Dogs that Ate Plants: Changes in the Canine Diet During the Late Bronze Age and the First Iron Age in the Northeast Iberian Peninsula

Silvia Albizuri[1], Aurora Grandal-d'Anglade[2], Julià Maroto[3], Mònica Oliva[4], Alba Rodríguez[5], Noemí Terrats[6], Antoni Palomo[7], F. Javier López-Cachero[1]

How to cite
Albizuri, S., Grandal-d'Anglade, A., Maroto, J. et al. Dogs that Ate Plants: Changes in the Canine Diet During the Late Bronze Age and the First Iron Age in the Northeast Iberian Peninsula. *J World Prehist* **34**, 75–119 (2021). https://doi.org/10.1007/s10963-021-09153-9

Abstract

We studied 36 dogs (*Canis familiaris*) from the Can Roqueta site in the Catalan prelittoral depression (Barcelona), dated between the Late Bronze Age and the First Iron Age (1300 and 550 cal BC). We used a sample of 27 specimens to analyse the evolution of the dogs' diet based on the carbon $\delta^{13}C$ and nitrogen $\delta^{15}N$ isotope composition. The results show a marked human influence in that these natural carnivores display a highly plant-based diet. The offset between canids and herbivorous ungulates does not reach the minimum established for a trophic level, which implies an input of C_3 and C_4 (millet) cultivated plants. Moreover, the homogeneity in the values indicates that humans prepared their dogs' food.

Keywords

Iberian Peninsula; Dogs; Diet evolution; Human control; Late Bronze Age; Early Iron Age

Introduction

This article is the second part of a study on the canine diet at the Can Roqueta (Bar-celona) site. In recent research we analysed the diet of the Early–Middle Bronze Age canine and human populations of Can Roqueta. We found a canine population mainly composed of dogs with a diet basically made up of group C_3 cereals (Gran-dal-d'Anglade et al. 2019).

The importance of the Can Roqueta site is due to the unusual set of dogs recorded there. A total of 82 canids were buried at this site during the Bronze Age and Early Iron Age: 79 dogs (*Canis familiaris*), 2 large canids and 1 fox (*Vulpes vulpes*).

A total of 45 dogs (including 1 large canid or possible wolf, CRII 459) and 1 fox are recorded buried in the Early–Middle Bronze Age (E–MBA). All of them

---

[1] SERP, Departament d'Història i Arqueologia, Universitat de Barcelona, Montealegre 6-8, 08001 Barcelona, Catalonia, Spain
[2] Instituto Universitario de Xeoloxía of the Universidade da Coruña, ESCI, Campus de Elviña, 15071 A Coruña, Galicia, Spain
[3] Institut de Recerca Històrica, Universitat de Girona, Àrea de Prehistòria, pl. Ferrater Mora 1, 17004 Girona, Catalonia, Spain
[4] Independent Researcher, l'Estartit 701, 08718 Cabrera d'Anoia, Catalonia, Spain
[5] Museu of Sant Cugat, 08172 Sant Cugat del Vallès, Catalonia, Spain
[6] Independent Researcher, Anselm Clavé 77, 08100 Mollet del Vallès, Catalonia, Spain
[7] Museu d'Arqueologia de Catalunya – Barcelona, Passeig de Santa Madrona 39, 08038 Barcelona, Catalonia, Spain

* silvia.albizuri@upc.edu

were found in funerary structures or in structures clustered to the funerary structures (Albizuri 2011a).

Twelve dogs are recorded for the Late Bronze Age (LBA), and 22 individuals are identified (include 1 large canid resembling a dog, CRII 381-1) for the Early Iron Age (EIA). In these two phases, dogs are more frequent in the groupings of domestic structures (silos and pit houses), although there are also some cases that are associated with the inhumations recorded. Two dogs could not be assigned to either the first or the second phase and have been classified in the LBA/EIA due to the lack of radiocarbon dates and the absence of identificatory archaeological material.

The present paper focuses on the evolution of the canine diet by analysing the carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotopes. We analysed the isotopic markers in 36 canids recorded in the LBA and EIA to determine changes in relation to the previous period (E–MBA). We also aimed to reinforce the differences between wolves, dogs and hybrids to provide support for the morphometric study carried out. Basically, we hypothesized that the isotopic ratios related to diets can be used to distinguish bone fragments of the Eurasian wolf (*Canis lupus*) or hybrids from domestic dogs. Our aim is to ascertain what type of diet they had, how great the degree of human control over their diet was, and what changes took place diachronically over the course of the proto-historic period under study.

Dogs and Humans at Archaeological Sites

The close relationship between canids, especially dogs, and humans represents a significant theme in archaeology, with a world-wide significance and long chronological scope. This evidence extends from the Upper Palaeolithic through to the modern era in Eurasia, Africa and the Americas, with the large number of human graves where canid remains have been deposited. There are also isolated deposits of canine remains that have been interpreted as genuine tombs for the animals or as part of the ritual activity of past populations (Hill 2018; Germonpré et al. 2009, 2012; Losey et al. 2011; Mitchell 2015; Morey 2006, 2010; Olsen 2000; Radovanovic 1999). Deposits of wolves and foxes are less common, and are more closely associated with totemic images (Bruck 1999). Among the indigenous American populations, the wolf was considered an animal with notable spiritual qualities. This gave rise to a special relationship with warriors due to their strategic behaviour (Morey 2010). In Mexico, dogs, coyotes and hybrids were deposited in ritual areas, symbolizing the entrance to the underworld, rebirth and hence fertility (Russell 2012). From antiquity onward dogs played a significant role in funerary rituals, foundation offerings, purification rites, sacrifices, and were even used as healing agents (see e.g. De Grossi Mazzorin 2008). Northwest Siberia has a relatively rich ethnographic record. Dog sacrifice is described in the Yamal region, where dogs were killed to honour kin spirits and deities (Losey et al. 2018). Dogs in Ipiutak and Old Bering Sea contexts were traditionally used as vehicles (akin to scapegoats or ‘sin eaters’) into which human diseases could be thought to have been transferred (Hill 2018).

In the Iberian Peninsula, dog phenomena are known from the Middle Neolithic in agropastoral communities. The examples recorded in Catalonia in the pre-littoral strip stand out in particular, especially the Bòbila Madurell necropolis (Albizuri et al. 2019a), which is very close to Can Roqueta. The series of Middle Neolithic examples in Catalonia could be related to a new ceremonial activity around dog sacrifice that lasted for hundreds of years in different cultural environments. The continuity of this phenomenon is of particular importance in ritual and funerary structures of the Chalcolithic and Bronze Age in the Iberian Peninsula (Albizuri 2011a, b; Altuna 1994; Cámara Serrano et al. 2008; Catagnano 2016; Conlin 2003; Daza 2011; Grandal-d'Anglade et al. 2019; Liesau et al. 2013; Ruiz et al. 2014; Sanchís and Sarrión 2004; Valera et al. 2010) and continued with less importance during the Iron Age (Catagnano 2016).

Can Roqueta's deposits contain a large number of dog remains, and are important for demonstrating a long continuity for this practice, starting in the Early-to-Middle Bronze Age and extending down to the Earlier (First or Initial) Iron Age, from which time the burial of dogs inside or near human tombs decreased considerably.

The Role of Dogs

The role of dogs in past societies evolved from the Palaeolithic in Europe and could be multiple and variable during the life of the animal and among the various dogs of a community (Hill 2018). The dog could be a source of raw material: meat, marrow, fur. Dogs' capacities in specialised work converted them into a fundamental tool for hunting, protection of human and animal communities, and transport. They also played an important role in eliminating waste and for company (Arbogast et al. 2005; Horard-Herbin et al. 2014), not forgetting the role played by dogs in war. Archaeological evidence of their use in combat includes bone remains of Rottweiler-type dogs in military bog offerings of the Iron Age phase of Hjortspring (Scandinavia). This deposit indicates that fighting hounds were used, possibly by the commanders (Randsborg 2001). However, there were already very large dogs in Assyria in the thirteenth century BC, as evidenced by representations in Babylon and Nineveh ruins. These Assyrian mastiffs were used for hunting and war (Landry 1998).

Dogs played a crucial role in performing daily tasks and acquired the status of valuable members of the group based on their competence. This explains the many dog burials in the pits of prehistoric and proto-historic populations. The prevalence of sled- and hunting-dog burials in the ethnographic record also indicates their importance within some groups (Hill 2018; Perri 2019).

In agropastoral societies where hunting was not important for subsistence, the most important role that dogs played is undoubtedly that of protection of the human and animal communities. These animals were guardians of the house, farm and livestock, helping protect animals from wild carnivores and guide and move them; however, these works were probably only carried out by some of the dogs. Others could have been used in activities such as transportation and load-carrying, as known from ethnographic examples of North American Indians.

Chroniclers of the tribes of North Dakota—such as the Hidtasa, Assiniboine and Arikara—describe how the dogs' primary function was to transport firewood and other materials, using a *travois* or carrying loads directly on their backs, basically assisting women and children, until the adoption of the domestic horse in the nineteenth century AD (Wilson 1924).

The dog's adaptability to the *travois* and difficult terrains made it the animal *par excellence* for carrying loads. They were trained from a few months old until 6 months when they could pull the *travois* sledge with other adult dogs. Dogs were trained and selectively bred exclusively by women, whose usual tasks included collecting wood for the maintenance of homes. Many of the northern tribes had hundreds of dogs, and each family had an average of between eight and ten dogs that were used to transport the camps when they moved, or to carry hunted animals (furs, meat, etc.). However, generally only three or four dogs were used for the *travois*, with which it was possible to collect firewood for a week at one time. The remaining dogs were breeders and the older dogs served for protection and warning of dangers. Dogs played a broad role, including companionship and playing with children, although their main function was transport. Controlling them required the preparation of specific food from waste meat, sometimes with corn porridge.

The archaeological record of North America supports the information provided by ethnography as it documents bone deformations in the dorsal spinous process of the thoracic and lumbar vertebrae in the Paleo-Indian dog populations of Alabama (Dust Cave site) and Illinois (Kuehn 2014; Morey 2010; Warren 2004). These deformations are normally manifested as lateral deviations and flattening of vertebral spinous processes and are interpreted as a consequence of the use of dogs for pulling *travois* or carrying packs since ancient times in this part of the world, although some authors argue that these deformations in the spinous process could be related to the age-associated degenerative disease spondylosis deformans, which even affects wild specimens, or to other pathological events (blunt trauma, repaired fractures, nutritional secondary hyperparathyroidism, stress, etc.) (Latham and Losey 2019; Lawler et al. 2016). In response to this, we should point out that the recurrent use of young dogs in loading tasks, when the flexibility of the bone is greater, could be one of the causes of deformations and fractures in the vertebral apophyses due to continued overexertion, especially when these alterations are not related to the formation of bony spurs called osteophytes at the margins of vertebral bodies, produced by the degenerative disease spondylosis deformans.

However, recent studies justify the deviation of the dorsal spinous process with the natural phenomenon 'imperfect bilateral symmetry', which would spread in certain communities due to inbreeding (Janssens et al. 2018). A new study by Latham and Losey (2019) suggests that spondylosis deformans might be more visible in modern dogs that did not participate in transport activities than in those that did. The authors do not find any convincing evidence that transport dogs experienced higher rates of this disease than other canid groups. However, they did find a correlation between body mass and the occurrence of spondylosis deformans in domestic dogs. Future studies might look for correlations between involvement in transport and degenerative changes in other parts of the skeleton, particularly the limb joints, or changes in limb robusticity and shape in relation to habitual differences in loading (Latham and Losey 2019). The hypothesis on the changes in limb robusticity and shape was proposed by N. Peterson in her PhD thesis. She provides an explanation for the variability in the size and robustness of limb bones of a significant number of specimens from Swedish Mesolithic sites.

She interprets this variability in terms of the diversity of uses dogs had in work and transportation. The dogs that suffered the greatest stress in their extremities were those that had swelling of the bone tissue, probably due to the transport of heavy loads (Peterson 2006).

In Europe there are very few records of ancient spinal anomalies (Losey et al. 2011), although on the island of Zhokhov (Pitulko and Kasparov 2017) numerous remains of sleds and dogs have been identified dated in the early Holocene that could show that the use of dogs in sledding also dates back to ancient times in this area of the world. Spinous process deviations in the neural processes have been studied in three complete individuals (between 1 and 2.5 years old) from the Can Roqueta site, dated in the Early–Middle Bronze Age. These cases represent the first pathological evidence studied in the Iberian Peninsula without other signs of the effects of degenerative diseases, spondylosis deformans or traumatic lesions (Albizuri, Fernández and Tomás 2011b; Grandal-d'Anglade et al. 2019). The vertebral bodies were normal, but different spinous processes in all the individuals showed a lateral curving at some point above the spinous base and in different directions (right, left). This, rules out a deformation by infectious causes, because in that case all the spinous processes would be deflected in the same direction (Lawler et al. 2016). It has therefore been interpreted as a sign that the dogs constantly carried vertical loads on their backs. In addition, other pathological cases found at Can Roqueta and dated in the EIA are also likely to be related to stress due to carrying loads and are being studied with veterinary advice.

Although these pathologies are very difficult to diagnose, they suggest that dogs were used in carrying loads and transport activities in Europe from ancient times, especially in light of direct examples such as the pictorial representation of a sled pulled by dogs on a 500 BC Greek vase, or the image on Roman terracotta from the second century BC (De Lavigne 2014). Furthermore, the use of dogs in carrying loads and pulling sleds could have been far more widespread in past European societies than currently documented, judging by the evidence of dogs used to pull sleds and carry loads from the Middle Ages to the nineteenth century (Agricola 1556/1912; Bizet 2000; Chevalier Charlotte 2013; De Lavigne 2014).

Stable Isotopes and the Dog Diet

Carbon and nitrogen stable isotopes ($\delta^{13}C$, $\delta^{15}N$) of bone collagen have been widely used to study human and animal diets from archaeological sites (Hedges and Reynard 2007; Lee Thorp 2008; Schoeninger and Moore 1992). Currently, isotopic studies are routinely performed on archaeological remains. Bone collagen is synthesized from dietary protein (Ambrose and Norr 1993) and records the average diet of an animal during the period of bone growth or remodelling (usually several years). It thus indicates the trophic level of an animal (DeNiro and Epstein 1985), the terrestrial or marine source of the protein consumed (Peterson and Fry 1987), and the type of plants in the diet according to their photosynthetic pathway or their nitrogen fixation mechanism (Farquhar et al. 1989; Van der Merwe 1982).

Various isotopic studies of dogs and humans of an archaeological origin have come to the conclusion that the diet of dogs is a reflection of the human diet and the socioeconomic system (Cannon et al. 1999; Noe-Nygaard 1988; for a review see Guiry 2012; Guiry and Grimes 2013). This is consistent with a variety of ethnographic studies. The canine diet thus adapts to the particularities of the human group with which the dogs live. At sites in North America and Japan, for example, dogs have been described as having a diet based almost exclusively on marine resources (Ames et al. 2015; Tsutaya et al. 2014). In hunting communities, the dogs are fed with parts of the hunted animals (Bocherens et al. 2015; Perri 2019; Tankersley and Koster 2012). In North America and Mesoamerica, it has been detected that dogs as well as humans consumed maize (*Zea mays*) (Rick et al. 2011; Tankersley and Koster 2009). In the eighteenth century AD among the Hidatsa of North Dakota, women were responsible for training the dogs and fed them with a soup made of corn and meat scraps (Wilson 1924). In Eurasia the gradual expansion of millet (*Panicum miliaceum*, *Setaria italica*) is recorded as providing a basis for the human and animal diets (Dai et al. 2016; Pearson et al. 2015; Pechenkina et al. 2005). Indeed, this adaptation has gone so far as to transform the diet of this carnivore into a diet with a marked tendency towards vegetarianism, as is observed at certain Neolithic sites. In the Iberian Peninsula, a recent study has identified a mixed diet composed of vegetables with gluten (group C_3) and proteins of animal origin in dogs of the Middle Neolithic at sites near Can Roqueta (Albizuri et al. 2019a). Other Neolithic examples, such as those of China (Pechenkina et al. 2005), also include gluten-free cereals of the C_4 group, such as millet, as in other French and Italian Neolithic and Bronze Age sites (Herrscher and Le Bras-Goude 2010; Laffranchi et al. 2016), where the economy was based on agriculture and the settlement mode indicates a sedentary lifestyle. Feeding dogs with group C_4 cereals must have been widespread according to studies of populations from the recent past. In Moravia during the ninth–early tenth century AD dogs had a diet based on type C_4 cereals like the human population (Halffman and Velemínský 2015).

In Can Roqueta the E–MBA archaeological record indicates that in some cases the wild animals had a diet based on C_4 cereals, which would indicate a commensal relationship with the human communities.

