Research article

Livestock trade during the Early Roman period: first clues from the trading post of Empúries (Catalonia)

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Abstract

Written sources show that livestock were traded during the Roman period. However, there is scarce information available to characterise this trade due to its invisibility in the archaeological record. In our paper, we shed light on this issue by applying both osteometric and genetic analyses on cattle remains from the Roman trading post of Empúries (Catalonia) to determine how livestock contributed to Roman trade and, thus, to the economy of the Empire. Analysis of twenty-six cattle metacarpals from Empúries has allowed us to document the presence of different cattle morphotypes in this city during its Early Roman occupation. The morphological and genetic differences seen in Empúries cattle can be explained though trade of different cattle varieties, more appropriate for milk production and/or traction than the local stock. Once arrived at the port of Empúries, these imported cattle would have then been distributed to surrounding villas.

1. Introduction

At its height, the Roman Empire dominated a vast area of Europe, southwest Asia and northern Africa. Part of its success was its ability to connect efficiently the various territories under its control due to the construction and maintenance of large communication networks, which consisted of integrated systems combining sea, river and land transport. In the Roman period, maritime trade was the most lucrative and cheapest method of transport, involving long voyages over open water, as well as coast-to-coast journeys (Tchernia, 2011; de Soto, 2013). It was possible to move huge loads in a short time, from the straits of Gibraltar, as far away as southwest Asia, across the entire Mediterranean basin (Arnaud, 2005). Riverine trade was the second most economic mode of transport, with the main rivers and many of their tributaries being the leading form of access to deep inland areas (Parodi Álvarez, 2001; Adams, 2012). Once trade products had arrived to a maritime and/or fluvial port, terrestrial networks of roads allowed connection with the interior nucleus of a population. Land transport was probably the system that was most used on a daily basis, and was essential to maintain permanent communications between all the territories of the Empire (de Soto, 2013).

The products traded were diverse. Written sources show that merchants traded both luxury and/or manufactured products [precious stones, beads, fabrics such as silk and associated dyes, ivory and wooden objects, perfumes, oils and fragrances, wine and slaves], as well as indispensable items [cereals, livestock and horses] (Apocalypse, XVIII, 12-13 [14] and 23 [14], referenced in Tchernia, 2011). Archaeology has investigated this trade mainly through the study of shipwrecks (Rauh, 2003) and the non-perishable materials recovered inside them, such as ceramics, stones or metals, which has provided information about trade routes and the distribution of traded materials (Arnaud, 2005). However, scarce information is available about the trade of perishable materials, such as food, or living beings, such as slaves or livestock.

The information about livestock trade in the Roman period mainly comes from written sources; for example, in his book *De re Rustica*, Lucius Junius Moderatus Columella (AD 4 – *c*.70)

recommends the importation of cattle from the Italian region of Altinum for milk production (VI, 24 [5]), while also suggesting that, if the agronomist wants to buy cattle from distant lands, he must visit to ensure that these sites have similar natural conditions (VI, 2 [13]). Columella explains how his paternal uncle, Marcus Columella, bought several African wild sheep at Cadiz in order to breed them with local sheep, thereby achieving wool of a different colour (VII, 2 [4]). However, although we know that livestock trade existed during the Roman period, we do not have any archaeological information that allows us to characterise this trade.

Taking into account these considerations, the aim of our paper was to explore Roman livestock trade through the application of osteometric and genetic analyses on bone remains. Osteometry is used to characterise animal morphology. This information is valuable to the study of animal manipulation and improvement (Albarella, 1997; Tekkouk & Guintard, 2007; Klein et al., 2010), and data can inform on animal mobility (Lauwerier, 1988; Murphy et al., 2000; Vigne et al., 2009). Ancient DNA analyses allow genetic characterisation of contemporaneous populations, providing information on issues such as migration (for example, Edwards et al., 2003; Bollongino et al., 2006; Tresset et al., 2009; Colominas et al., 2015). Thus, the combined use of osteometry and genetics has great potential to give us a better understanding of the trade in animals in the past.

To carry out our investigation, we selected the Roman site of Empúries, a trading post in the northeast of the Iberian Peninsula. The commercial activity of Empúries in the Roman period is attested through both archaeology, with the presence of port installations (Nieto et al., 2005; Vivar, 2012) and imported objects (Tremoleda, 2012), and from written sources. Titus Livius emphasises the role of the commercial port at Empúries in facilitating the trade of foreign goods inland and the exportation of agricultural products from the surrounding areas (*Ad urbe condita* XXXIV, 9). Empúries was a well-connected city where trade products from inland arrived to the port via land transport routes, and foreign products arrived by maritime routes. With this paper, our aim was to further analyse if livestock contributed to this trade.

