within husbandry practices characterized by taxonomic diversity and multipurpose exploitation suggests that during the Neolithic, Coro Trasito played a more complex role than sheepfold. The increase of MNI pig in N-II shows the importance of this specie in meat production during the Neolithic. Moreover, the results obtained demonstrated the rapid adaptation of herds of Coro Trasito to the region, flocks with diverse dietary needs and reproductive behaviors. The combination of archaeozoology and isotopic results and archaeological context suggests that Coro Trasito was not primarily a site for short-term occupations.

Furthermore, the presence of transformation activities related to dairy and fat products, and the existence of storage structures within the cave indicates the complexity of neolithisation processes in the central Pyrenees and how these areas were quickly integrated into a broader economic system.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

VN: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Writing—original draft, Writing—review & editing. AV: Conceptualization, Investigation, Methodology, Resources, Writing—review & editing, Formal analysis. IC-C: Conceptualization, Funding acquisition, Investigation, Resources, Writing—review & editing. EG: Conceptualization, Funding acquisition, Investigation, Resources, Writing—review & editing. JR: Conceptualization, Investigation, Resources, Writing—review & editing. MS: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Resources, Writing—review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This research was supported by the Ministerio de Economía y Competitividad, Spain: HAR2017-88304-P (MS), PID2020-115715GB-I00 (MS), PID2020-115205GB-100 (IC-C and EG), and ICREA Academia by MS.

Acknowledgments

The authors thank reviewers for their valuable comments on this article. The authors thank Dr. Pau Comes (ICTA-UAB) for his help with the IRMS data. Research by VN was supported by the Research Project CEECIND/03351/2020 (Fundação para a Ciência e a Tecnologia, Portugal). Part of this research has been carried out in 2021 SGR 00527 (EarlyFoods).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Alt, K. W., Tejedor Rodrígues, C., Nicklisch, N., Roth, D., Szécsényi Nagy, A., Knipper, C., et al. (2020). A massacre of early Neolithic farmers in the high Pyrenees at Els Trocs, Spain. *Sci. Rep.* 10, 21–31. doi: 10.1038/s41598-020-58483-9

Ambrose, S. H. (1990). Preparation and characterization of bone and tooth collagen for isotopic analysis. *J. Archaeol. Sci.* 17, 431–451. doi: 10.1016/0305-4403(90)90007-R

Ambrose, S. H., and Norr, L. (1993). "Experimental evidence for the relationship of the carbon isotope ratios of whole diet and dietary protein to those of bone collagen and carbonate. Prehistoric Human Bone-Archaeology at the Molecular Level". in *Prehistoric Human Bone*, ed J. B Lambert (Springer, Berlin), 1–37.

Amorosi, T. (1989). "A postcranial guide to domestic neo-natal and juvenile mammals: the identification and ageing of old world species (No. 533-534)," in *British Archaeological Reports International Series 1533*, ed B. A. R (Oxford: Archaeopress).

Antolín, F., and Jacomet, S. (2015). Wild fruit use among early farmers in the Neolithic (5400–2300 cal. BC) in the north-east of the Iberian Peninsula: an intensive practice? *Veg. Hist. Archaeobot.* 24, 19–33. doi: 10.1007/s00334-014-0483-x

Antolín, F., Navarrete, V., Saña, M., Viñerta, A., and Gassiot, E. (2018). Herders in the mountains and farmers in the plains? A comparative evaluation of the archaeobiological record from Neolithic sites in the eastern Iberian Pyrenees and the southern lower lands. *Quat. Int.* 484, 75–93. doi: 10.1016/j.quaint.2017.05.056

Antolín, F., Steiner, B. L., Akeret, Ö., Brombacher, C., Kühn, M., and Vandorpe, P. (2017). Studying the preservation of plant macroremains from waterlogged archaeological deposits for an assessment of layer taphonomy. *Rev. Palaeobot. Palynol.* 246, 120–145. doi: 10.1016/j.revpalbo.2017.06.010

Balasse, M., Evin, A., Tornero, C., Radu, V., Fiorillo, D., Popovici, D., et al. (2016). Wild, domestic and feral? Investigating the status of suids in the Romanian Gumelnita (5th mil. cal BC) with biogeochemistry and geometric morphometrics. *J. Anthropol. Archaeol.* 42, 27–36. doi: 10.1016/j.jaa.2016.02.002

Barone, R. (1976). Anatomie comparée des mammifères domestiques. *Ostéologie* 1, 179–185.