For instance, the signature displayed by the fox from structure CRII 481 is omnivorous, poorer in ^{15}N yet richer in ^{13}C than that typical of dogs. This deviation could be interpreted as being the result of the introduction C_4 plants (millet) or foodstuffs of a marine origin into its diet. However, the scant evidence of marine resources is a constant in all the excavated sectors of Can Roqueta in all the cultural phases, strengthening the supposition that this animal was probably fed by humans with millet. This can only be interpreted as evidence of commensalism, not domestication (Grandal-d'Anglade et al. 2019).

Other cases suggest close relationships between humans and wild animals, for instance the cats of the Quanhucun site in China, dated between 5560 and 5280 cal BP. Their $\delta^{13}C$ and $\delta^{15}N$ bone collagen values revealed substantial consumption of millet, which indicates that they were fed by people (Hu et al. 2014).

Description of the Site

The site of Can Roqueta, situated in the Catalan Pre-littoral Depression, is located 20 km from the coast of Barcelona, between the current municipalities of Sabadell and Barberà del Vallès. It extends over an area of roughly 2.5 km^2. Its geographical boundaries are defined by the Serra de la Salut to the east, and the River Ripoll to the west (Carlús et al. 2007; Fig. 1).

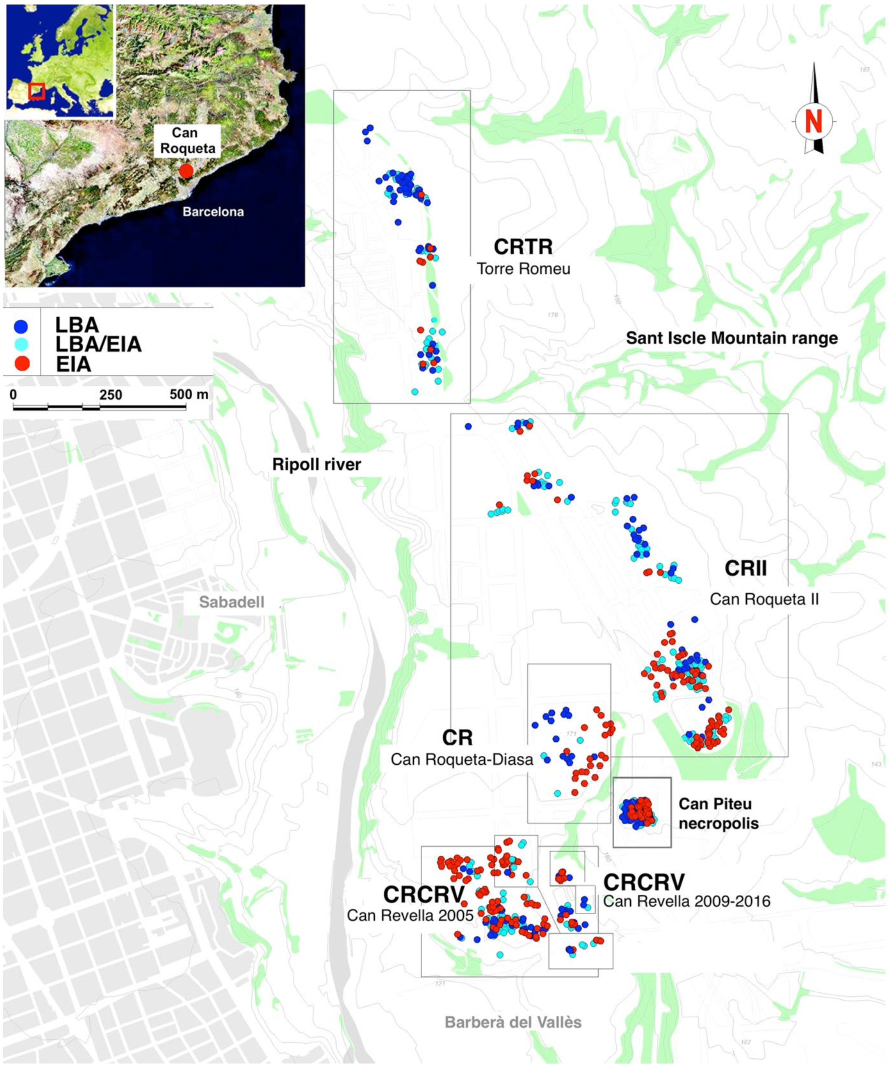


Fig. 1 Map of the Can Roqueta location and site, showing archaeological areas. (Cartographic base: © Institut Cartogràfic de Catalunya, 1: 25,000)

The landscape consists of an undulating plain no more than 200 m above sea level, with shallow valleys and a variety of watercourses that run through and drain it. These features make Can Roqueta an area of great fertility and plentiful natural resources, which has notably fostered the development of human groups from prehistoric times through to today.

Can Roqueta is one of the most remarkable prehistoric and proto-historic archaeological sites in the northeast of the Iberian Peninsula, and around 2700 archaeological structures have been documented there among the various excavated sectors. From north to south, the sectors with the highest concentration of structures are Torre Romeu (CRTR), Can Roqueta II (CRII), Can Roqueta DIASA (CR), Can Revella (CRCRV), and the cremation necropolis of Can Piteu (Fig. 1). The chronological sequence encompasses a broad time span, from the first Neolithic communities to the Iberian period, with a notable occupation in the Early–Middle Bronze Age (E–MBA) (2300–1300 cal BC), the Late Bronze Age (LBA) (1300–750 cal BC), and the Early Iron Age (EIA) (750–550 cal BC) (Carlús et al. 2008).

There are numerous funerary structures from the E–MBA in the site that are distributed and mixed between living and storage structures in the different archaeological sectors, but authentic necropolis areas cannot be distinguished. From the LBA, the excavated residential spaces occupy differentiated areas and seem to be located at a minimum distance of 500 m from each other. One major necropolis area is currently defined. This reflects a model of territorial occupation comprising pit houses, excavated or semi-excavated in the subsoil and made from nearby raw materials such as clays, wood and plant fibres (leaves, branches and bark, etc.); fields for cultivation and grazing; silos; combustion structures; and spaces with a funerary use. All this is surrounded by ample areas of vegetation in the form of a mosaic of woodland, meadowland and underbrush, without forgetting the fundamental role played by the Ripoll River as a vehicle of cultural transmission as well as social and economic communication.

Can Roqueta did not remain unaffected by the significant changes that took place in the territories between the south of France and the northeast Iberian Peninsula from the LBA onwards. One of the most important is the general switch to cremation burial from 1000 cal BC (Capuzzo and López-Cachero 2017), of which the extensive Can Piteu-Can Roqueta necropolis is one of the foremost examples, with more than a thousand tombs (Carlús et al. 2007; Fig. 1). Increasing contact with southeastern France is also evident, as well as a more moderate contact with Phoenician people, especially from the eighth and seventh century cal BC (Albizuri et al. 2020; Marlasca 2007). Despite its location about 20 km from the coast, Can Roqueta was an important focus of commercial relations during the EIA. Metallic objects in bronze and iron from the Can Piteu necropolis are proof of this, since they have typologies shared with northern Catalonia and the French Midi (López-Cachero and Rovira 2012).

Funerary Structures and Animal Deposits

From the E–MBA numerous funeral structures are present throughout the different archaeological sectors. It is evident that whole animals or partial or isolated remains (mainly skulls) were intentionally deposited in the burial structures of this period.

Domestic animals are the most frequently represented, and dogs stand out in this period (in total there were 45 specimens deposited in human tombs and attached structures that are considered to be part of rituals or accompanying the funeral ritual).

Domestic and funeral spaces were definitively separated during the LBA–EIA, especially between 1000 and 600 cal. BC. From the LBA there is a large necropolis with more than a thousand cremation tombs in Can Piteu–Can Roqueta (Fig. 1), which continued during the EIA. Animal remains have been recorded among the grave inclusions in the cremation tombs (Fig. 2), sometimes incinerated and sometimes deposited in a fresh state. The predominance of domestic animals and the absence of dog remains stand out.

A total of eight burial structures with human remains are also recorded for the EIA, three of them with very fragmentary skeletal remains and five more with complete skeletons. These structures are concentrated in the south of the archaeological site, specifically in the Can Roqueta II and Can Revella sectors. A striking feature of these latter burials is their connection to nearby structures with faunal remains, among which dogs and horses predominate. Faunal remains have also been found inside the human burials, although they belong exclusively to domestic animals and only in one case (CRCRV 110) was a dog skull recorded (Fig. 2).

Other animal deposits (ABG according to Morris 2011) are also documented during the LBA and EIA associated with living areas and domestic areas that have silos and pit houses. In these animal deposits, horses and dogs clearly predominate over other domestic species (López Cachero et al. in press).

Exploitation of Crops, Livestock and Natural Resources

The archaeobotanical and archaeozoological studies indicate an economy based on cultivating cereals and legumes (Albizuri, Alonso and López Cachero 2011a), complemented by raising livestock for meat, milk and traction. In the E–MBA, the main crop was barley (*Hordeum vulgare*), followed by the token presence of naked wheats (*Triticum aestivum/durum*) and legumes, including lentils (*Lens culinaris*) and peas (*Pisum sativum*). However, acorns are plentiful in various funerary structures in the Can Roqueta/Revella sector, suggesting that this fruit could have been ground and have served as a diet supplement. Livestock is centred mainly on herding sheep and goats, cows and pigs (Grandal-d'Anglade et al. 2019). A considerable increase in the production of wheat over barley and the appearance of foreign group C_4 plants, such as millets (*Panicum miliaceum* and *Setaria italica*), is visible from the LBA. These two millet species increased until they became staple in the EIA (Albizuri et al. in press). In the LBA and EIA sheep and goats came to predominate over other species such as pigs, cows and horses. The age of the animals indicates that three species (sheep, goat, and pig) were principally used to obtain meat and milk. In addition, cows and horses became the main providers of field work and heavy transport, although as adults they were also used for their meat (Albizuri et al. in press). Animal representation does not differ greatly during the EIA with respect to the previous stage. In contrast, from the EIA onwards there is a very significant increase

Fig. 2 **a** Burial of adult man in a silo (CRCRV 110). **b** dog skull in burial CRCRV 110. **c** metallic material in cremation burial of Can Piteu-Roqueta (CPR 296). **d** ceramic material in cremation burial of Can Piteu-Roqueta (CPR 930). **e** ceramic material in domestic structure (CRCRV 83)

of dog and horse remains, mostly registered in special deposits. It is possible that at some point horse meat was also, exceptionally, eaten, but dogs were normally deposited whole and show no signs of consumption. So, we can infer a relation between this increase in archaeological representation and the increased use of these animals in ceremonial acts. In this context there are also two hens (*Gallus gallus*), represented by three sets of remains appearing in two different structures (Albizuri et al. 2020). In the northern half of the Iberian Peninsula, horse remains in domestic waste contexts have appeared sporadically in some 3rd and 2nd millennium BC settlements, but their presence does not become widespread until the twelfth century BC, as in Can Roqueta. These remains only begin to be recorded in the LBA and it is not until the EIA that their number indicates that the inhabitants of Can Roqueta used these animals for riding and pulling loads. The mortality and sex profiles point to the presence of adult animals, while the absence of neonatal and juvenile remains raises the question of whether these individuals may have originated from other sites specialised in equid breeding. The strontium values obtained from six individuals suggest that some equids were reared in a geological area with a similar strontium signature to that of the Vallès area, where the site is located. However, three animals present a different strontium signature, pointing to a possibly different geographical origin (Albizuri et al. 2019b). Terrestrial wild animals were only occasionally exploited for the human diet. Wild species also include marine molluscs (Palomo et al. 2016), although there is only scarce evidence of this.

A recent isotopic study of the burials recorded in the EIA indicates that these humans had a mixed diet (Albizuri et al. in press). They ate a high proportion of animal protein (meat and/or milk), higher than in the E–MBA. This increase may be associated with the consumption of meat and also of milk and derivatives. It may also be associated with the growing importance of sheep and goats, which provided most of the milk for human consumption, as well as meat. As regards cattle, the ages of death indicate that these animals were used principally for work in the fields and in transport. The cremation cemetery of Can Roqueta-Piteu reflects the social complexity of the community at this time, which may also have prompted the increase in the intake of animal protein and the celebration of events where meat and alcoholic beverages played important roles. Indeed, four meat spits were found in various structures inside the cemetery of Can Piteu. During the EIA the slight increase in the remains of goats and especially sheep may reflect a greater exploitation of the milk and wool of these animals. Furthermore, from the E–MBA onwards, finds of perforated vessels interpreted as strainers serve as European evidence of the processing to prepare fermented products such as cheese (Salque et al. 2013) essential to human nutrition. The plant species consumed were mainly cereals with gluten, such as barley (*Hordeum vulgare* s.l.), naked wheat (*Triticum aestivum/durum/turgidum*), emmer (*Triticum dicoccum*) and einkorn (*Triticum monococcum*); and pulses, including lentils (*Lens culinaris*), peas (*Pisum sativum*) and broad beans (*Vicia faba*). There was also a low proportion of type C_4 cereals without gluten, such as broomcorn millet (*Panicum miliaceum*) and foxtail millet (*Setaria italica*).

Dogs at the Can Roqueta Site

A total of 82 individuals are buried and represented by complete and partial skeletons (approximately 50% of the skeleton), or by isolated remains, such as the skull or jaw bones. In the E–MBA, 44 dogs and one large canid or possible wolf (CRII 459) are concentrated in clustered structures. Some of these are human burials, while others are adjacent pits with animal deposits classified as ‘ritual deposition’ due to their close spatial association and similar deposition patterns. In these ritual structures the animal remains are interpreted as offerings of accompaniment for the deceased (Albizuri 2011a, b; Grandal-d’Anglade et al. 2019).

In the LBA and the EIA, a total of 35 dogs and 1 possible hybrid are placed in pits around domestic areas and in pits near structures (tomb-silo) with inhumation of human remains (López Cachero et al. in press) (Table 1). In contrast to the earlier E–MBA cases, 55% of these dogs are situated in domestic areas (Table 1) and can be interpreted as examples of ritual activity related to the daily life of the populations (Fig. 3), which elsewhere in Europe has been interpreted as having the intention of promoting fertility (De Grossi 2008). Their burial could also be a reflection of a privileged status that involved almost human treatment, perhaps after an accidental or natural death or due to the elimination of dogs that were no longer useful (Perri 2019). This category could include dogs that were sacrificed due to dangerous diseases and buried as a hygienic measure to avoid contagion. It is worth noting that in the fourth century BC Aristotle described the main diseases that affect dogs: 'dogs are susceptible to three diseases: rabies, distemper and hard-pad. Rabies is fatal to the dog itself, and to any animal it bites. Distemper is also fatal to dogs, and few recover' (King et al. 2004).

Materials and Methods

The Sample Under Study

The zooarchaeological study was carried out on the 36 specimens recorded in 26 LBA and EIA structures. One of the priorities has been to differentiate between wolves, dogs and hybrids. Another priority was to characterize them according to morphometric characteristics (see Tables 1, 2) to observe differences or similarities in their diets.

A total of 27 dogs from the LBA–EIA were subjected to isotopic analysis (see Table 3). These were compared with dog and human samples already studied from the E–MBA (Grandal-d'Anglade et al. 2019) and with the available human samples from the EIA (Albizuri et al. in press). Most humans were incinerated and buried in the Can Piteu-Roqueta necropolis during the LBA and EIA and therefore only inhumed individuals from the EIA could be referenced (Albizuri et al. in press).

Isotopic analysis was also conducted on the remains of other species consumed or processed at the same site during the LBA and EIA. This made it possible to establish an isotopic baseline from the strictly herbivorous and carnivorous animals (Casey and Post 2011) and thus to draw comparisons. Bone samples belonging to carnivores were selected, which included one wildcat (*Felis sylvestris*), one badger (*Meles meles*) and one brown bear (*Ursus arctos*). Analysed domestic ungulates included cows (*Bos taurus*) as strict herbivores, and pigs (*Sus domesticus*) as omnivores (see Table 4).