2. Materials and Methods

2.1. The sites

In this paper, although our focus is on the early Roman occupation of Empúries (first century BC to third century AD), we also consider zooarchaeological data from the second century BC at this site. In addition, we compare the Empúries data with third century BC, and first century BC to third century AD, sites located near Empúries (**Figure 1**).

2.1.1. The site of Empúries

The city of Empúries was established by the Greeks in the northeast of the Iberian Peninsula, now modern-day Catalonia, as a western Mediterranean trading post in the sixth century BC (**Figure 1**; Aquilué et al., 1999). With the second Punic war (218 – 201 BC), the Romans arrived in Empúries and began the conquest of the Peninsula, and the site became a key element in the strategy of military, administrative and economic control of the region (Santos, 2008). In the early first century BC, the Romans built a new city (**Figure 1**), which, during the Augustan period (44 BC – AD 14), assimilated the old Greek city and cemented its important commercial role in the region (Aquilué et al., 1999). During the Roman period, monumental and administrative buildings were constructed in the centre of the city, emphasising its economic and political importance to the Empire (Tremoleda, 2008). Although its commercial vitality had already started to decline at the end of the third century AD, the city was occupied into the medieval period (Tremoleda, 2008).

Zooarchaeological data show that pigs were the most abundant animals during the Roman occupation (more than 50 % of the sample), followed by cattle and sheep/goat. Kill-off patterns reveal that pigs were killed at juvenile and subadult ages, while cattle and sheep/goat were mainly slaughtered when adult (Buxó et al., 2007).

2.1.2. The late Iron Age sites

Zooarchaeological data were sourced from three Iron Age sites – Mas Castellar de Pontós, Sant Julià de Ramis and Sant Sebastià de la Guarda (**Figure 1**). These sites were selected for their proximity to Empúries and the presence of large faunal assemblages. These sites were oppida (large fortified settlements) with a third century BC occupation, during which animal husbandry was focused on sheep and goats. Cattle were the second most abundant species, followed by pigs. Kill-off patterns show that cattle were slaughtered at adult and juvenile ages, suggesting that meat, traction and milk were all used from these animals, with no specialisation in any particular production (Colominas, 2013; Colominas et al., 2014).

2.1.3. The early Roman sites

Zooarchaeological data were also assessed from three early Roman sites – Olivet d'en Pujol, Vilauba and Tolegassos (**Figure 1**). As with the late Iron Age, these sites were selected for their proximity to Empúries and the presence of large faunal assemblages.

Olivet d'en Pujol was a storage place as a support facility of a farmstead. It was occupied during the first century BC. Among the main domestic mammals, cattle represent 59 % of the faunal remains, followed by sheep/goat and pigs.

Vilauba was a villa occupied from the first to the fifth century AD. Animal husbandry here was also focused on cattle, with pig being the second most abundant species, followed by sheep and goats.

Tolegassos was a villa occupied from the first century BC to the third century AD. Data suggest that animal husbandry was focused on sheep/goat and cattle at this site, with pig being less important in their relative frequency.

The analysis of cattle mortality profiles from these three sites shows that their husbandry was more oriented towards traction rather than meat and milk production (Colominas, 2013; Colominas et al., 2014).

2.2. Cattle

The focus is on cattle as this animal has a well-documented change in morphology during the Roman period (Forest & Rodet-Belarbi, 2002; Lepetz & Yvinec, 2002; MacKinnon, 2004; Oueslati, 2006; Duval et al., 2013). The possibility that this change might be due to the presence of different (non-indigenous) cattle in the new territories of the Roman Empire as a result of trade has been suggested by numerous studies (Murphy et al., 2000; Schlumbaum et al., 2003; Albarella et al., 2008; Colominas et al., 2014), although this trade has not been directly investigated.

Another reason for focusing on cattle is that the diversification and movement of *B. taurus* has been extensively investigated using mitochondrial (mt) DNA analyses of both modern and ancient samples (for example: Troy et al., 2001; Bollongino et al., 2006; Beja-Pereira et al., 2006; Ginja et al., 2010; Colominas et al., 2015). Using data from these previous studies allows us to compare genetic diversity with our Empúries sequences.

Our study focuses on one site that covers a wide period in time, and the combined use of osteometric and genetic analyses will help us better understand the movement of animals during the Roman era. Our hypothesis is that the presence of new morphotypes and varied or increased genetic diversity will be a marker for a greater variety of cattle types, which would indicate cattle trade when put in the context of Roman Empire expansion.

2.3. Osteometric analysis

As it is possible to infer the presence of different morphotypes by estimating the size and shape of metacarpals (Albarella, 1997; Tekkouk & Guintard, 2007; Klein et al., 2010), we chose to focus the osteometric analysis on this skeletal element. Another reason for selecting metacarpals was to avoid studying an element that might be linked with trade of preserved meat, such as the humerus, femur or scapula – even though several studies have shown that the commonly preserved meat during the Roman period was that of pork, with preserved lamb and mutton meat rarely being eaten (Maltby, 2006).