Bogaard, A., Fraser, R., Heaton, T. H., Wallace, M., Vaiglova, P., Charles, M., et al. (2013). Crop manuring and intensive land management by Europe's first farmers. *Proc. Natl. Acad. Sci.* 110, 12589–12594. doi: 10.1073/pnas.1305918110

Bogaard, A., Heaton, T. H. E., Poulton, P., and Merbach, I. (2007). The impact of manuring on nitrogen isotope ratios in cereals: archaeological implications for reconstruction of diet and crop management practices. *J. Archaeol. Sci.* 34, 335–343. doi: 10.1016/j.jas.2006.04.009

Brown, T. A., Nelson, E. E., Vogel, S. J., and Southon, J. R. (1988). Improved collagen extraction by modified Longin method. *Radiocarbon* 30, 171–177. doi: 10.1017/S0033822200044118

Clemente-Conte, I., Gassiot Ballbe, E., Rey Lanaspa, J., Antolín, F., Obea, L., Viñerta, A., et al. (2016). "Cueva de Coro Trasito (Tella-Sin, Huesca): Un asentamiento pastoril en el Pirineo central con ocupaciones del Neolítico antiguo y del Bronce reciente," in *I Congreso de Arqueologia y Patrimonio Aragones*, eds J. I. Lorenzo Lizalde and J. M Rodanés Vicente (Aragón: Colegio Oficial de Doctores y Licenciados en Filosofía y Letras y en Ciencias de Aragón), 71–79.

Clemente-Conte, I., Gassiot Ballbè, E., Rey Lanaspa, J., Mazzucco, N., and Obea Gómez, L. (2014). "Cort o Transito- Coro trasito- o corral de tránsito: una cueva pastoril del Neolítico Antiguo en el corazón de Sobrarbe," in *Sobrarbe antes de Sobrarbe: pinceladas de historia de los Pirineos*, eds. I. Clemente, E. Gassiot, and R. Rey (Aragón: Centro de Estudios de Sobrarbe (CES), Instituto de estudios Altoaragoneses), 11–31.

Clemente-Conte, I., Gassiot, E., and Rey, J. (2020). Arqueología y Prehistoria en Sobrarbe (2009-2019): una década de colaboraciones. *Sobrarbe Centro de Estudios de Sobrarbe (Boltaña)* 18, 9–92.

Clemente-Conte, I., and Mazzucco, N. (in press). *Aproximación traceológica a la ocupación humana en el Pirineo oscense: los casos de Coro Trasito, Espluga de La Puyascada y Chaves*, eds J. Ruiz Fernández, R. Luelmo Lautenschlaeger, S. Pérez Díaz, C. García Hernández, J. A. López Sáez, F. Alba Sánchez, D. Gallinar, M. Ruiz Alonso, A. García, and B. González Díaz. *Socio-ecología, arqueología y geohistoria de los paisajes de montaña ibéricos: una mirada multidisciplinar* (Oviedo: Servicio de Publicaciones de la Universidad de Oviedo).

CORINE Land Cover (2018). *Coordination of Information of the Environment*. Available online at: https://www.ign.es/web/resources/docs/IGNCnig/actividades/OBS/Programa_Marco_Copernicus_User_Uptake/9_Corine_Land_Cover (accessed October 10, 2023).

Craig, O. E., Biazzo, M., Colonese, A. C., Di Giuseppe, Z., Martinez-Labarga, C., Lo Vetro, D., et al. (2010). Stable isotope analysis of Late Upper Palaeolithic human and faunal remains from Grotta del Romito (Cosenza), Italy. *J. Archaeol. Sci.* 37, 2504–2512. doi: 10.1016/j.jas.2010.05.010

Crosby, A. W. (1986). *Ecological Imperialism: The Biological Expansion of Europe 900–1900*. Cambridge: Cambridge University.