Methodology of the Zooarchaeological Analysis

The age range studied in dogs was determined from the degree of epiphyseal fusion of their long bones and dental eruption or wear (Horard-Herbin 2000; Piérard 1967). Age ranges were assigned based on the period of natural lactation as well as bone and reproductive maturity. They are called puppies in the first 3 months of life,

Table 1 Data on dog samples: phase and radiometric data, sector/structure (individual), situation of structure, anatomical representation of dogs, MNI (minimum number of individuals), age and sex, average shoulder height

Phase/cal BC ± 2σ	Sector/Structure(individual)	Situation	Anatomical representation	MNI	Age	Sex	Average shoulder height (cm)
LBA	CRCRV09 290	Domestic area	Skull	1	24–36 m		
LBA	CRTR 194	Domestic area	Full skeleton	1	Adult (> 12 m)		53.3
LBA	CRTR 222	Domestic area	Full skeleton	1	5.5 y		58.6
LBA	CRTR 267 (1)	Domestic area	Full skeleton	1	6 y		**44.5**
LBA	CRTR 267 (2)	Domestic area	Partial	1	6 y		43.8
LBA	CRII 836 (1)	Near human remains	Full skeleton	1	3–4 y	F?	46.7
LBA	CRII 836 (2)	Near human remains	Partial	1	2.5 y		**54.6**
LBA	CRII 836 (3)	Near human remains	Full skeleton	1	7 y	M	49.3
LBA	CRII 836 (4)	Near human remains	Full skeleton	1	7 y	F?	47.6
LBA	CR 32	Domestic area	Isolated hand and teeth (M1 inf/PM4 sup)	1	7–8 m		**58.5**
LBA/1047-792	CR 85	Domestic area	Skull	1	12–24 m		
LBA/945-803	CR 97	Domestic area	Skull	1	3–4 y		
LBA/EIA	CRCRV05 82	Domestic area	Skull	1	6.5 y		
LBA/EIA	CRII 629	Near human remains	Parcial	1	30 m		55.5
EIA	CRCRV05 63	Domestic area	Full skeleton	1	7 y		42.2
EIA	CRCRV05 68	Domestic area	Full skeleton	1	> 7 y		49.7
EIA/805-770	CRCRV05 79	Domestic area	Partial	1	> 12 m		43.7
EIA	CRCRV05 95	Domestic area	Full skeleton	1	2.5 y		41.7
EIA/791-540	CRCRV05 110	Funerary structure	Skull	1	> 7 y		
EIA	CRCRV05 133	Domestic area	Isolated mandibles	1	7 y		
EIA	CRCRV05 183 (1)	Domestic area	Skull	1	3.5 y		
EIA	CRCRV05 183 (2)	Domestic area	Skull	1	Adult		

Table 1 (continued)

Phase/cal BC ± 2σ	Sector/Structure(individual)	Situation	Anatomical representation	MNI	Age	Sex	Average shoulder height (cm)
EIA/751-408	CRCRV05 198 (1)	Domestic area	Full skeleton	1	7 y		53.2
EIA/751-408	CRCRV05 198 (2)	Domestic area	Full skeleton	1	12 m		
EIA/751-408	CRCRV05 198 (4)	Domestic area	Full skeleton	1	6.5 y		53.7
EIA/751-408	CRCRV05 198 (5)	Domestic area	Full skeleton	1	< 1 m		
EIA	CRCRV09 277	Domestic area	Skull	1	24 m		
EIA	CRCRV16 45	Domestic area	Skull	1	3–4 y		
EIA/795-550	CRII 223	Domestic area	Skull	1	5–6 m		
EIA	CRII 363	Near human remains	Full skeleton	1	6 y	M	47.5
EIA	CRII 381 (1)	Near human remains	Full skeleton	1	18–24 m	F?	64.9
EIA	CRII 381 (2)	Near human remains	Full skeleton	1	5–6 m		
EIA	CRII 381 (3)	Near human remains	Full skeleton	1	6–12 m		
EIA/739-401	CRII 808	Near human remains	Full skeleton	1	12–24 m		**47**
EIA/774-482	CRII 814	Near human remains	Full skeleton	1	5–7 y	M	43.7
EIA/788-537	CR 112	Domestic area	Full skeleton	1	12 m	M	

The data in bold were obtained from a single bone measurement

Fig. 3 Dog deposits of the Early Iron Age. **a** Can Revella, structure CRCRV 63. **b** Can Revella, structure CRCRV 198-4. **c** Can Roqueta II, structure CRII 381-1

after which they definitively cease to suckle. Young dogs are those in the process of replacing their teeth and they have not yet reached bone and reproductive maturity, between 4 and 10 months of age. The adult dog category begins between 10 and 12 months, when the skeleton reaches bone and reproductive maturity. Sex was estimated by the presence/absence of the penile bone, only when the skeleton was whole or sufficiently represented.

The conventional method for separating dog bones from those of wolves is comparing their size, on the premise that wild animals are always taller than pets. Measurements were taken with a standard calliper, according to the methodology of von den Driesch (1976). The withers height was estimated following the methodologies proposed by Harcourt (1974) and Clark (1995) for prehistoric domestic dogs. The slenderness index (SI) for each long limb bone was calculated by comparing the smallest transverse diameter of diaphysis (SD) with the greatest length of the different limb bones (GL) (slenderness index = SD*100/GL; see De Grossi Mazzorin and Tagliacozzo 2000). The weight was estimated based on the allometric *equation for femur circumference* (Onar 2005).

For the comparative osteometric study, we obtained limb measurements and dentition of three specimens of present-day Iberian Peninsula wolves from the Barcelona Zoo from the collection of the Zoology Museum of Barcelona: MZB-1 adult female born in freedom in the south of the Iberian Peninsula; MZB-2 young male born in captivity; MMZB-3 adult male born in captivity. The references of current

Table 2 Femur osteometric data for dog samples and weight estimation

Sector structure-individual	Phase	Femur length (GL)	Shoulder height (cm)	Mid-shaft diameter (SD)	Weight (kg)	S. Index SD × 100/GL
CRII 474-1	E–MBA	167	51.1	12	13.8	7.2
CRII 474-2	E–MBA	158	48.3	12.2	14.5	7.7
CRII 481-1	E–MBA			13	17.4	
CRII 533-1	E–MBA			11	10.7	
CRII 505-1	E–MBA			12.5	15.5	
CRII 591-1	E–MBA	172	52.7	13.5	19.4	7.8
CRII 628-1	E–MBA			11.5	12.2	
CRII 836-1	LBA	153	46.7	11.4	12.0	7.5
CRII 836-3	LBA	167	51.1	14.2	22.4	8.5
CRII 836-4	LBA	163.5	50.0	12.0	13.9	7.4
CRTR 194	LBA			12.4	15.2	
CRTR 222	LBA	192.2	59.1	12.7	16.2	6.7
CRTR 267-1	LBA			11.9	13.5	
CRCRV05 63	EIA			10.9	10.5	
CRCRV05 68	EIA			12.3	14.8	
CRCRV05 79	EIA			10.7	9.9	
CRCRV05 95	EIA			11.0	10.7	
CRCRV05 198-1	EIA			13.5	19.4	
CRCRV05 198-4	EIA	182.6	56.0	12.7	16.2	7.0
CRII 381-1	EIA	219.0	67.5	14.7	24.9	6.7
CRII 363	EIA	160.6	49.1	12.5	15.7	7.8
CR 112	EIA			12.6	15.9	

dog breeds (setter and pointer) and those of a modern Italian wolf from the Pigorini Museum (Rome) come from the work of Catagnano (2016). The references of present-day wolves in northern Portugal come from the work of Moreno-García et al. (2016).

Methodology of the Isotope Analysis

The laboratory criteria for selecting the sample were as follows: exclusive use of bone (never teeth); and prioritization of compact tissue. These 27 individuals were found in 22 different structures (see Table 3). The analysis of these structures does not correspond to a selection, and many were ruled out in advance for failing to comply with the laboratory criteria for obtaining collagen. Each dog was represented by a single remnant, with the exception of one dog (CRII 223) for which two remains were analysed, but in this case the very similar results obtained have been represented by a single point, corresponding to the arithmetic mean of the two values.

Table 3 Dog samples: isotopic ratio for N and C and isotopic analysis values of the bone collagen quality parameters (collagen %N and %C, collagen yield in % and atomic C/N)

Sample	Sector	Phase	Taxa	δ^{15}N	δ^{13}C	Yield %	% N col	% C col	C/N at
290-1	CRCRV09	LBA	*Canis familiaris*	9.1	− 19.0	5.0	11.9	32.8	3.2
836-1	CRII	LBA	*Canis familiaris*	8.5	− 18.7	3.5	13.9	38.3	3.2
836-3	CRII	LBA	*Canis familiaris*	8.0	− 18.8	16.5	8.6	23.7	3.2
836-4	CRII	LBA	*Canis familiaris*	8.3	− 19.4	10.9	8.9	25.0	3.3
194	CRTR	LBA	*Canis familiaris*	6.2	− 19.4	8.2	14.7	40.3	3.2
222	CRTR	LBA	*Canis familiaris*	8.3	− 19.1	9.7	15.0	41.2	3.2
32	CR	LBA	*Canis familiaris*	8.7	− 18.7	14.06	13.7	38.5	3.3
85	CR	LBA	*Canis familiaris*	9.3	− 18.8	5.71	13.1	35.3	3.1
97	CR	LBA	*Canis familiaris*	9.4	− 17.1	9.23	12.5	33.8	3.2
82	CRCRV05	LBA/EIA	*Canis familiaris*	9.5	− 17.0	5.3	13.1	35.5	3.2
629	CRII	LBA/EIA	*Canis familiaris*	9.1	− 18.4	5.7	12.9	34.9	3.2
112	CR	EIA	*Canis familiaris*	7.4	− 16.6	5.26	13.2	35.8	3.2
63	CRCRV05	EIA	*Canis familiaris*	8.9	− 16.8	3.8	12.7	35.3	3.3
68	CRCRV05	EIA	*Canis familiaris*	10.3	− 19.2	4.2	8.7	24.2	3.2
79	CRCRV05	EIA	*Canis familiaris*	8.9	− 17.9	7.9	13.9	38.2	3.2
95	CRCRV05	EIA	*Canis familiaris*	8.5	− 19.0	4.5	12.0	33.4	3.2

Table 3 (continued)

Sample	Sector	Phase	Taxa	$\delta^{15}N$	$\delta^{13}C$	Yield %	% N col	% C col	C/N at
183	CRCRV05	EIA	*Canis familiaris*	8.8	− 18.4	3.9	11.6	30.8	3.1
198-1	CRCRV05	EIA	*Canis familiaris*	8.5	− 19.1	9.9	11.4	31.7	3.3
198-4	CRCRV05	EIA	*Canis familiaris*	8.8	− 16.9	4.8	9.9	27.6	3.3
223-a(skull)	CRII	EIA	*Canis familiaris*	8.8	− 17.4	4.2	12.0	31.3	3.0
223-b(vertebra)	CRII	EIA	*Canis familiaris*	8.6	− 17.6	4.4	14.0	36.1	3.0
363	CRII	EIA	*Canis familiaris*	9.3	− 18.0	6.3	14.4	39.5	3.2
381-1	CRII	EIA	*Canis familiaris*	8.8	− 17.3	3.7	11.5	32.0	3.3
381-2	CRII	EIA	*Canis familiaris*	7.1	− 17.9	7.7	11.8	33.0	3.3
381-3	CRII	EIA	*Canis familiaris*	8.1	− 16.0	6.8	12.7	35.7	3.3
110	CRCRV05	EIA	*Canis familiaris*	9.1	− 18.1	5.2	13.0	36.1	3.2
814	CRII	EIA	*Canis familiaris*	9.9	− 18.9	3.9	12.6	34.5	3.2
808	CRII	EIA	*Canis familiaris*	7.9	− 14.7	4.9	13.5	37.3	3.2

From each bone, a sample of about 2 g was removed with a diamond saw, repeatedly rinsed in an ultrasonic bath with deionized water and acetone in succession (a minimum of 5 washes in acetone and 6 in water, or more if necessary, until turbidity was no longer observed), then air-dried at room temperature for at least 48 h.

For each specimen studied, 200–500 mg chunks of compact bone were powdered manually with an agate mortar and pestle and sieved to yield the < 0.5 mm fraction. Most samples were measured for whole-bone nitrogen in order to evaluate the collagen preservation. This preliminary analysis made it possible to discard samples in which collagen might not be preserved in sufficient quantities ($\% N < 0.4$) and

Table 4 Domestic ungulates and carnivore samples: isotopic ratio for N and C and isotopic analysis values of the bone collagen quality parameters (collagen %N and %C, collagen yield in % and atomic C/N)

Sample	Sector	Phase/cal BC ± 2σ	Taxa	$\delta^{15}N$	$\delta^{13}C$	Yield %	% N col	% C col	C/N at	Source
111	CRCRV	LBA/829-747	*Felis sylvestris*	10.3	− 18.6	11.7	11.4	31.9	3.3	Albizuri et al. in press
290-4	CRCRV	LBA	*Bos taurus*	5.2	− 18.4	4.5	12.7	34.8	3.2	
210	CRTR	LBA	*Bos taurus*	7.4	− 16.3	7.5	7.8	21.2	3.2	
212-1	CRTR	LBA	*Bos taurus*	5.7	− 19.7	11.4	13.8	39.0	3.3	
212-2	CRTR	LBA	*Bos taurus*	5.8	− 19.6	1.6	6.4	17.2	3.1	
212-3	CRTR	LBA	*Bos taurus*	6.4	− 19.3	7.2	6.1	17.5	3.3	
81	CR	LBA	*Bos taurus*	6.6	− 19.2	4.0	13.7	37.9	3.2	
210	CRTR	LBA/1002-835	*Sus domesticus*	7.4	− 17.5	1.6	12.3	33.6	3.2	
210	CRTR	LBA/1002-835	*Sus domesticus*	8.5	− 18.7	9.9	12.5	33.9	3.2	
198-3	CRCRV	EIA/751-408	*Meles meles*	7.6	− 18.8	5.6	6.7	18.9	3.3	
45-5	CRCRV	EIA	*Ursus arctos*	8.4	− 18.7	4.9	15.6	42.0	3.2	
223	CRII	EIA	*Bos taurus*	7.0	− 17.2	2.9	12.9	33.9	3.1	Albizuri et al. in press
12-1	CRCRV16	EIA	*Bos taurus*	6.6	− 18.4	10.0	13.6	38.7	3.3	Albizuri et al. in press
18	CRCRV16	EIA	*Bos taurus*	8.7	− 17.2	6.0	11.3	31.3	3.2	Albizuri et al. in press
20-1	CRCRV16	EIA	*Bos taurus*	8.5	− 16.6	8.0	13.0	35.8	3.2	Albizuri et al. in press
12-2	CRCRV16	EIA	*Bos taurus*	5.4	− 20.1	10.7	13.0	36.6	3.3	Albizuri et al. in press
20-2	CRCRV16	EIA	*Bos taurus*	6.4	− 17.8	4.0	11.4	31.6	3.2	Albizuri et al. in press
30	CRCRV16	EIA	*Bos taurus*	8.7	− 16.7	4.6	10.4	28.1	3.2	Albizuri et al. in press
45-1	CRCRV16	EIA	*Bos taurus*	6.2	− 18.3	5.8	12.9	35.8	3.2	Albizuri et al. in press
45-4	CRCRV	EIA	*Sus domesticus*	8.9	− 19.8	5.4	12.8	35.8	3.3	
30	CRCRV16	EIA	*Sus domesticus*	7.2	− 19.4	9.6	13.4	36.8	3.2	
12	CRCRV	EIA	*Sus domesticus*	7.8	− 19.0	12.6	14.9	41.7	3.3	
2	CRCRV	EIA	*Sus domesticus*	8.6	− 18.7	3.7	11.6	33.1	3.3	

Table 4 (continued)

Sample	Sector	Phase/cal BC ± 2σ	Taxa	$\delta^{15}N$	$\delta^{13}C$	Yield %	% N col	% C col	C/N at	Source
3	CRCRV	EIA	*Sus domesticus*	7.7	− 20.5	15.1	14.6	40.9	3.3	
14	CRCRV16	EIA	*Sus domesticus*	7.5	− 19.7	19.5	14.7	40.2	3.2	

enabled us to calculate the optimal amount of bone powder to be treated, which varied between 230 and 300 mg. The collagen extraction protocol follows a method modified from Longin (1971), as described in Bocherens et al. (1997). The bone powder was demineralized in 1 M hydrochloric acid for 20 min, washed to neutral pH and filtered through 5μ filters. The solid residue was digested for 20 h at room temperature in sodium hydroxide 0.125 N to eliminate possible organic contaminants such as fats or humic acids. After washing to neutral pH and filtration, the solid fraction containing collagen was solubilized in 0.1 M hydrochloric acid for 17 h at 100°, freeze-dried and weighed to calculate the extraction yield. The isotope measurements on the freeze-dried collagen were performed by the Instrumental Analysis Techniques Unit (UTIA) of the Research Support Services of the University of A Coruña in an elemental analyser (FlashEA 1112, ThermoFinnigan) connected through a Conflo II interface (ThermoFinnigan) to a Delta plus (ThermoFinnigan) isotopic ratio mass spectrometer, with analytical reproducibility better than 2‰ for both $\delta^{13}C$ and $\delta^{15}N$. All data were averaged from two replicates. The results were referred to international standards, V-PDB for the C and atmospheric nitrogen (AIR) for the N. Isotopic abundances are presented using δ (delta) notation, as follows:

$$\delta = \left[(\text{Rsample}/\text{Rstandard}) - 1\right] \times 1000, \text{ where } R =^{15} \text{N}/^{14}\text{N or } ^{13}\text{C}/^{12}\text{C}.$$

The quality of the collagen obtained was assessed according to three criteria: (i) the collagen yield, expressed as a percentage of the original bone weight, must be $\geq 3.5\%$; (ii) the percentage of carbon and nitrogen in the collagen must be $\geq 13\%$ and $\geq 5\%$ respectively; and (iii) the atomic ratio of carbon to nitrogen must fall between 2.9 and 3.6 (Ambrose 1990; DeNiro 1985; van Klinken 1999; Schoeninger et al. 1983). To compare isotopic values, parametric (*t*-test) and non-parametric (Mann–Whitney-*U*) tests were used for small sample sizes, as well as Cluster analysis (Ward's method) for grouping specimens by affinity in their isotopic values. All statistics were performed with the PAST 3.12 software (Hammer, Harper and Ryan 2001).

Results

Morphological Traits in Dogs

We have attempted to reconstruct the size and weight of the Can Roqueta dog using measurements of length and diameter of limb bones. The comparison of the shoulder heights suggests a medium-sized dog population, although the size range of the animals varies throughout the Bronze Age until the EIA (Table 1; Fig. 4).

In the E–MBA the averages obtained yield a value of 47.8 cm (measurements from 44.3 to 62.4 cm), with a 5.3 cm standard deviation. The individual CRII 459, which measures 62.4 cm, is identified as a large canid classified as a possible wolf (*Canis* cf. *lupus*), or as dog resembling a wolf, based on the comparison with the size and osteometric data of various dogs the site (Albizuri et al. 2015). It is represented by a proximal fragment of the olecranon epiphysis of a right ulna, and by a robust diaphysis of a right radius where the height at withers has been approximated (Grandal-d'Anglade et al. 2019).

In the LBA the average for the complete individuals increases to 50.8 cm (43.8–58.6 cm) with a 5.7 cm standard deviation. In the EIA the values return to a lower level, with an average of 49.3 cm (41.7–64.9 cm) with a 7.0 cm standard deviation.

The size range in the Bronze Age and EIA included two clear outlier specimens, one in the E–MBA (CRII 459, 62.4 cm) and the other in the EIA (CRII 381-1, 64.9 cm), both of large size that exceeds the averages in the 'morphometric' dog group. In two more specimens of the LBA, heights at withers close to 60 cm were obtained (CR 32, 58.5 cm and CRTR 222, 58.6 cm), indicating that in this period there were also large dogs.

The weight estimation in the LBA–EIA dog population has been parameterized from the circumference of the femur (LBA: between 12 and 22.4 kg; EIA: between 9.9 and 24.9 kg) (Table 2; Fig. 5). The values show lighter and heavier specimens than in the E–MBA (between 10.7 and 19.4 kg). The averages are quite similar (E–MBA: 14.8 kg, LBA: 15.5 kg, EIA: 15.3 kg), although there is a progressive increase in the standard deviation.

The variability observed in the height is also reflected in the slenderness indices that have been calculated in radii and tibias (Figs. 6, 7). This variability does not seem linked to sexual dimorphism, since the specimens identified with certainty as males, although scarce, also show variation. In particular, four specimens (CRII 495, CR 32, CRTR 222 and CRII 381-1) are of large size, but in the cases of CRTR 222 and CRII 381-1, the slenderness of the radius and tibia places them below the studied sample of wolves (Figs. 6, 7). However, the slenderness index of the radius of CRII 495 includes this animal in the analysed group of present-day wolves (Figs. 6).

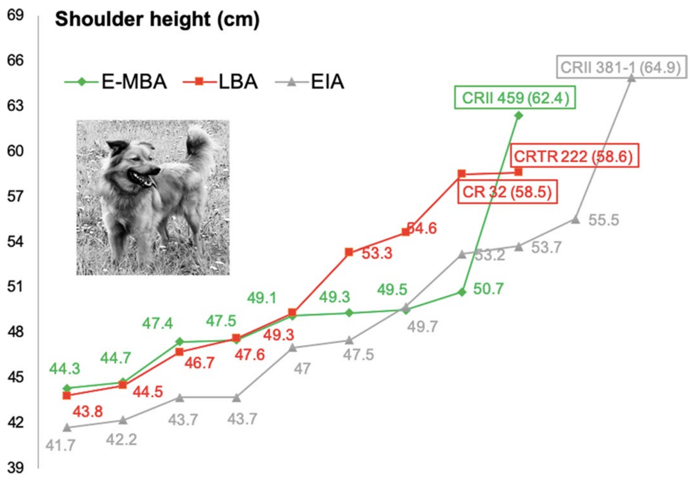


Fig. 4 Shoulder height estimations (cm) in complete dogs of the E–MBA (n = 8), LBA (n = 9) and EIA (n = 11). Image of the *Euskal Artzain Txakurra* shepherd dog of the Basque Country (Spain)

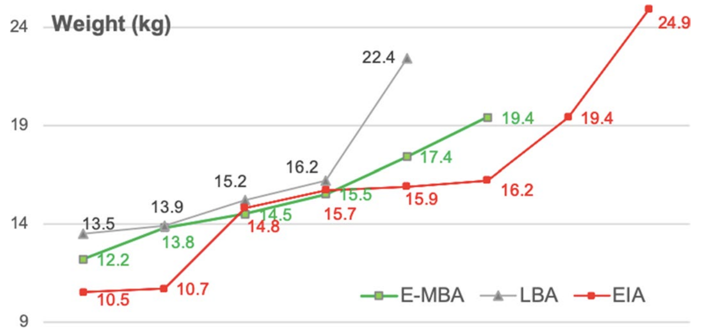


Fig. 5 Weight estimations (kg) in femur circumference of adult dogs (> 12 m)

In comparison with modern breeds, LBA–EIA dogs resembled current-day Pyrenean sheepdog breeds, such as the *Euskal Artzain Txakurra* or Basque Shepherd, which ranges in height from 46 to 61 cm and in weight from 17 to 36 kg. However, the low body weight calculated in Can Roqueta reflects a more gracile animal, as suggested by the narrow diameter of limb bone mid-shafts.

The measures obtained in the lower carnassial (M1) also differentiate the group of dogs and wolves in general. Only the largest specimen, CRII 381-1, is located near the female wolf of the Iberian Peninsula (Fig. 8). As we can see in Fig. 8, the variability observed in the dog sample is also reflected in the Mediterranean wolves studied.

These results show that the range of variability of the LBA and EIA canine population included medium and large-sized dogs. In the largest cases the variability in robustness suggests the possibility that there were hybrids among the canine

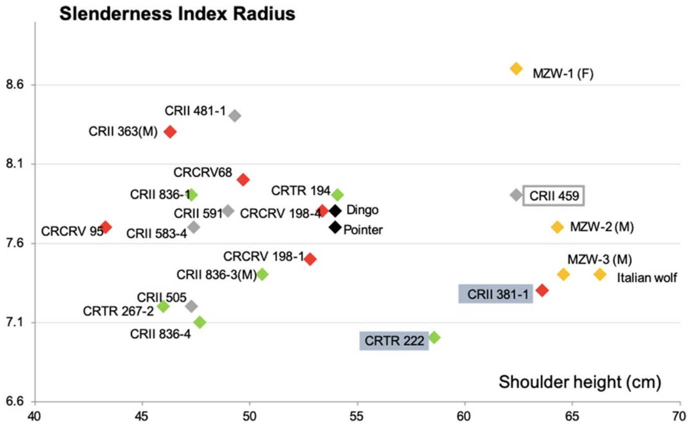


Fig. 6 Scatter plot illustrating the relationship between the slenderness index of the radius and its total length (GL) in Can Roqueta dogs: E–MBA (grey), LBA (green) and EIA (red) and in recent wolves (yellow) and a modern dog breed (black) (Color figure online)

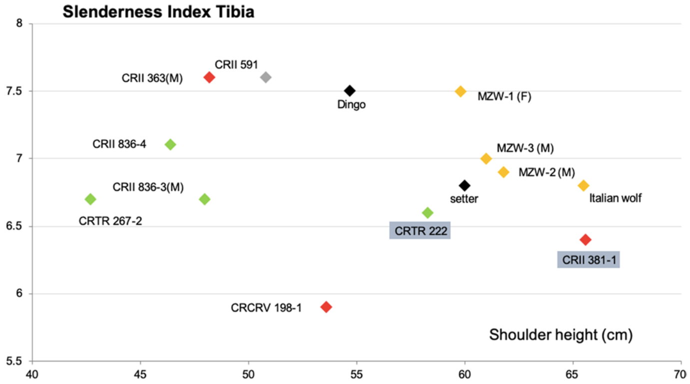


Fig. 7 Scatter plot illustrating the relationship between the slenderness index of the tibia and its total length (GL) in Can Roqueta dogs: E–MBA (grey), LBA (green) and EIA (red) and in recent wolves (yellow) and a modern dog breed (black) (Color figure online)

population, especially in the most gracile specimens studied, such as CRII 381-1 and CRTR 222.

Isotopic Results

All of the analysed samples met the collagen quality indicators. In all samples, atomic C/N falls between 2.9 and 3.6 (average 3.2 ± 0.07). The average collagen in the bone (yield) is 7.1‰ ± 3.9. None of the samples yielded less than 1.5‰ of collagen. Carbon and nitrogen content in collagen were close to fresh bone (%N ≥ 11, %C ≥ 30) in 47 of 57 samples. This is a fairly restrictive quality criterion proposed by some authors (Bocherens et al. 2005). Ten of 56 samples showed slightly lower

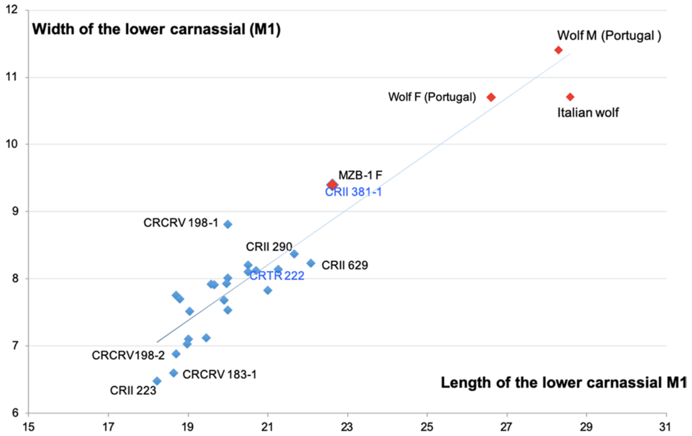


Fig. 8 Scatter plot illustrating the relationship between the length and width (mm) of the lower carnassial (M1) in Can Roqueta specimens and in current wolf populations

C and N percentages, although they were over the commonly accepted minimum (%N ≥ 5, %C ≥ 13), which is more frequent in archaeological samples (Ambrose 1990). However, the differences in mean, maximum and minimum values of the dog and cattle sets, either including or excluding the samples with less restrictive quality criteria, were null or not greater than the analytical precision of the spectrometer.

The results (Tables 3 and 4) show a set of 27 dogs (dog CRII 223 was analysed in duplicate) with average δ^{15}N values of 8.6‰ ± 0.8 and average δ^{13}C values of -18.0‰ ± 1.2, whereas the strict herbivores (cows, n = 14) show an average δ^{15}N of 6.7‰ ± 1.2 and an average δ^{13}C of -18.2‰ ± 1.3.

The difference between dogs and strict herbivores in the mean values of the carbon isotopes ($\Delta\ ^{13}C = 0.2$‰) does not exceed that calculated for one trophic level, which can vary between 0 and 2‰ (Bocherens and Drucker 2003). The difference between the mean values of the nitrogen signature ($\Delta\ ^{15}N = 1.9$‰) is much lower than would be expected for a trophic level, which generally varies between 3 and 5‰ (Bocherens and Drucker 2003). This seems to indicate that at least some dogs had a notable proportion of plants in their diet.

The pigs show intermediate nitrogen signatures (average $\delta^{15}N = 7.9$‰ ± 0.9 and more negative values for carbon (average $\delta^{13}C = -19.1$‰ ± 0.8). The other species are represented by only one specimen each. The wildcat shows the highest δ^{15}N signature in conformity with its typical hyper-carnivorous diet. The brown bear occupies a position that coincides with the mean values of dogs, slightly more negative in δ^{13}C. The brown bear is essentially an omnivorous animal, but there are variations within its broad geographical distribution. In the Iberian Peninsula, the Holocene and present-day Cantabrian brown bears have a hypocarnivorous diet, whereas Pyrenean brown bears, both fossils and from the historical era, are characterized by a higher intake of meat (García Vázquez et al. 2018). The badger, with a δ^{15}N slightly lower than the bear, also shows isotope values corresponding to an omnivorous diet, habitual in this opportunistic species.

Isotopic Signatures of Dogs Over Time

The assemblage of LBA–EIA dogs shows a dispersion of values for the isotopic signatures of nitrogen of between 6.2 and 10.3‰, and of carbon between −14.7 and −19.4‰ (Table 3). An analysis of the results by period reveals variability in the isotopic signatures from the E–MBA onwards, which increases in the EIA (Fig. 9).

In the E–MBA the sample of dogs (n = 21) showed δ^{13}C values between − 20.0 and − 18.3‰ (average − 19.2‰). This means that the basis of their diet was composed of group C_3 cereals. The variation in the values for δ^{15}N is greater, with a range between 6.5 and 9.2‰, and an average value of 7.9‰. Particularly notable are some specimens with very low values, showing a diet very poor in animal protein, contrasting with some specimens with a more carnivorous diet, as occurs with the large canid CRII 459 that has a characteristic carnivore offset (+ 3.8‰) (Grandal-d'Anglade et al. 2019).

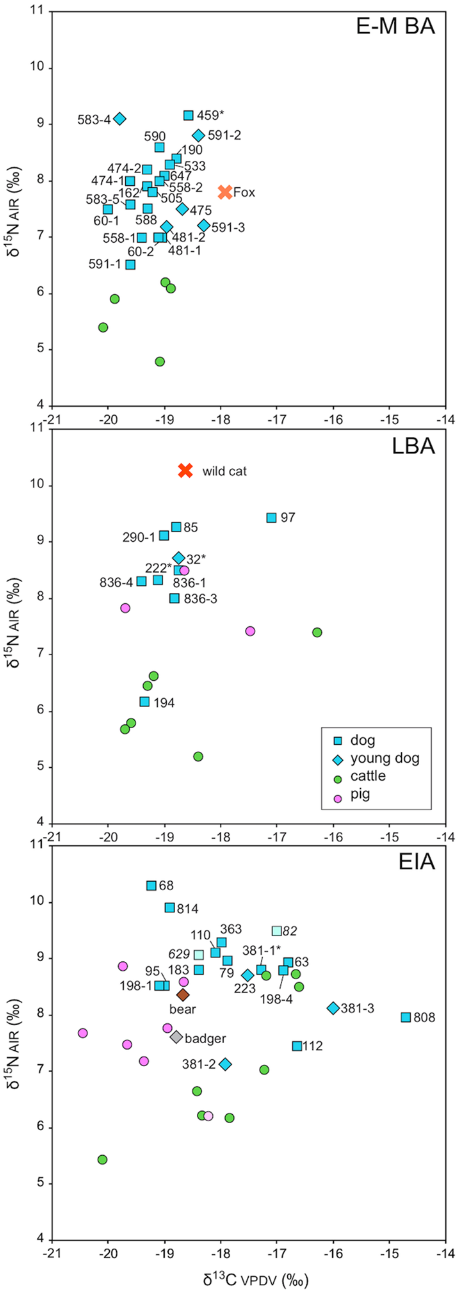


Fig. 9 Bivariate plots of isotopic signatures of dogs and other animals from Can Roqueta, classified by periods. Lighter symbols in two dogs and one pig identify animals from the LBA/EIA. The large canids are marked with an asterisk. The Early–Middle Bronze Age data are taken from Grandal-d'Anglade et al. (2019)

In the LBA, 9 dogs show a large range of $\delta^{15}N$ values (6.2 to 9.3‰), although the mean value (8.4‰) is higher than in the previous era. The mean $\delta^{13}C$ value is − 18.8‰, with a span from − 19.4 to − 17.1‰.

Greater variability is seen in the isotopic signatures of 18 dogs of the EIA (with 2 examples of LBA/EIA), some of which markedly deviated towards less negative δ^{13}C values (average − 17.7‰, with extreme cases showing values between − 14.7 and − 19.1‰). The deviation is not consistent in all the individuals, which rules out environmental change as the cause because such a change would have affected the whole ecosystem, including the cattle. The δ^{15}N values also vary across a broad range (average 8.8‰, from 7.1 to 10.3‰). It is noteworthy that there are dogs with an especially low δ^{15}N value (for example CRII 381-2), and dogs with a similar value to that of the wildcat from the Late Bronze Age (for example CRCRV05-68). However, the set of dogs studied includes some young or very young animals in all periods, whose isotopic signatures may fail to correspond to the habitual diet of an adult, as we will discuss below.

Discussion

Morphological Traits of Can Roqueta Dogs

The increase in the standard deviation recorded during the EIA may indicate a growing diversification in dog breeding over time, probably aimed at obtaining dogs to perform more differentiated and specialized tasks. However, most dogs are medium-sized animals, which may point to a certain control over their reproduction due to inbreeding and conformation trait selection (Stock et al. 2012).