De Niro, M. J., and Epstein, S. (1978). Influence of diet on the distribution of carbon isotopes in animals. *Geochim. Cosmochim. Acta* 42, 495–506. doi: 10.1016/0016-7037(78)90199-0

DeNiro, M. J. (1985). Postmortem preservation and alteration of *in vivo* bone collagen isotope ratios in relation to palaeodietary reconstruction. *Nature* 317, 806–809. doi: 10.1038/317806a0

Díaz Bonilla, S., Obea, L., Gassiot Ballbe, E., Clemente, I., García Casas, D., Rodríguez-Anton, D., et al. (2016). Arqueología y patrimonio en la alta montaña. Resultados de las prospecciones en el valle de Goriz (Fanlo, Huesca). *I Congreso de Arqueología y Patrimonio Aragonés* 609–616.

Dumont, B. (1997). Diet preferences of herbivores at pasture. *Annal. Zootech.* 46–2, 105–116. doi: 10.1051/animres:19970201

Ebersbach, R. (2010). "My farmland - our livestock. Forms of subsistence farming and forms of sharing in peasant communities," in *The Principle of Sharing. Segregation and Construction of Social Identities at the Transition from Foraging to Farming. Proceedings of a Symposium Held on 29th-31st January 2009 at the Albert-ludwigs-university of Freiburg*, eds. M. Benz (Berlín: Exoriente), 159–182.

Fraser, R. A., Bogaard, A., Heaton, T., Charles, M., Jones, G., Christensen, B. T., et al. (2011). Manuring and stable nitrogen isotope ratios in cereals and pulses: towards a new archaeobotanical approach to the inference of land use and dietary practices. *J. Archaeol. Sci.* 38, 2790–2804. doi: 10.1016/j.jas.2011.06.024

Gassiot, E., Mazzucco, N., Díaz-Bonilla, S., Obea-Gómez, L., Rey-Lanaspa, J., Barba-Pérez, M., et al. (2021). Mountains, herds and crops: notes on new evidence from the early neolithic in the Southern Central Pyrenees. *Open Archaeol.* 7, 1015–1034. doi: 10.1515/opar-2020-0193

Gassiot, E., Rey Lanaspa, J., Clemente Conte, I., Obea Gómez, L., Díaz Bonilla, S., Quesada Carrasco, M., et al. (2018). "Estructuras de almacenaje prehistóricas en la Cueva redil de Coro Trasito (Tella-Sin, Huesca)," in *II Congreso CAPA*, eds. J. I. Lorenzo and J. M. Rodanés (Arqueología Patrimonio Aragonés. Colegio Oficial de Doctores y Licenciados en Filosofía y Letras y en Ciencias de Aragón), 41–48.

Gassiot, E., Rodríguez Antón, D., Burjachs, F., Antolín, F., and Ballesteros, A. (2012). Poblamiento, explotación y entorno natural de los estadios alpinos y subalpinos del Pirineo central durante la primera mitad del Holoceno. *Cuaternario Geomorfol.* 26, 26–42.

Gassiot, E., Salvador-Baiges, G., Clemente-Conte, I., Díaz-Bonilla, S., Garcia-Casas, D., Mazzucco, N., et al. (2022). "Early Neolithic farming activities in high mountain landscapes of the Pyrenees: simulating changes in settlement patterns," in *Simulating Transitions to Agriculture in Prehistory*, eds. S. Pardo-Grodó and S. Bergin (Cham: Springer International Publishing), 139–164.

Grant, A. (1982). "The use of tooth wear as a guide to the age of domestic animals," in *Ageing and Sexing Animal Bones from Archaeological Sites*, eds. B. Wilson, C. Grigson, and S. Payne (Oxford: British Archaeological Reports. International Series 1109, Archaeopress), 91–108.

Hadjikoumis, A. (2012). Traditional pig herding practices in Southwest Iberia: questions of scale and zooarchaeological implications. *J. Anthropol. Archaeol.* 31, 353–364. doi: 10.1016/j.jaa.2012.02.002

Hamilton, J., and Thomas, R. (2012). Pannage, pulses and pigs: isotopic and zooarchaeological evidence for changing pig management practices in later medieval England. *Med. Archaeol.* 56, 234–259. doi: 10.1179/0076609712Z.00000 00008

Hammer, Ø., Harper, D., and Ryan, P. D. (2001). PAST: Paleontological Statistics Software Package for education and data analysis. *Palaeontol. Electron.* 4, 1–9.