The size range of the E–MBA, LBA and EIA included four outlier specimens (CRII 459, CRTR 222, CR 32 and CRII 381-1) that have a large size exceeding the averages (Fig. 4). In those where it was possible to calculate the slenderness index, the values show gracile individuals, except for CRII 459 (E–MBA) (Fig. 6).

It is difficult to determine whether these dogs represent the upper limit of the size range of middle-sized populations, stemming from slightly larger populations persisting in certain regions of Europe (in Austria, at the Durezza cave site, the size range of dogs from the First Iron Age was from 49 to 64 cm: Galik 2000), or whether they were the result of specific breeding that has not been identified through archaeological contexts.

This variability could correspond to sexual dimorphism among animals, although in the case of largest specimens, CRII 459 and CRII 381-1, their height leads us to consider the presence of dogs that could be hybrids. In spite of this, the isotopic values of CR 32 and CRTR 222 and CRII 381-1 show a mixed diet that includes a high proportion of vegetables. However, the diet of CRII 459 is highly carnivorous (Fig. 9).

Natural hybridization is documented in modern populations, and most frequently occurs near human settlements where wolves are found at low densities and feral and domestic dogs are common; however, hybrids have little chance of reproducing and surviving in freedom (Vilà and Wayne 1999).

In recent years, new data provided by genetic markers of current wolf populations suggest that the percentage of hybrid wolves in Italy and the Iberian Peninsula could be as high as 4–5% (Godinho et al. 2011). In the Iberian Peninsula hybridization seems to be evident in the Chalcolithic deposit of Camino del Molino (Catagnano 2016).

Following current examples, the value of selecting certain characteristics, such as a larger size or aggressiveness, can be appreciated through hybridization with wolves. During the pre-horse days, most American Plains tribes selectively bred their dogs. Only the larger, better-tempered puppies in each litter were kept and the rest were killed or given away. Then, when the selected puppies were older, most of the males were castrated so they would be gentle, but one or two of the best ones were left for breeding purposes (Wilson 1924). In this way, the owners were able to control the size of their dogs and be assured of a continuous supply of animals that were strong and capable of pulling a *travois*. In the northern areas, it was not uncommon for wolves and female dogs to breed. Wolves came boldly into camp, even during the day, to mingle with the dogs. The Indians did not try to stop this because they felt infusion of wild blood kept dog breeds strong and prolific (Henderson 1993). Classical sources also mention such practices, especially to increase the aggressiveness of the animals so they could fight attacks from wolves. These large specimens could be the predecessors of the mastiffs or Molossian dogs described in a Roman treatise of the second century BC that mentions the existence of two types of dogs: one used for hunting predators and game, and a second type for protecting the herds (Landry 1998).

Variation in the Diet of Herbivores Over Time

The objective of including isotope data from strict herbivores such as cows is to establish an isotopic baseline for interpreting the diet of dogs from isotopic signatures. Variation in the isotopic values of the cattle is inferred in the animals of the LBA but becomes more marked during the EIA (Albizuri et al. in press) (see Fig. 9 and increasing standard deviations in Table 5). This variation can be attributed to changes in the environments frequented by the animals, since isotopic signatures vary with factors such as the aridity of the habitat, temperature, height above sea level, and even the degree of tree cover (Drucker et al. 2008; Flohr et al. 2011; Handley et al. 1999; Heaton 1999; Hobson et al. 2003; Männel et al. 2007; Mariotti et al. 1980). Environmental conditions may also have changed over time. Some studies have noted an increase in the aridity of the region from the Bronze Age to the

Table 5 Isotopic values and standard deviations in adult dogs and cattle

Period	$\delta^{13}C$ ‰			$\delta^{15}N$ ‰		
	E–MBA	LBA	EIA	E–MBA	LBA	EIA
Dog mean ± SD	− 19.3 ± 0.3	− 18.8 ± 0.7	− 17.8 ± 1.3	7.7 ± 0.6	8.4 ± 1.0	8.9 ± 0.7
Cattle mean ± SD	− 19.4 ± 0.6	− 18.8 ± 1.3	− 17.8 ± 1.2	5.7 ± 0.6	6.2 ± 0.8	7.2 ± 1.3
$\Delta_{dog–cattle}$	0.1	0.0	0.0	2.0	2.2	1.7

Isotopic offset between cows and dogs according to the period. The data of the Early–Middle Bronze Age are taken from Grandal-d’Anglade et al. (2019)

Iron Age (Araus et al. 1997), which might have caused a variation over time in the isotopic signatures of the animals in question. Aridity would raise the δ^{15}N values. To determine whether there are significant differences between cattle of different periods, including E–MBA cows (Grandal-d'Anglade et al. 2019), a non-parametric test for equal medians was carried out (Kruskal Wallis test). This test yielded no significant differences between sample medians for δ^{15}N ($p = 0.0602$) or for δ^{13}C ($p = 0.074$) at alpha = 0.05. However, the cattle isotopic values show an increasing dispersion over time, extending towards more positive values in both isotopes. The shift is stronger in δ^{13}C. However, because it is not possible to differentiate beforehand a possible climate effect from an increase in C_4 plants in the diet, we took only the bovines of each chronology as the baseline of each period studied.

The pigs show intermediate nitrogen signatures (average δ^{15}N in LBA = 7.9‰ ± 0.56, average δ^{15}N in EIA = 8.0‰ ± 0.66). Iron Age pigs show more negative δ^{13}C values than the dogs and other omnivores (average δ^{13}C = − 19.5‰ ± 0.64).

Isotopic Signatures in Young Dogs

Lactation in mammals causes an apparent increase in trophic level that is reflected in the isotopic signature (Fogel, Tuross and Owsley 1989). Although the sample under isotopic study does not include the youngest specimen (less than 1 month old), it does include some juvenile individuals in which it is possible that the lactation signature had not yet faded from their collagen. To our knowledge, it has not yet been established how long the isotopic signature for lactation lasts in canids, but in the cave bear (*Ursus spelaeus*) it has been seen to fade away once individuals reach a size equivalent to 35% of the adult size (Pérez-Rama et al. 2011). In dogs, even those belonging to large breeds, this size would be reached at an age of less than six months (Hawthorne et al. 2004). In other carnivores, such as the brown bear or the striped skunk, it has been observed that individuals that are actively growing display decreasing δ^{15}N values as the protein of the diet is routed to somatic growth, whereas in adults the protein ingested follows various metabolic pathways involving extra fractionation (Hobson and Quirk 2014; García-Vázquez et al. 2018).

The evolution in the diet of dogs from birth until they reach adulthood should be reflected by δ^{15}N values that increase during lactation and decrease in the time of active growth. Figure 10 shows this variation in dogs up to 8 months of age, comparing them with the average values of adults of each period. The values vary considerably and do not become stabilized in animals close to one year of age. The youngest specimens analysed show extreme δ^{15}N values. These extreme values around 9 ‰ can correspond to the effects of lactation, weaning and growth, which condition the different bone renewal rates of each skeletal element (Evans and Lahunta 2013). Cases with values close to 7 ‰ may reflect specific diets for certain animals that have been prepared mainly with cereals, as was observed in two puppies of the E–MBA (CRII 475 and CRII 481-2) (Grandal-d'Anglade et al. 2019).

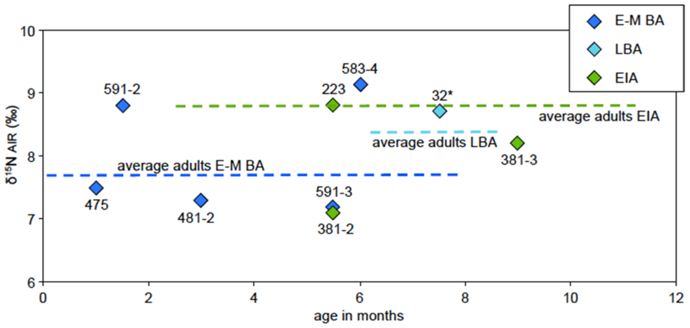


Fig. 10 Nitrogen isotope values of juvenile dogs. Adult mean values for both periods are represented for comparison

Isotopic Signatures in Adult Dogs

The isotopic data for the dogs under study show an assemblage of animals with a varied diet. Some dogs have isotopic values that reflect a highly carnivorous diet similar to that of the large canid CRII 459 of the E–MBA (dated to the range 1932–1630 cal BC), or to that of the hyper-carnivorous wildcat. Others at the opposite extreme, have a significant proportion of plants in their diet, and scarcely differ from the domestic ungulates. In total, 17 of the 23 adult dogs studied have $\delta^{15}N$ values lower than the large dog CRII 459, and only one (CRCRV05-68) has values equal to the wild cat (Fig. 9).

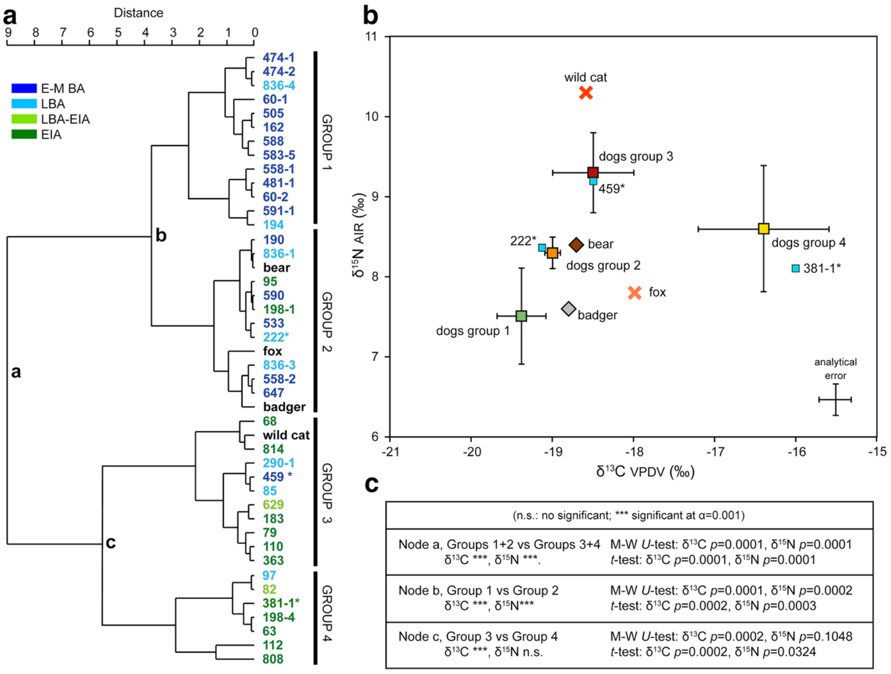
Leaving aside juvenile specimens, the gap between mean values of dogs and cattle in each period studied is practically nil in $\delta^{13}C$ and below that expected for a complete trophic level in $\delta^{15}N$ (Table 5).

However, the standard deviation in both isotopes (especially in $\delta^{13}C$) is high in the LBA and particularly notable in the EIA. Therefore, it does not seem very accurate to rely only on the comparison of mean values to describe the canine diet.

Another way to compare the different types of canine diets is a cluster analysis, including adult dogs and the remaining carnivores. Interestingly, the dogs are grouped into four clusters that we interpret as four main diet types for Can Roqueta dogs (Fig. 11).

The dogs in group 1 are mainly from the E–MBA (two are from the LBA) and show the lowest average $\delta^{15}N$ values and most negative $\delta^{13}C$ values (Table 6). The diet of these dogs would have contained a substantial proportion of vegetable protein derived from C_3 plants. They differ significantly from group 2, which includes dogs of all periods and carnivores with mixed diets (bears, foxes and badgers). They have intermediate isotopic values and could be considered genuinely omnivorous.

Group 3 is made up of the animals with the most carnivorous diet, including some LBA and EIA dogs along with the possible wolf CRII459 from the E–MBA. They are characterized by higher isotopic values, mainly in $\delta^{15}N$, but also in $\delta^{13}C$. The only canid classified by its osteometric data as a wolf reveals higher values, indicating that it consumed more meat than the other canids of the E–MBA, although



(n.s.: no significant; *** significant at α=0.001)	
Node a, Groups 1+2 vs Groups 3+4 $\delta^{13}C$ ***, $\delta^{15}N$ ***.	M-W *U*-test: $\delta^{13}C$ $p=0.0001$, $\delta^{15}N$ $p=0.0001$ *t*-test: $\delta^{13}C$ $p=0.0001$, $\delta^{15}N$ $p=0.0001$
Node b, Group 1 vs Group 2 $\delta^{13}C$ ***, $\delta^{15}N$***	M-W *U*-test: $\delta^{13}C$ $p=0.0001$, $\delta^{15}N$ $p=0.0002$ *t*-test: $\delta^{13}C$ $p=0.0002$, $\delta^{15}N$ $p=0.0003$
Node c, Group 3 vs Group 4 $\delta^{13}C$ ***, $\delta^{15}N$ n.s.	M-W *U*-test: $\delta^{13}C$ $p=0.0002$, $\delta^{15}N$ $p=0.1048$ *t*-test: $\delta^{13}C$ $p=0.0002$, $\delta^{15}N$ $p=0.0324$

Fig. 11 **a** Cluster analysis (Ward's method) of adult dogs and other carnivores from Can Roqueta. The large canids are marked with an asterisk. **b** Bivariate diagram showing mean isotopic values of the four groups of adult dogs (bars are ± standard error) and single values of other carnivores. Large canids, although included in the groups, are represented separately. **c** Mann–Whitney U- and t-test of the differences between the dietary groups obtained in the cluster. The Early–Middle Bronze Age data are taken from Grandal-d'Anglade et al. (2019)

Table 6 Isotopic values of the dog groups obtained in the cluster analysis

	n	$\delta^{13}C$ ‰				$\delta^{15}N$ ‰			
		Average	SD	Min	Max	Average	SD	Min	Max
Group 1	13	−19.4	0.3	−20	−19	7.5	0.6	6.2	8.2
Group 2	10	−19	0.1	−18.7	−19.1	8.3	0.2	8	8.6
Group 3	9	−18.7	0.5	−17.9	−19.2	9.4	0.5	8.8	10.3
Group 4	7	−16.4	0.8	−14.7	−17.1	8.6	0.8	7.4	9.5

this is below the level of human males, who have more animal protein in their diet. Therefore, the isotopic data does not confirm the classification based on the archaeozoological analysis and raises questions about whether this canid was a larger dog, even a hybrid that fed differently. Also, LBA and EIA dogs are located within the levels of humans in the EIA.

Finally, group 4 is composed of a set of mainly EIA dogs (only one is from the LBA) that are clearly differentiated by a marked shift towards less negative $\delta^{13}C$ values, yet without a proportional increase in $\delta^{15}N$ values, which in turn vary greatly.

This deviation in $\delta^{13}C$ (Group 4) might be interpreted as being a result of the introduction of foodstuffs of a marine origin into the diet. However, the lack of evidence of this type of alimentation (recall that the use of marine resources was only sporadic) is a constant in all the excavated sectors within the archaeological area of Can Roqueta in the Bronze Age and EIA, even in periods when ceramic materials indicative of connections with the Mediterranean are frequent. However, only the coastal prehistoric sites in the Mediterranean area have the potential to incorporate a significantly marine diet. Irrespective of their distance from the coast, none of the Bronze Age sites where isotopic studies have been carried out in Mediterranean Iberia (Motilla del Azuer, Cova de La Pastora, Coveta del Frare, Castillejo del Bonete) has any record of foodstuffs of a marine origin (García Borja et al. 2013; McClure et al. 2011; Nájera Colino et al. 2010; Salazar-García et al. 2013). Nor has this type of alimentation been detected at localities in the Balearic Islands (Van Strydonck et al. 2005) or Sardinia (Lai et al. 2013) from the same era.

Ruling out the possibility of foodstuffs of a marine origin, the most plausible explanation for this variation is the introduction of C_4 plants such as millet. The contribution of millet could be either direct or indirect, that is, through other animals fed with millet. The $\delta^{15}N$ values of some of the Group 4 dogs reflect a notable consumption of animal protein, but millet does not appear to have played a relevant role in the feeding of domestic livestock (EIA pigs do not show any evidence of this type of feed). Only some of the analysed EIA cows show evidence of the consumption of C_4 plants, and they also have higher $\delta^{15}N$ values, similar to those of the dogs (see Fig. 9).