Handley, L. L., Austin, A. T., Stewart, G. R., Robinson, D., Scrimgeour, C. M., Raven, J. A., et al. (1999). The 15N natural abundances (δ15N) of ecosystem samples reflects measures of water availability. *Aust. J. Plant Physiol.* 26, 185–199. doi: 10.1071/PP98146

Helmer, D. (1992). *La domestication des animaux par les hommes prehistoriques*. Paris: Editions Masson.

Hodgson, J., Forbes, T. D. A., Armstrong, R. H., Beattie, M. M., and Hunter, E. A. (1991). Comparative studies of the ingestive behaviour and herbage intake of sheep and cattle grazing indigenous hill plant communities. *J. Appl. Ecol.* 28, 205–227. doi: 10.2307/2404126

Jones, G. G. (2006). "Tooth eruption and wear observed in live sheep from Butser Hill, the Cotswold Farm Park and five farms in the Pentland Hills, UK," in *Recent Advances in Ageing and Sexing Animal Bones. Proceedings of the 9th Icaz Conference, Durham 2002*, ed. D. Ruscillo (Oxford: Oxbow Books), 155–178.

Lancelotti, C., Balbo, A. L., Madella, M., Iriarte, E., Rojo-Guerra, M., Royo, J. I., et al. (2014). The missing crop: investigating the use of grasses at Els Trocs, a Neolithic cave site in the Pyrenees (1564 m asl). *J. Archaeol. Sci.* 42, 456–466. doi: 10.1016/j.jas.2013.11.021

Lemoine, X., Zeder, M. A., Bishop, K., and Rufolo, S. (2014). A new system for computing dentition-based age profiles in Sus scrofa. *J. Archaeol. Sci.* 47–1, 179–193. doi: 10.1016/j.jas.2014.04.002

Longin, R. (1971). New method of collagen extraction for radiocarbon dating. *Nature* 230, 241–242. doi: 10.1038/230241a0

Lyman, R. L. (1994). Quantitative units and terminology in zooarchaeology. *Am. Antiq.* 59–1, 36–71. doi: 10.2307/3085500

Madgwick, R., Mulville, J., and Stevens, R. E. (2012). Diversity in foddering strategy and herd management in late Bronze Age Britain: an isotopic investigation of pigs and other fauna from two midden sites. *Environ. Archaeol.* 17–2, 126–140. doi: 10.1179/1461410312Z.00000000011

MAPAMA (1996). *Clasificación climática de J. Papadakis. Mapa de Caraterización agroclimática del Ministerio de Agricultura, Pesca y Alimentación, España*. Available online at: https://wms.mapama.gob.es/sig/Agricultura/CaractAgroClimaticas/wms.aspx? (accessed October 10, 2023).

Martín, A., Edo, M., Tarrús, J., and Clop, X. (2010). Le Neolithique ancien de Catalogne (VIe-premiere moitie du Ve millenaire av. J.-c.). Les sequences chronoculturelles. *Societe Prehistorique française* LI, 197–214.

Martín, P., García-Gonzalez, R., Nadal, J., and Verges, J. M. (2016). Perinatal ovicaprine remains and evidence of shepherding activities in early Holocene enclosure caves: el Mirador (Sierra de Atapuerca, Spain). *Quat. Int.* 414, 316–329. doi: 10.1016/j.quaint.2015.08.024

Martín, P., and Oms, F. X. (2021). Early neolithic husbandry in the pre-pyrenean area. The management of herds at the cova colomera (Serra del Montsec, Spain) and its implications for the early occupation of the region. *Open Archaeol.* 7–1, 1216–1234. doi: 10.1515/opar-2020-0190

Martin, P., Tornero, C., García, D. C. S., and Vergès, J. M. (2021). Early sheep herd management in the inland of the Iberian Peninsula: results of the incremental isotopic analyses of dental remains from El Mirador cave (Sierra de Atapuerca, Spain). *Archaeol. Anthropol. Sci.* 13–6, 99. doi: 10.1007/s12520-021-01355-8

Mellor, D. J., and Stafford, K. J. (2004). Animal welfare implications of neonatal mortality and morbidity in farm animals. *Vet. J.* 168–2, 118–133 doi: 10.1016/j.tvjl.2003.08.004

Müldner, G., Britton, K., and Ervynck, A. (2014). Inferring animal husbandry strategies in coastal zones through stable isotope analysis: new evidence from the Flemish coastal plain (Belgium, 1st−15th century AD). *J. Archaeol. Sci.* 41, 322–332. doi: 10.1016/j.jas.2013.08.010