The strongly vegetarian signal of C_3 is evident in the E–MBA, both in humans and dogs (Grandal-d'Anglade et al. 2019). In dogs this is interpreted as a specific food preparation, richer in cereals for larger dogs (probably devoted to carrying loads) (Grandal-d'Anglade et al. 2019). Although the dogs' diet continues to show a certain homogeneity, from the LBA dogs ate more animal protein, while in the EIA there was increased variety among dogs, perhaps reflecting greater social diversity among the humans who kept them. Interestingly, the analysed EIA humans also show slightly more carnivorous values (possibly more meat and/or more milk) than the E–MBA humans (Albizuri et al. in press). These differences could be linked with the type of social structure of each period. The social structure was much more homogeneous in the E–MBA, when no differentiation is seen in the funerary furnishings (Albizuri 2011a); however, it became more unequal from the Late Bronze Age onwards, judging from the materials studied at the nearby Can Piteu urnfield necropolis. From the EIA, Can Piteu contained imported materials, which suggests the emergence of an elite who controlled commerce with other areas of the Mediterranean. All this raises important questions about the economic specialisation of certain settlements, about mobility and trade in this period, and about the growing importance of the horse at a time when social differentiation, militarisation and territoriality were increasing (López Cachero and Albizuri 2009; López-Cachero 2014). In short, the growing social inequality that comes to light in the Can Piteu necropolis can be assumed to be connected with the increase in the variability of the canine morphology and diet that is discerned from the EIA on.

Origins of the Variability in the Diet of Dogs

In the case of Can Roqueta, the variety within mixed diets indicates that the dogs of the Bronze Age and EIA did not feed freely. The choice of a diet rich in vegetable proteins and carbohydrates suggests that humans provided their food. The dogs of the E–MBA and LBA are characterized by an omnivorous diet that gradually became more carnivorous with the onset of the EIA, when the greatest variability in the canine diet is observed. An exception is provided by a few individuals with $\delta^{13}C$ signatures that have shifted towards more positive values, which are interpreted as a new cereal input, albeit in this case of a C_4 type. The range of diets of EIA dogs is remarkably broad and there could be several overlapping explanations.

Making use of both ethnographic and isotopic data, some researchers have associated the nitrogen and carbon values seen in dogs and pigs with the coprophagy that is habitual in the two species (Losey et al. 2013; Tankersley and Koster 2009). The consumption of human faeces would explain the homogeneity of the isotopic values in the cases cited, but not in Can Roqueta, where the pattern observed from the LBA is different (Fig. 9). The pigs studied show values different from those of the dogs.

In Can Roqueta the dogs may have adapted to the diet of their masters and been fed by them in accordance with a specific dietary regime from period to period. The aim of this type of diet may have been to provide these animals with the energy required to carry out strenuous tasks such as herding. This would explain the need to supply certain specimens with a large quantity of carbohydrates to ensure they had an efficient high-energy diet for work. Let us not forget that during the LBA and EIA sheep and goats came to predominate over other species and that herding or guarding the flock would have been one of the most common tasks for dogs. A significant percentage of EIA dogs were fed a higher proportion of cereals, something also seen in modern-day livestock guardian dogs, such as the Kangals from Turkey. Kangals are traditionally nourished with a mixture of barley flour, oats and wheat, with the addition of whey or milk and yogurt, called yal. Only on very rare occasions are they given leftovers of lamb bone. Meat is normally available to dogs only in the form of what they can catch, usually rodents in the desert or around the village, or an odd bird or hare (Isik 2009).

The strongest E–MBA specimens, some with load pathologies, show diets with a high proportion of cereal, which could be related to their activity (Grandal-d'Anglade et al. 2019). However, dogs—especially the heaviest—were probably only used as pack animals occasionally for short–medium distances. An experiment conducted in North America with huskies as a reasonable proxy for extinct Plains dog breeds demonstrated that animals weighing 25 kg, with a 12–14 kg load, were able to travel 27 km in 7 h. Environmental conditions are important because the load is lighter in summer than in winter. Cooler temperatures kept dogs from overheating and snow both reduced friction on the *travois* and provided dogs with water (Henderson 1993). A few other cases with this pathology have been detected in the

EIA (currently under study) and may therefore indicate that dogs were used for carrying loads over time, even when equids were already well represented at the site. From the EIA, the economy seems more diversified with higher cereal production, evidenced by the EIA silos, which are larger than those of the LBA or the E–MBA (Albizuri, Alonso and López Cachero 2011a). This may be related to the increase in commerce and greater transportation needs, with surplus cereal being sent to other points along the coast, for which horses and bovines would be necessary.

The increase in trade and diversification of economic activity could be related to the variability in the canine diet, which, from the EIA, includes a more carnivorous group that could correspond to the different use of these animals. One possibility is that dogs were used in hunting activities or to accompany people on medium and long-distance journeys (to stock up on minerals and other raw materials, as well as make exchanges with other groups), which would involve obtaining meat. Another possibility is that the dogs used for herding or as livestock guardians could be fed with a mixture of cereals and dairy just like the modern-day Kangal.

Dogs in current mobile hunter-gatherer societies are basically fed with hunted animals, that is, with easily obtainable food that does not require prior storage. In sedentary agropastoral societies, dogs are fed with a mixture of flour derived from cereals and water or milk, among other things, due to the presence of storage infrastructures.

Ethnographic studies of American populations, such as the Miskito of Nicaragua, have revealed that hunter-gatherer societies paid considerable attention to the diet of their dogs because for them the dogs are a fundamental work tool. The dogs must not go hungry to ensure that they perform their work as expected, and their food is the same as that prepared at home for the human population (Tankersley and Koster 2012). In the region of Lake Baikal in Siberia the food given to the dogs is cooked separately, and although it is very similar to the human nutrition, it includes less favoured items such as tendons, hoof, periosteum, intestines and blood (Bocherens et al. 2015).

In general, it is not surprising that the canine diet became more diversified as EIA communities in Europe became more mobile, with extensive contacts that suggest the arrival in the Iberian Peninsula of new foodstuffs and animals, such as wine, oil, chicken, donkeys, preserved fish, and so on (Albizuri et al. in press). With the current state of research, assessing the isotopic impact of so many dietary changes on the human diet is complicated. Equally complicated would be to assess this impact on the feeding of dogs; however, in general, the entry of new foods would easily explain the existence of more diversified diets.

Cereals and Legumes in the Diet of Dogs

The diet of the hypocarnivorous dogs, so different from that of their undomesticated ancestors, calls for reflection. This diet could be based on a combination of C_3 cereals and possibly pulses that, as fixers of atmospheric nitrogen, contribute to reducing the $\delta^{15}N$ value. These two types of plants have complementary compositions of essential amino acids and an optimal protein content (Hendricks 1999). Together with a small quantity of animal protein, they could meet the dietary requirements of an adult dog (Shoveller and Atkinson 2008) and provide a high level of energy in the form of carbohydrates.

The isotopic values obtained from Can Roqueta point to a diet that includes C_3 cereals with gluten in the E–MBA, and C_4 millet, without gluten, in the EIA. The two types of cereals are recorded in the diets of animals, mainly dogs and pigs, in Asia and Europe from the Neolithic onwards (Dai et al. 2016; Pearson et al. 2015; Pechenkina et al. 2005). At the Neolithic site of Çatalhöyük (Turkey), the 19 dogs analysed have values that fluctuate between -21.3‰ and -16.3‰ for carbon, and between 7.7‰ and 13.2‰ for nitrogen. This indicates that the canids directly or indirectly consumed C_4 plants and they had variable diets with some individuals being highly carnivorous and others having a mixed diet. According to the authors of the study, however, these ranges could be explained by the consumption of the intestines of herbivorous animals and their contents (Pearson et al. 2015).

The dependence on cereals as a staple food can also be seen at some Neolithic sites in Languedoc (southern France), where the isotopic signatures of eight dogs fall within the same range as the humans studied, and the $\delta^{15}N$ enrichment with respect to the ovicaprines is less than 2‰ (Herrscher and Le Bras-Goude 2010).

This type of diet is not surprising in the light of certain genetic studies that have shown that metabolic adaptation to a diet rich in starch, as may have occurred in agricultural societies, was a determining factor in the domestication of the dog (Axelsson et al. 2013).

In the northeast of the Iberian Peninsula, it is known that broomcorn millet (*Panicum miliaceum*) and foxtail millet (*Setaria viridis* spp. *Italica*) were cultivated, albeit scarcely, from the E–MBA onwards (Alonso 2000). The same is true of central France (Herrscher and Bras-Goude 2008, 2010) and northern Italy (Tafuri et al. 2009). In Can Roqueta (Can Revella sector) their presence has been identified in structures from the LBA to EIA, increasing over time (Grandal-d'Anglade et al. 2019; Albizuri et al. in press); however, they were possibly already cultivated in the E–MBA (remember the diet of the fox CRII 481). These cereals are also detected based on carbon levels in the canine diet of the LBA and above all the EIA. Moreover, remains of broomcorn and foxtail millet have been recovered from nearby EIA sites: Bòbila Madurell (Sant Quirze del Vallès) and the Sitges site of the U.A.B. (Cerdanyola del Vallès) (Albizuri, Alonso and López Cachero 2011a; Alonso 2000).

Some dogs and cows from Can Roqueta may thus have consumed broomcorn millet or foxtail millet in the form of meal mixed with other foodstuffs to produce fodder, a traditional practice with other species such as pigs and cows in Galicia (NW Iberian Peninsula) during the Roman period of the Castro culture (Vázquez Varela 1994).

From the E–MBA, millet crops were introduced into the Iberian Peninsula from France via the central-eastern Pyrenees, but these crops expanded greatly throughout the western Mediterranean from the seventh to sixth centuries BC (Alonso 2000). This coincides with the representation of this cereal in Can Roqueta (Albizuri et al. in press) and with the isotopic values observed in the canine diet from the EIA onwards. The spread of millet represented an advance for agriculture and an improvement in the diet because it is a spring crop, which allows the period of field exploitation to be extended and thus makes the most of available resources. Moreover, it adapts easily to all sorts of terrains and climates, although it originated in dry regions and its cycle is short. As it does not contain gluten, it is easier to digest. It can be used for grazing, silage or dry fodder. Its leaves and fine stalks make it highly desirable as fodder. Its nutritional value, including the protein content, exceeds that of many summer fodder crops.

Legumes have been cultivated in the Iberian part of the Mediterranean since the Early Neolithic. Ervil (*Vicia ervilia*), the broad bean (*Vicia fava*), peas (*Pisum sativum*), lentils (*Lens culinaris*) and grass peas/red peas (*Lathyrus cicera/sativus*) have been recorded dating to the middle of the sixth millennium cal BC (Buxó and Piqué 2008). In Can Roqueta the cultivation of legumes is recorded from the E–MBA onwards, with the presence of peas, whereas in the Late Bronze Age the presence of lentils and peas is documented, and in the EIA lentils and broad beans are documented (Grandal-d'Anglade et al. 2019; Albizuri et al. in press).

Conclusion

The canid population from the LBA to EIA in Can Roqueta showed a morphological homogeneity that may indicate a certain control over their reproduction (or inbreeding); however, greater diversity is evident during the EIA. The presence of large canids may reflect selective breeding by choosing reproductive specimens with specific physical features to perform different tasks. The osteometric data of the largest and most gracile specimen CRII 381-1 lead us to propose classifying it as a hybrid, taking into account that its diet included millet, which reinforces this interpretation.

The isotopic results indicate changes from the E–MBA. Humans had a mixed diet but ate a higher proportion of animal protein (meat and/or milk) than in the E–MBA. The plant species consumed were mainly cereals with gluten (C_3), but include a low proportion of type C_4 cereals without gluten, such as broomcorn millet and foxtail millet.

Thus in Can Roqueta the dogs may well have adapted to the diet of their masters (as mentioned above). The aim of this type of diet may have been to provide these animals with the energy required to carry out strenuous tasks such as herding. In the E–MBA the appearance of C_3 cereals and probably legumes can be observed in the diet of dogs, which were probably bred as working animals. By controlling their alimentation, their effectiveness in performing their tasks would have been ensured, whereas poorly-fed dogs would have spent their time trying to find food, thus neglecting their work.

From the LBA there is an increase in variability in the canid population, and four groups can be differentiated throughout the entire chronological sequence considered here. To a greater or lesser extent, the diet was based on the combination of group C_3 and C_4 plants, such as broomcorn millet or foxtail millet, highlighting the appearance of a carnivorous group of dogs.

A large number of the dogs were fed a high proportion of vegetables. Ethnographic comparison suggests that this may be related to the use of dogs for herding or guarding sheep and goats, remembering that ovicaprines made up the main herd in Can Roqueta. It is also possible that dogs were used in transport tasks and pulling loads, especially from the pathologies analysed in the E–MBA. Another group of dogs, however, had a more carnivorous diet, including the large canid CRII 459 of E–MBA. This diet is similar to that of the seven analysed humans from the EIA. These humans were buried in silo-like structures, unlike most of the population that was incinerated in the Can Piteu necropolis. In this case, these dogs could have carried out a type of differentiated activity that may have been related to the greater mobility of their owners, perhaps linked to trade or the search for raw materials. These dogs seem to have played a special role associated with funeral rituals in which the animal accompanies a deceased human.

In any case, it should be remembered that from the EIA a growing variability in socio-economic activities is evident, highlighted by the increase in cereal production and trade. This context is consistent with the diversity observed in both morphology and diet, so we can assume that EIA dogs would have performed different functions within the society and played increasingly diverse and specialized roles. This greater variability in the canine diet may reflect the diversity of the sources of food consumed by humans and their dogs, or perhaps corresponds to the adaptation of dogs to various uses: herding, transport work, guarding the community, hunting, rituals, etc. It may have also been a response to the expansion of economic activities, trade and the increasing social stratification that is evident from the EIA. In general, it is not surprising that the canine diet became more diversified as the EIA communities in Europe became more mobile, with extensive contacts that would imply the arrival of new foods and animals (wine, oil, chicken, donkeys, preserved fish, etc.) in the Iberian Peninsula.

Acknowledgements This paper was written as part of the research undertaken by the consolidated research group SGR2017-00011 *Seminari d'Estudis I Recerques Prehistòriques* (SERP) and within the Projects HAR2013-48010-P and HAR2017-87695-P funded by the Spanish Ministry of Economy and Competitiveness. We want to thank the reviewers of this paper because their insights have helped improve the work.

References

Agricola, G. (1556/1912). *De Re Metallica*. (H. C. Hoover & L. H. Hoover, Ed., H. C. Hoover & L. H. Hoover, Trans.). Dover Publications.

Albizuri, S. (2011a). *La ofrenda animal durante el Bronce Inicial en Can Roqueta II (Sabadell, Vallès Occidental): Arqueozoología del ritual funerario*. PhD dissertation, Universitat de Girona, Girona, Spain. Departament d'Història i Història de l'Art (2009). http://hdl.handle.net/10803/84118.

Albizuri, S. (2011b). Animales sacrificados para el cortejo fúnebre durante el Bronce Inicial (2300–1300 cal BC): El asentamiento de Can Roqueta II (Sabadell, Barcelona). *Quaderns de Prehistòria i Arqueologia de Castelló, 29,* 7–26.

Albizuri, S., Alonso, N., & López Cachero, F. J. (2011a). Economia i canvi social a Catalunya durant el bronze final. In S. Valenzuela-Lamas, N. Padrós, M. C. Belarte, & J. Sanmartí (Eds.), *Economia agropecuària i canvi social a partir de les restes bioarqueològiques: El primer mil·lenni aC a la Mediterrània occidental*. V Reunió Internacional d'Arqueologia de Calafell (Abril 2009). Arqueo Mediterrània, 12 (pp. 11–36). Barcelona: Universitat de Barcelona.

Albizuri, S., Fernández, M., & Tomás, X. (2011b). Evidencias sobre el uso del perro en la carga durante el Bronce Inicial en la Península Ibérica: El caso de Can Roqueta II (Sabadell, Barcelona). *Archaeofauna, 20,* 139–155.

Albizuri, S., Maroto, J., Nadal, J., Majó, T., Sánchez Marco, A., Carlús, X., Rodríguez, A., & Palomo, A. (2015). Wild carnivore and wild bird deposits in an agro-pastoral community during the Bronze Age: Can Roqueta II (Northeast Iberian Peninsula). *Munibe Antropologia-Arkeologia, 66,* 163–184.

Albizuri, S., Nadal, J., Martín, P., Gibaja, J. F., Martín Cólliga, A., Esteve, X., Oms, X., Martí, M., Pou, R., López-Onaindia, D., & Subirà, M. E. (2019a). Dogs in funerary contexts during the Middle Neolithic in the northeastern Iberian Peninsula (5th–early 4th millennium BCE). *Journal of Archaeological Science: Reports, 24,* 198–207.

Albizuri, S., Valenzuela-Lamas, S., Bosch, D., Fernández, M., & López Cachero, F. J. (2019b). Equid use and provision during the Early Iron Age in Can Roqueta (NE Iberian Peninsula): Zooarchaeological study and first strontium isotope results (^{87}Sr/^{86}Sr). *Journal of Archaeological Science: Reports*. https://doi.org/10.1016/j.jasrep.2019.101907

Albizuri, S., López Cachero, F. J., Marlasca, R., Terrats, N., García, A., Majó, T., Carlús, X., Oliva, M., Rodríguez, A., & Palomo, A. (2020). Los restos de Gallo (*Gallus gallus*) como bioindicador de presencia foránea: El paraje de Can Roqueta en el noreste de la Península Ibérica y su relación con el comercio fenicio. In S. Celestino Pérez & E. Rodríguez González (Eds.), *Un viaje entre el Oriente y el Occidente del Mediterráneo*. Actas del IX Congreso Internacional de Estudios Fenicios y Púnicos, Mytra 5, Vol. II (pp. 675–687). Mérida: Instituto de arqueologia de Mérida.

Albizuri, S., Grandal-d'Anglade, A., Terrats, N., Oliva, M., Majó, T. Antolín, F., & López Cachero, F. J. (in press). Continuity and innovation in human diets through bioarchaeological analysis: The community of Can Roqueta in the pre-coastal of Barcelona and its Mediterranean contacts, 8th–6th centuries BC. In *Mixed tastes: Diets, cuisines and consumption practices in ancient Western Mediterranean*. Annual Papers of Mediterranean Archaeology.

Alonso, N. (2000). Registro arqueobotánico de Cataluña Occidental durante el II y I milenio A.N.E. *Complutum, 11,* 221–238.

Altuna, J. (1994). El perro en los yacimentos arqueológicos del norte de la Península Ibérica. In J. A. Lasheras (Ed.), *Homenaje al Dr. Joaquín González Echegaray*. Monografías Museo y Centro de Investigación de Altamira 17 (pp. 159–162). Madrid: Ministerio de Cultura.

Ambrose, S. H. (1990). Preparation and characterization of bone and tooth collagen for isotopic analysis. *Journal of Archaeological Science, 17,* 431–451.

Ambrose, S. H., & 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. In J. B. Lambert & G. Grupe (Eds.), *Prehistoric human bone archaeology at the molecular level* (pp. 1–37). Berlin: Springer-Verlag.

Ames, K. M., Richards, M. P., Speller, C. F., Yang, D. Y., Lyman, R. L., & Butler, V. L. (2015). Stable isotope and ancient DNA analysis of dog remains from Cathlapotle (45CL1), a contact-era site on the Lower Columbia River. *Journal of Archaeological Science, 57,* 268–282.

Araus, J. L., Febrero, A., Buxó, R., Camalich, M. D., Martín, D., Molina, F., Rodríguez-Ariza, M. O., & Romagosa, I. (1997). Changes in carbon isotope discrimination in grain cereals from different regions of the western Mediterranean Basin during the past seven millennia: Palaeoenvironmental evidence of a differential change in aridity during the late Holocene. *Global Change Biology, 3,* 107–118.

Arbogast, R. M., Deschler-Erb, S., Marti-Grädel, E., Plüss, P., Hüster Plogmann, H., & Schibler, J. (2005). Du loup au 'chien des tourbières' : Les restes de canidés sur les sites lacustres entre Alpes et Jura. *Hommage à Louis Chaix* (pp. 171–183). Geneva: Muséum d'Histoire naturelle Genève.

Axelsson, E., Ratnakumar, A., Arendt, M. L., Maqbool, K., Webster, M. T., Perloski, M., Liberg, O., Arnemo, J. M., Hedhammar, A., & Lindblad-Toh, K. (2013). The genomic signature of dog domestication reveals adaptation to a starch-rich diet. *Nature, 495,* 360–364.

Bizet, Y. (2000). Il était une fois: Les voitures à chien au début du XXème siècle. Romorantin. http://www.chapitre.com/CHAPITRE/fr/search/Default.aspx?editeur=Communication%20Presse%20Edition.

Bocherens, H., & Drucker, D. (2003). Trophic level isotopic enrichment of carbon and nitrogen in bone collagen: Case studies from recent and ancient terrestrial ecosystems. *International Journal of Osteoarchaeology, 13*(1–2), 46–53.

Bocherens, H., Billiou, D., Patou-Mathis, M., Bonjean, D., Otte, M., & Mariotti, A. (1997). Paleobiological implications of the isotopic signatures (^{13}C, ^{15}N) of fossil mammal collagen in Scladina Cave (Sclayn, Belgium). *Quaternary Research, 48,* 370–380.

Bocherens, H., Drucker, D., Billiou, D., & Moussa, I. (2005). Une nouvelle approche pour évaluer l'état de conservation de l'os et du collagène pour les mesures isotopiques (datation au radiocarbone, isotopes stables du carbone et de l'azote). *L'Anthropologie, 109,* 557–567.

Bocherens, H., Drucker, D., Germonpré, M., Lázničková-Galetová, M., Naito, Y. I., Wissing, C., Brůžek, J., & Oliva, M. (2015). Reconstruction of the Gravettian food-web at Předmostí I using multi-isotopic tracking (^{13}C, ^{15}N, ^{34}S) of bone collagen. *Quaternary International, 359–360,* 211–228.

Bruck, J. (1999). Ritual and rationality: Some problems of interpretation in European archaeology. *European Journal of Archaeology, 2*(3), 313–314.

Buxó, R., & Piqué, R. (2008). *Arqueobotánica: Los usos de las plantas en la península Ibérica*. Barcelona: Ariel.

Cámara Serrano, J. A., Lizcano, R., Pérez Bareas, C., & Gómez del Toro, E. (2008). Apropiación, sacrificio, consumo y exhibición ritual de los animales en el polideportivo de Martos: Sus implicaciones en los orígenes de la desigualdad social. *Cuadernos de prehistoria y arqueología de la Universidad de Granada, 18,* 55–90.

Cannon, A., Schwarcz, H. P., & Knyf, M. (1999). Marine based subsistence trends and the stable isotope analysis of dog bones from Namu, British Columbia. *Journal of Archaeological Science, 26,* 399–407.

Capuzzo, G., & López-Cachero, F. J. (2017). De la inhumación a la cremación en el nordeste peninsular: Cronología y sociedad. In J. A. Barceló, I. Bogdanovic, & B. Morell (Eds.), *Ibercrono: Cronometrías para la historia de la Península Ibérica* (pp. 192–208). Barcelona: CEUR-WS. Org.

Carlús, X., López Cachero, F. J., Oliva, M., Palomo, A., Rodríguez, A., Terrats, N., Lara, C., & Villena, N. (Eds.). (2007). *Cabanes, sitges i tombes: El paratge de Can Roqueta (Sabadell, Vallès Occidental) del 1300 al 500 aC. Quaderns d'Arqueologia 4*. Sabadell: Museu d'Història de Sabadell.

Carlús, X., López Cachero, F. J., Terrats, N., Oliva, M., Palomo, A., & Rodríguez, A. (2008). Diacronia durant la prehistòria recent a Can Roqueta (Sabadell-Barberà del Vallès, Vallès Occidental) entre el VI i el I mil·lenni cal ANE. *Cypsela, 17,* 115–142.

Casey, M. M., & Post, D. M. (2011). The problem of isotopic baseline: Reconstructing the diet and trophic position of fossil animals. *Earth-Science Reviews, 106,* 131–148.

Catagnano, V. (2016). *Aproximación morfométrica y paleogenética al estudio de la variabilidad de canis l. familiaris en la península ibérica desde el neolítico hasta época romana y su contextualización en el ámbito del mediterráneo occidental*. PhD dissertation, Universitat Autònoma de Barcelona, Departament de Prehistòria.

Chevallier Charlotte, A. G. (2013). *Le chien de trait, d'hier à aujourd'hui*. Thèse Docteur Vétérinaire. Lyon: Université Claude Bernard.

Clark, K. M. (1995). The later prehistoric and protohistoric dog: The emergence of canine diversity. *Archaeozoologia, 7,* 9–32.

Conlin, E. (2003). Los inicios del III milenio a.C. en Carmona: Las evidencias arqueológicas. *Carel, 1,* 83–143.

Dai, L. L., Li, Z. P., Zhao, C. Q., Yuan, J., Hou, L. L., Wang, C. S., Fuller, B. T., & Hu, Y. W. (2016). An isotopic perspective on animal husbandry at the Xinzhai site during the initial stage of the legendary Xia Dynasty (2070–1600 BC). *International Journal of Osteoarchaeology, 26,* 885–896.

Daza, A. (2011). Los depósitos de perros. In C. Blasco, C. Liesau, & P. Ríos, (Eds.), *Yacimientos calcolíticos con campaniforme de la región de Madrid* (pp. 211–222). Madrid: Universidad Autónoma de Madrid, Patrimonio Arqueológico 6.

De Grossi, J. (2008). L'uso dei cani nei riti di fondazione, purificazione e passaggio nel mondo antico. In F. D'Andria, J. De Grossi, & G. Fiorentino (Eds.), *Uomini, piante e animali nella dimensione del sacro* (pp. 71–81). Bari: Edipuglia.

De Grossi Mazzorin, J., & Tagliacozzo, A. (2000). Morphological and osteological changes in the dog from the Neolithic to the Roman Period in Italy. In S. J. Crockford (Ed.), *Dogs through time: An archaeological perspective.* BAR International Series 889 (pp. 141–161). Oxford: Archaeopress.

De Lavigne, G. (2014). *The draft dog, past and present*. E-book, Lulu.com

De Niro, M. J. (1985). Post-mortem preservation and alteration of *in vivo* bone collagen isotope ratios in relation to paleodietary reconstruction. *Nature, 317,* 806–809.

Drucker, D. G., Bridault, A., Hobson, K. A., Szuma, E., & Bocherens, H. (2008). Can carbon-13 in large herbivores reflect the canopy effect in temperate and boreal ecosystems? Evidence from modern and ancient ungulates. *Palaeogeography, Palaeoclimatology, Palaeoecology, 266,* 69–82.

Evans, H. E., & Lahunta, A. (2013). *Miller's anatomy of the dog* (4th ed.). Saint Louis: Elsevier Saunders.

Farquhar, G. D., Ehleringer, J. R., & Hubick, K. T. (1989). Carbon isotope discrimination and photosynthesis. *Annual Review of Plant Physiology and Plant Molecular Biology, 40,* 503–537.

Flohr, P., Muldner, G., & Jenkins, E. (2011). Carbon stable isotope analysis of cereal remains as a way to reconstruct water availability: Preliminary results. *Water History, 3*(2), 121–144.

Fogel, M. L., Tuross, N., & Owsley, D. W. (1989). Nitrogen isotope tracers of human lactation in modern and archaeological populations. In *Annual report of the Director 1988–1989* (pp. 111–116). Washington: Geophysical Laboratory, Carnegie Institute of Washington.

Galik, A. (2000). *Dog remains from the Late Hallstatt period (500–400 BC) of the Chimney Cave Durezza, near Villach, Austria*. BAR International Series 889 (pp.129–140). Oxford: Archaeopress.

García Borja, P., Pérez Fernández, A., Biosca Cirujeda, V., Ribera i Gomes, A., & Salazar-García. D. C. (2013). Los restos humanos de la Coveta del Frare (La Font de la Figuera, València). In P. García Borja, E. Revert Francés, A. Ribera i Gomes, & V. Biosca Cirujeda, (Eds.), *El naixement d'un poble: Història i arqueologia de La Font de la Figuera* (pp. 47–61). La Font de la Figuera: Ajuntament de la Font de la Figuera.

García Vázquez, A., Pinto-Llona, A. C., & Grandal-d'Anglade, A. (2018). Brown bear (*Ursus arctos* L.) paleoecology in the Upper Pleistocene and Holocene of the NW of the Iberian Peninsula: A stable isotopes study. *Quaternary International, 481,* 43–51.

Germonpré, M., Lázničková-Galetová, M., & Sablin, M. V. (2012). Palaeolithic dog skulls at the Gravetian Předmostí site, the Czech Republic. *Journal of Archaeological Science, 39,* 184–202.

Germonpré, M., Sablin, M., Stevens, R. E., Hedges, R. E. M., Hofreiter, M., & Després, V. (2009). Fossil dogs and wolves from Palaeolithic sites in Belgium, the Ukraine and Russia: Osteometry, ancient DNA and stable isotopes. *Journal of Archaeological Science, 36,* 473–490.

Godinho, R., Llaneza, L., Blanco, J. C., Lopes, S., Álvares, F., García, E. J., & Ferrand, N. (2011). Genetic evidence for multiple events of hybridization between wolves and domestic dogs in the Iberian Peninsula. *Molecular Ecology, 20*(24), 5154–5166.

Grandal-d'Anglade, A., Albizuri, S., Nieto, A., Majó, T., Agustí, B., Alonso, N., Antolín, F., López, J. B., Moya, A., Rodríguez, A., & Palomo, A. (2019). Dogs and foxes in Early–Middle Bronze Age funerary structures in the northeast of the Iberian Peninsula: Human control of canid diet at the sites of Can Roqueta (Barcelona) and Minferri (Lleida). *Archaeological and Anthropolgical Sciences, 11*(8), 3949–3978.

Guiry, E. J. (2012). Dog as analogs in human stable isotope based paleodietary reconstructions: A review and consideration for future use. *Journal of Archaeological Method and Theory, 19*(3), 351–376.

Guiry, E. J., & Grimes, V. (2013). Domestic dog (*Canis familiaris*) diets among coastal Late Archaic groups of northeastern North America: A case study for the canine surrogacy approach. *Journal of Anthropological Archaeology, 32*(4), 732–745.

Halffman, C. M., & Velemínský, P. (2015). Stable isotope evidence for diet in early medieval Great Moravia (Czech Republic). *Journal of Archaeological Science: Reports, 2,* 1–8.

Hammer, O., Harper, D. A. T., & Ryan, P. D. (2001). PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica, 4*(1), 1–9.

Handley, L. L., Austin, A. T., Stewart, G. R., Robinson, D., Scrimgeour, C. M., Raven, J. A., Heaton, T. H. E., & Schmidt, S. (1999). The ^{15}N natural abundance (δ^{15}N) of ecosystem samples reflects measures of water availability. *Australian Journal of Plant Physiology, 26,* 185–199.

Harcourt, R. A. (1974). The dog in prehistoric and early historic Britain. *Journal of Archaeological Science, 1*(2), 151–175.

Hawthorne, A. J., Booles, D., Nugent, P. A., Gettinby, G., & Wilkinson, J. (2004). Body weight changes during growth in puppies of different breeds. *Journal of Nutrition, 134,* 2027–2030.

Heaton, T. H. E. (1999). Spatial, species, and temporal variations in the ^{13}C /^{12}C ratios of C_3 plants: Implications for palaeodiet studies. *Journal of Archaeological Science, 26,* 637–649.

Hedges, R., & Reynard, L. (2007). Nitrogen isotopes and the trophic level of humans in archaeology. *Journal of Archaeological Science, 34,* 1240–1251.

Henderson, N. (1993). Replicating dog travois travel on the northern plains. *Plains Anthropologist, 39*(148), 145–159.

Hendriks, W. H. (1999). Cats and dogs versus pigs and poultry: A nutritional perspective. *Recent Advances in Animal Nutrition in Australia, 12,* 107–114.

Herrscher, E., & Le Bras-Goude, G. (2008). Viande, laitage, poissons ou végétaux? Approche biochimique de l'alimentation néolithique en Toulousain. In J. Vaquer, M. Gandelin, M. Remicourt, & Y. Tchérémissinoff (Eds.), *Défunts néolithiques en Toulousain* (pp. 209–218). Carcassonne: Archives d'Écologie préhistorique.

Herrscher, E., & Le Bras-Goude, G. (2010). Southern French Neolithic populations: Isotopic evidence for regional specificities in environment and diet. *American Journal of Physical Anthropology, 141*(2), 259–272.

Hill, E. (2018). The archaeology of human–dog relations in northwest Alaska. In R. J. Losey, R. P. Wishart, & J. P. Laurens (Eds.), *Dogs in the North: Stories of cooperation and co-domestication*. Arctic worlds communities: Political ecology and ways of knowing (pp. 87–104). London: Routledge.

Hobson, K., Wassenaar, L. I., Milá, B., Lovette, I., Dingle, C., & Smith, T. B. (2003). Stable isotopes as indicators of altitudinal distributions and movements in an Ecuadorean hummingbird community. *Oecologia, 136,* 302–308.

Hobson, K. A., & Quirk, T. W. (2014). Effect of age and ration on diet-tissue isotopic (Δ^{13}C, Δ^{15}N) discrimination in striped skunks (*Mephitis mephitis*). *Isotopes in Environmental and Health Studies, 50*(3), 300–306.

Horard-Herbin, M. P. (2000). Dog management and use in the late Iron Age: The evidence from the Gallic site of Levroux (France). In S. J. Crockford (Ed.), *Dogs through time: An archaeological perspective*. International Council for Archaeozoology, Symposium on the History of the Domestic Dog. BAR International Series 889 (pp. 115–123). Oxford: Archaeopress.

Horard-Herbin, M. P., Tresset, A., & Vigne, J. D. (2014). Domestication and uses of the dog in western Europe from the Paleolithic to the Iron Age. *Animal Frontiers, 4*(3), 23–31.

Hu, Y., Hu, S., Wang, W., Wu, X., Marshalle, F. B., Chen, X., Hou, L., & Wang, C. (2014). Earliest evidence for commensal processes of cat domestication. *PNAS, 111*(1), 116–120.