Navarrete, V., Colonese, A. C., Tornero, C., Antolín, F., Von Tersch, M., Subir,à, E., et al. (2017). Feeding management strategies among the early Neolithic pigs in the NE of the Iberian Peninsula. *Int. J. Osteoarchaeol.* 27–5, 839–852. doi: 10.1002/oa.2598

Navarrete, V., and Saña, M. (2013). "*Informe de l'anàlisi arqueozoològica del jaciment de la Cova del Sardo (Vall de Boí, Alta Ribagorça)*," (report). Laboratori d'Arqueozoologia. Universitat Autònoma de Barcelona, Barcelona, Spain.

Navarrete, V., Sierra, A., Alcàntara, R., Camalich, M. D., Martín-Socas, D., and Saña, M. (Accepted). Integrative approaches to the study of animal management practices during the Neolithic of South Iberian Peninsula: the case of El Toro cave (Antequera, Málaga, Spain). *Archaeol. Anthropol. Sci.*

Navarrete, V., Tornero, C., Balasse, M., and Saña, M. (2019). Food management of early introduced caprine and bovine herds in the early Neolithic site of La Draga (Banyoles): an isotopic approach. *Int. J. Osteoarchaeol.* 29, 986–998. doi: 10.1002/oa.2812

Ninyerola, M., Pons, X. Y., and Roure, J. M. (2005). *Atlas Climático Digital de la Península Ibérica. Metodología y aplicaciones en bioclimatología y geobotánica*. Bellaterra: Universidad Autónoma de Barcelona. Available online at: https://www.opengis.grumets.cat/cgi-bin/iberia/MiraMon5_0.cgi? (accessed October 10, 2023).

Obea, L. O., Martinez, M. C., Huerta, R. P., Ballbè, E. G., Seijo, M. M., Baiges, G. S., et al. (2021). Firewood-gathering strategies in high mountain areas of the Parc Nacional d'Aigüestortes i Estany de Sant Maurici (Central Pyrenees) during Prehistory. *Quat. Int.* 593, 129–143. doi: 10.1016/j.quaint.2020.11.044

O'Leary, M. H. (1988). Carbon isotopes in photosynthesis: fractionation techniques may reveal new aspects of carbon dynamics in plants. *Bioscience* 38, 328–336. doi: 10.2307/1310735

Palomo, A., Gassiot, E., Bosch, À., Mazzucco, N., Tarrús, J., Díaz, S., et al. (2022). Sites, rhythms and establishment and exploitation Dynamics in the territory in the Early Neolithic (5,500-4,500 cal BC): the Pyrenees and Pre-Pyrenean mountain ranges. *Cypsela Rev. Prehistòria i Protohist.* 22, 259–284.

Payne, S. (1985). Morphological distinctions between the mandibular teeth of young sheep, Ovis, and goats, Capra. *J. Archaeol. Sci.* 12–2, 139–147. doi: 10.1016/0305-4403(85)90058-5

Payne, S. (1987). Reference codes for wear states in the mandibular cheek teeth of sheep and goats. *J. Archaeol. Sci.* 14–6, 609–614. doi: 10.1016/0305-4403(87)90079-3

Richards, M. P., and Hedges, R. E. (1999). Stable isotope evidence for similarities in the types of marine foods used by Late Mesolithic humans at sites along the Atlantic coast of Europe. *J. Archaeol. Sci.* 26–6, 717–722. doi: 10.1006/jasc.1998.0387

Rodríguez-Antón, D. (2020). "*Ocupación e impacto humano en la alta montaña durante la prehistoria. Un estudio arqueoambiental de Aigüestortes (8–4 Ka calBP)*" (doctoral dissertation). Universidad Autónoma de Barcelona, Barcelona, Spain.

Rojo-Guerra, M., Arcusa, H., Peña, L., Royo, J., Tejedor, C., García Martínez de Lagrán, I., et al. (2014). "Los primeros pastores trashumantes de la Alta Ribagorza," in *Sobrarbe antes de Sobrarbe: pinceladas de historia de los Pirineos*, eds. I. Clemente, E. Gassiot, and J. Rey (Aragón: Centro de Estudios de Sobrarbe, Instituto de estudios Altoaragoneses), 127–151.

Rojo-Guerra, M., Peña, L., Royo, J., Tejedor, C., García Martínez de Lagrán,.I., Arcusa, H., et al. (2013). Pastores trashumantes del Neolítico Antiguo en un entorno de alta montaña: secuencia crono-cultural de la Cova de Els Trocs (San Feliú de Veri, Huesca). *BSAA* LXXIX, 9–54.

Saña, M., Antolín, F., Bergedà, M., Castells, L., Craig, O., Edo, M., et al. (2015). "Prácticas agropecuarias durante el Neolítico antiguo y medio en la cueva de Can Sadurní (Begues, Barcelona)," in *Actas do 5° Congresso do Neolítico Peninsular*, eds V. S. Gonçalves, M. Diniz and A. C. Sousa (Lisboa: UNIARQ, Centro de Arqueologia da Universidade de Lisboa), 57–67.

Sierra, A., Bréhard, S., Montes, L., Utrilla, P., and Saña, M. (2019). Sheep exploitation and husbandry in first farming societies: from production to consumption in Central Pyrenees in the Early Neolithic. *Archaeol. Anthropol. Sci.* 11, 5813–5829. doi: 10.1007/s12520-019-00907-3

Silver, I. A. (1969). "The ageing of domestic animals," in *Science in Archaeology: A Survey of Progress and Research*, eds R. Brothwell, and E. S. Higgs (London: Thames and Hudson), 283–302.

Szpak, P. (2014). Complexities of nitrogen isotope biogeochemistry in plant-soil systems: implications for the study of ancient agricultural and animal management practices. *Front. Plant Sci.* 5, 288. doi: 10.3389/fpls.2014.00288

Tarifa, N. (2019). "*Pottery use on the Mediterranean coast of the Iberian Peninsula*," (doctoral dissertation). Universidad Autónoma de Barcelona, Barcelona, Spain.

Tejedor-Rodríguez, C., Moreno-García, M., Tornero, C., Hoffmann, A., García-Martínez de Lagrán, Í., Arcusa-Magallón, H., et al. (2021). Investigating Neolithic caprine husbandry in the Central Pyrenees: Insights from a multi-proxy study at Els Trocs cave (Bisaurri, Spain). *PLoS ONE* 16–1, e0244139. doi: 10.1371/journal.pone.0244139

Tornero, C., Aguilera, M., Ferrio, J. P., Arcusa, H., Moreno-García, M., Garcia-Reig, S., et al. (2018). Vertical sheep mobility along the altitudinal gradient through stable isotope analyses in tooth molar bioapatite, meteoric water and pastures: a reference from the Ebro valley to the Central Pyrenees. *quarter. Int.* 484, 94–106. doi: 10.1016/j.quaint.2016.11.042

Uría, N. (2013). Registros sedimentarios como indicadores paleoambientales y de la actividad antrópica durante la Neolitización: La Cueva de Els Trocs y su entorno (Abella, Huesca). *CKQ Estudios de Cuaternario/Leioa* 3, 123–134.

Van Klinken, G. J. (1999). Bone collagen quality indicators for palaeodietary and radiocarbon measurements. *J. Archaeol. Sci.* 26, 687–695. doi: 10.1006/jasc.1998.0385

Villalba-Mouco, V., Utrilla, P., Laborda, R., Lorenzo, J. I., Martínez-Labarga, C., and Salazar-García, D. C. (2018). Reconstruction of human subsistence and husbandry strategies from the Iberian Early Neolithic: a stable isotope approach. *Am. J. Phys. Anthropol.* 167–2, 257–271. doi: 10.1002/ajpa.23622

Viñerta, A. (2015). "*El análisis de la Fauna de los niveles neolíticos de Coro Trasito (Tella-Sin, Sobrarbe)*," (dissertation). Universidad Autónoma de Barcelona, Barcelona, Spain.

Viñerta, A., and Saña, M. (2019). El desarrollo de la ganadería en la alta montaña durante el Neolítico y la Edad del Bronce: el ejemplo de Coro Trasito (Tella-Sin, Huesca). *Sobrarbe* 17, 7–21.

Zeder, M. A. (2006). Central questions in the domestication of plants and animals. *Evol. Anthropol.* 15, 105–117. doi: 10.1002/evan.20101