Isik, G. (2009). Yal: The traditional dog food in Anatolia. *Choban chatter*, *Anatolian Shepherd Dogs International*, *19*(1), 1–6.

Janssens, L. A., Vitales, T., & Lawer, D. (2018). Are spinal deformities in ancient dogs related to weight bearing? The importance of fluctuating asymmetry. *International Journal of Osteoarchaeology, 29,* 168–173.

King, A. A., Fooks, A. R., Aubert, M., & Wandeler, A. I. (Eds.). (2004). *Historical perspective of rabies in Europe and the Mediterranean Basin*. Paris: World Organization for Animal Health (OIE).

Koster, J. M., & Tankersley, K. B. (2012). Heterogeneity of hunting ability and nutritional status among domestic dogs in lowland Nicaragua. *PNAS, 109*(8), E463–E470.

Kuehn, S. R. (2014). Prehistoric dog pathology in the American Bottom: Evidence from the Janey B. Goode Site (11S1232), St. Clair County, Illinois. *Illinois Archaeology, 26,* 97–129.

Laffranchi, Z., Delgado Huertas, A., Jiménez Brobeil, S. A., Granados Torres, A., & Riquelme Cantal, J. A. (2016). Stable C & N isotopes in 2100 year-B.P. human bone collagen indicate rare dietary dominance of C4 plants in NE-Italy. *Scientific Reports, 6,* 38817. https://doi.org/10.1038/srep38817

Lai, L., Tykot, R. H., Usai, E., Beckett, J. F., Floris, R., Fonzo, O., Goddard, E., Hollander, D., Manunza, M. R., & Usai, A. (2013). Diet in the Sardinian Bronze Age: Models, collagen isotopic data, issues and perspectives. *Préhistoires Méditerranéennes*. http://pm.revues.org/795.

Landry, J. M. (1998). L'utilisation du chien de protection dans les Alpes suisses : Une première analyse. *KORA Bericht, 2,* 1–33.

Latham, K. J., & Losey, R. (2019). Spondylosis deformans as an indicator of transport activities in archaeological dogs: A systematic evaluation of current methods for assessing archaeological specimens. *PLoS ONE, 14*(4), e0214575.

Lawler, D., Widga, F. C., Rubin, D. A., Reetz, J. A., Evans, R. H., Tangredi, B. P., Thomas, R. M., Martin, T. J., Hildebolt, C., Smith, K., Leib, D., Sackman, J. E., Avery, J. G., & Smith, G. K. (2016). Differential diagnosis of vertebral spinous process deviations in archaeological and modern domestic dogs. *Journal of Archaeological Science, 9,* 54–63.

Lee-Thorp, J. A. (2008). On isotopes and old bones. *Archaeometry, 50*(6), 925–950.

Liesau, C., Daza, A., Llorente, L., & Morales, A. (2013). More questions than answers: The singular animal deposits from Camino de Las Yeseras (Chalcolithic, Madrid, Spain). *Anthropozoologica, 48*(2), 277–286.

Longin, R. (1971). New method of collagen extraction for radiocarbon dating. *Nature, 230,* 241–242.

López-Cachero, F. J. (2014). Necròpolis d'incineració: Tombes i pràctiques de dipòsit funerari a finals de l'edat del bronze i principis de l'edat del ferro al nord-est peninsular. In *La transició bronze final—1a edat del ferro en els Pirineus i territoris veïns* (pp. 329–370). XII Col·loqui Internacional d'Arqueologia de Puigcerdà. Puigcerdà: Institut d'Estudis Ceretans.

López Cachero, F. J., & Albizuri, S. (2009). Comensalitat durant el bronze final i la primera edat del ferro: Anàlisi dels dipòsits relacionats amb el consum en contextos domèstics i funeraris. In J. Didoli, & S. Sardà, (Eds.), *Ideologia, pràctiques rituals i banquet al nord-est de la península Ibèrica durant la protohistòria* (pp. 57–95). Citerior 5, Tarragona: Arola.

López Cachero, F. J., Albizuri, S., Majó, T., Carlús, X., Oliva Poveda, M., Palomo, A., Rodriguez, A., & Terrats, N. (in press). Depósitos de caballo en Can Roqueta (Sabadell, Barcelona) durante el Bronce Final y la Primera Edad del Hierro. In *Congreso de Prehistoria y Protohistoria del Mediterráneo Occidental*. Museu de Menorca, 27–30 abril 2017.

López Cachero, F. J. & Rovira, M. C. (2012). El Món funerari a la depressió prelitoral catalana entre el bronze final i la primera edat del ferro: ritual i dinamisme social a partir del registre Arqueològic. In M. C. Rovira, F. J. López-Cachero & F. Maziere (Eds.), *Les necròpolis d'incineració entre l'Ebre i el Tíber (segles IX–VI a.C.)* (pp. 37–55). Barcelona: Monografies del Museu d'Arqueologia de Catalunya-Barcelona, 14.

Losey, R. J., Fleming, L. S., Nomokonova, T., Gusev, A. V., Fedorova, N. V., Garvie-Lok, S., Bachura, O. P., Kosintsev, P. A., & Sablin, M. V. (2018). Dogs were domesticated in the Arctic: Culling practices and dog sledding at Ust'-Polui. *Journal of Anthropological Archaeology, 51,* 113–126.

Losey, R. J., Garvie-Lok, S., Leonard, J. A., Katzenberg, M. A., Germonpré, M., Nomokonova, T., Sablin, M. V., Goriunova, O. I., Berdnikova, N. E., & Savel'ev, N. A. (2013). Burying dogs in ancient Cis-Baikal, Siberia: Temporal trends and relationships with human diet and subsistence practices. *PLoS One, 8*(5), 0063740.

Losey, R. J., Bazaliiskii, V., Garvie-Lok, S., Germonpré, M., Leonard, J. A., Allen, A. L., Katzenberg, M. A., & Sablin, M. V. (2011). Canids as persons: Early Neolithic dog and wolf burials, Cis-Baikal, Siberia. *Journal of Anthropological Archaeology, 30*(2), 174–189.

Männel, T. T., Auerswald, K., & Schnyder, H. (2007). Altitudinal gradients of grassland carbon and nitrogen isotope composition are recorded in the hair of grazers. *Global Ecology and Biogeography, 16,* 583–592.

Mariotti, A., Pierre, D., Vedy, J. C., Bruckert, S., & Guillemot, J. (1980). The abundance of natural nitrogen 15 in the organic matter of soils along an altitudinal gradient. *CATENA, 7,* 293–300.

Marlasca, R. (2007). Els materials ceràmics a torn d'importació. In X. Carlús, F. J. López-Cachero, M. Oliva Poveda, A. Palomo, A. Rodriguez, N. Terrats, C. Lara, & N. Villena (Eds.), *Cabanes, sitges i tombes: El paratge de Can Roqueta (Sabadell, Vallès Occidental) del 1300 al 500 ANE* (pp. 96–101). Sabadell: Quaderns d'Arqueologia 4, Museu d'Història de Sabadell.

McClure, S. B., García, O., Roca de Togores, C., Culleton, B. J., & Kennett, D. J. (2011). Osteological and paleodietary investigation of burials from Cova de la Pastora, Alicante, Spain. *Journal of Archaeological Science, 38,* 420–428.

Mitchell, P. (2015). Did disease constrain the spread of domestic dogs (*Canis familiaris*) into Sub-Saharan Africa? *Azania: Archaeological Research in Africa, 50*(1), 1–44.

Moreno-García, M., Pimenta, C., Martinez-Sanchez, R., Barroso, I., Pimenta, V., & Santos, N. (2016). *Caracterizaçao osteometrica das populaçoes atuais de lobo-iberico Canis lupus signatus—um alicerce para o seu reconhecimento no registo arqueozoológico (Poster)*. IV Congresso Iberico Do Lobo, Castelo Branco, Portugal.

Morey, D. F. (2006). Burying key evidence: The social bond between dogs and people. *Journal of Archaeological Science, 33,* 158–175.

Morey, D. F. (2010). *Dogs: Domestication and the development of a social bond*. Cambridge: Cambridge University Press.

Morris, J. (2011). *Investigating animal burials: Ritual, mundane and beyond*. BAR (British Series) 535. Oxford: Archaeopress.

Nájera Colino, T., Molina González, F., Jiménez-Brobeil, S. A., Sánchez Romero, M., Al Oumaoui, I., Aranda Jiménez, G., Delgado-Huertas, A., & Laffranchi, Z. (2010). La población infantil de la Motilla del Azuer: Un estudio bioarqueológico. *Complutum, 21,* 69–102.

Noe-Nygaard, N. (1988). 13C-values of dog bones reveal the nature of changes in Man's food resources at the Mesolithic–Neolithic transition, Denmark. *Chemical Geology: Isotope Geoscience section, 73*(1), 87–96.

Olsen, S. L. (2000). The secular and sacred roles of dogs at Botai, North Kazakhstan. In S. Crockford (Ed.) *Dogs through time: An archaeological perspective*. BAR International Series 889 (pp. 71–92). Oxford: Archaeopress.

Onar, V. (2005). Estimating the body weight of dogs unearthed from the Van-Yoncatepe necropolis in eastern Anatolia. *Turkish Journal of Veterinary and Animal Sciences, 29,* 495–498.

Palomo, A., Terrats, N., Oliva, M., Rodríguez, A., & Majó, T. (2016). El complex arqueològic de Can Roqueta: Un poblat paradigmàtic del bronze inicial a la Depressió Prelitoral Catalana. *Arraona, 36*, 130–141.

Pearson, J. A., Bogaard, A., Charles, M., Hillson, S. W., Larsen, C. S., Russell, N., & Twiss, K. (2015). Stable carbon and nitrogen isotope analysis at Neolithic Çatalhöyük: Evidence for human and animal diet and their relationship to households. *Journal Archaeological Science, 57,* 69–79.

Pechenkina, E. A., Ambrose, S. H., Xiaolin, M. A., & Benfer, R. A., Jr. (2005). Reconstructing northern Chinese Neolithic subsistence practices by isotopic analysis. *Journal of Archaeological Science, 32*(8), 1176–1189.

Pérez-Rama, M., Fernández Mosquera, D., & Grandal-d'Anglade, A. (2011). Recognizing growth patterns and maternal strategies in extinct species using stable isotopes: The case of the Cave Bear (*Ursus spelaeus* rosenmüller). *Quaternary International, 245*(2), 302–306.

Perri, A. R. (2019 preprint). Prehistoric dogs as hunting weapons: The advent of animal biotechnology. In B. Bethke & A. Burtt (Eds.), Dogs: Archaeology of the human–canine connection beyond domestication. Gainesville: University Press of Florida.

Peterson, B. J., & Fry, B. (1987). Stable isotopes in ecosystem studies. *Annual Review of Ecology and Systematics, 18,* 293–320.

Peterson, N. (2006). *Hundar kring benen: En analys av belastning och storleksvariation hos hundarna I det Mesolitiska Skane*. PhD dissertation, Lunds universitet, Lund, Sweden.

Piérard, J. (1967). Note d'anatomie appliquée, appréciation de l'âge du chien. *Canadian Veterinary Journal, 8*(9), 197–200.

Pitulko, V., & Kasparov, A. K. (2017). Archaeological dogs from the Early Holocene Zhokhov site in the eastern Siberian Arctic. *Journal of Archaeological Science: Reports, 13,* 491–515.

Radovanovic, I. (1999). Neither person nor beast: Dogs in the burial practice of the Iron Gates Mesolithic. *Documenta Praehistorica, 26,* 71–87.

Randsborg, K. (2001). From bronze to iron: The rise of European infantry. In T. Bekker-Nielsen & L. Hannestad (Eds.), *War as a cultural and social force: Essays on warfare in antiquity* (pp.155–165). Historisk Filosofiske Skrifter 22.

Rick, T. C., Culleton, B. C., Smith, C. B., Johnson, J. R., & Kennett, D. G. (2011). Stable isotope analysis of dog, fox, and human diets at a Late Holocene Chumash village (CA-SRI-2) on Santa Rosa Island, California. *Journal of Archaeological Science, 38*(6), 1385–1393.

Ruiz, C., Vázquez, J. M., Lomba, J., Aviles, A., Haber, M., Drenes, M., & Gil Cano, F. (2014). El yacimiento calcolítico 'Camino del Molino' (Caravaca de la Cruz, Murcia): Una oportunidad excepcional para estudiarlos cánidos que poblaron el sureste español hace 4000 años: Primeros resultados. *Orígenes y Raíces, 6,* 5–7.

Russell, N. (2012). Hunting sacrifice at Neolithic Çatalhöyük. In A. M. Porter & G. M. Schwartz (Eds.), *Sacred killing: The archaeology of sacrifice in the ancient Near East* (pp. 79–95). Winona Lake, Indiana: Eisenbrauns.

Salazar-García, D. C., De Lugo, B., Enrich, L. B., Álvarez García, H. J., & Benito Sánchez, M. (2013). Estudio diacrónico de la dieta de los pobladores antiguos de Terrinches (Ciudad Real) a partir del análisis de isótopos estables sobre restos óseos humanos. *Revista Española de Antropología Física, 34,* 6–14.

Salque, M., Bogucki, P., Pyzel, J., Sobkowiak-Tabaka, I., Grygiel, R., Szmit, M., & Evershed, R. P. (2013). Earliest evidence for cheese making in the sixth millennium BC in northern Europe. *Nature, 493,* 522–525.

Sanchís, A., & Sarrión, I. (2004). Restos de cánidos (*Canis familiaris* ssp.) en yacimientos valencianos de la Edad del Bronce. *Archivo de Prehistoria Levantina, 25,* 161–198.

Schoeninger, M. J., DeNiro, M. J., & Tauber, H. (1983). Stable nitrogen isotope ratios of bone collagen reflect marine and terrestrial components of prehistoric human diet. *Science, 220,* 1381–1383.

Schoeninger, M. J., & Moore, K. (1992). Bone stable isotope studies in archaeology. *Journal of World Prehistory, 6,* 247–296.

Shoveller, A. K., & Atkinson, J. L. (2008). Assessment of protein and amino acid requirements in adult mammals, with specific focus on cats, dogs and rabbits. In J. France & E. Kebreab (Eds.), *Mathematical modelling in animal nutrition* (pp. 295–315). London: Cabi Publishing.

Stock, K. F., Dammann, M., & Distl, O. (2012). Selection for conformation and conformational homogeneity of litters in the German shepherd dog. *American Society of Animal Science, 90,* 1088–1096.

Tafuri, A. N., Craig, O. E., & Canci, A. (2009). Stable isotope evidence for the consumption of millet and other plants in Bronze Age Italy. *American Journal of Physical Anthropology, 139,* 146–153.

Tankersley, K. B., & Koster, J. M. (2009). Sources of stable isotope variation in archaeological dog remains. *North American Archaeologist, 30,* 361–375.

Tsutaya, T., Naito, Y. I., Ishida, H., & Yoneda, M. (2014). Carbon and nitrogen isotope analyses of human and dog diet in the Okhotsk culture: Perspectives from the Moyoro site, Japan. *Anthropological Science, 122,* 89–99.

Valera, A. C., Nunes, T., & Costa, C. (2010). Enterramentos de canídeos no Neolítico: A fossa 5 de Corça 1 (Brinches, Serpa). *Apontamentos de Arqueologia e Património, 5,* 7–17.

Van Der Merwe, N. J. (1982). Carbon isotopes, photosynthesis, and archaeology. *American Scientist, 70,* 596–606.

Van Klinken, G. J. (1999). Bone collagen quality indicators for paleodietary and radiocarbon measurements. *Journal of Archaeological Science, 26,* 687–695.

Van Strydonck, M., Boudin, M., Ervynck, A., Orvay, J., & Borms, H. (2005). Spatial and temporal variation of dietary habits during the prehistory of the Balearic Islands as reflected by ^{14}C, δ^{15}N and δ^{13}C analyses on human and animal bones. *Mayurqa, 30,* 523–541.

Vázquez Varela, J. M. (1994). El cultivo del mijo, (*Panicum miliaceum*, l.), en la Cultura Castreña del noroeste de la Península Ibérica. *Cuadernos de Estudios Gallegos, 41*(106), 65–73.

Vilà, C., & Wayne, R. K. (1999). Hybridization between wolves and dogs. *Conservation Biology, 13*(1), 195–198.

von den Driesch, A. (1976). *A guide to the measurement of animal bones from archaeological sites* (p. 1). Cambridge, Mass: Peabody Museum Bulletin.

Warren, D. M. (2004). *Skeletal biology and paleopathology of domestic dogs from prehistoric Alabama, Illinois, Kentucky and Tennessee*. PhD dissertation, Indiana University, Bloomington.

Wilson, G. L. (1924). *The horse and dog in Hidatsa culture*. Anthropological Papers, Vol. XV, Part II. NewYork: American Museum of Natural History.