A total number of 26 complete metacarpals, from 26 different individuals, were available from Empúries: three from the Greek occupation (second century BC) and 23 from the Roman occupation (first century BC – third century AD) (**Table 1**). These 26 metacarpals constitute the only complete, unbroken and well preserved metacarpals from the entire assemblage at Empúries. Measurements were taken according to von den Driesch (1976) and included the greatest length (GL), the maximum width (Bp) and depth (Dp) of the proximal epiphysis, the maximum width (Bd) and depth (Dd) of the distal epiphysis with its condyles, and the minimum width of the diaphysis (SD). The log-ratio technique was used to pool all dimensional categories – this consists of calculating the difference between the decimal logarithms for each measurement taken from the archaeological material and the corresponding dimensions from a reference group or individual (Simpson, 1941; Meadow, 1999). The standard measurements for comparison corresponded to a modern cow from the Camargue breed (Helmer, 1979). This standard was considered the most appropriate in terms of the geographic area and the period under study. All bones were mature and had no sign of pathology. Size and shape relationships between metacarpal measurements were investigated using principal component analysis (PCA) using the PAST Package (Hammer et al., 2001). Where necessary, the Kruskall-Wallis test (as implemented in PAST) was used to determine the level of statistical validity for the observed differences.

2.4. Molecular analysis

In order to be able to directly compare the genetic and morphometric data, the same 26 metacarpals were used for the ancient DNA analyses. DNA was successfully amplified and analysed from 11 samples at the University of Cambridge. Extraction, contamination controls and amplification reactions were as described previously (Campana, 2007), and followed standard ancient DNA practice. For each sample, at least two independent DNA extractions were performed, and extraction and PCR negative controls all produced negative results. Samples were amplified with the primers detailed in Colominas et al. (2015), which amplified a 316 base pair (bp) sequence

of the control region of the mitochondrial genome, covering the most variable 240 bp region (Troy et al. 2001). Seven of the 11 samples that had endogenous DNA generated the full 240 bp fragment (**Table 1**).

A total of 294 mtDNA sequences from extant Spanish and Portuguese *B. taurus* breeds (from GenBank) were used to compare archaeological cattle diversity to that found in modern populations (**Table 2**). The mtDNA sequences were aligned in MEGA (ver. 6; Tamura et al., 2013) to the reference *B. taurus* sequence (Anderson et al. 1982), and all were truncated to the most variable 240 bp region (Troy et al., 2001). Median-joining networks were constructed following Bandelt et al. (1995). Analyses of inter-population genetic distances between extant and ancient populations were performed in ARLEQUIN (ver. 3.5; Excoffier et al., 2007) using published modern regional data from native breeds (**Table 2**; Cymbron et al., 1999; Miretti et al., 2004; Beja-Pereira et al., 2006; Ginja et al., 2010). In addition, all those samples that gave mitochondrial results (**Table 1**) were screened for a nuclear DNA SNP that characterises sex, using primers zfxyF and zfxyR as detailed in Svensson et al. (2008).

3. Results

3.1 Osteometric analysis

By ordering the osteometric log-ratio analysis of cattle metacarpals from Empúries and other sites in chronological order, an increase in cattle size can be seen through time (**Figure 2**). Although the Empúries sample from the second century BC only constituted a few animals, these were smaller than those present at the same site from the first century BC onwards. The cattle from the first century BC were similar to Roman Empúries cattle from the first to third centuries AD. Although no differences were documented between the Roman Empúries samples through the centuries, variability was more pronounced during this time, with considerable morphological variation. This change was clearer when we included cattle from late Iron Age sites (third to second centuries BC) located near Empúries (**Figure 1**). The variability was reduced during these earlier chronologies and cattle from these sites were similar to Empúries cattle from the second century BC. Similar considerations can be made when early Roman samples from sites located near Empúries are included (**Figure 1**), with cattle from these Roman sites being similar to Empúries cattle from the first century BC through to the third century AD.

The Kruskall-Wallis test corroborated these results (**Table 3**). There were statistically highly significant differences between the samples from the third/second century BC and each of the time periods of the first to third century AD. At the same time, no statistic differences were seen between the samples from the first, second or third century AD. Interestingly, first century BC samples were significantly different from third to second century BC samples, but not to samples from later periods.

In order to have an immediate visual comparison of shapes and sizes of Roman Empúries metacarpals, a log-ratio diagram was computed (**Figure 3**). The most striking information obtained from this diagram was the variability in size and shape of the Roman cattle metacarpals. It is possible to observe three sub-populations: (1) very robust and large specimens; (2) smaller more

gracile specimens (the majority of the sample); and (3) variably shaped but very small individuals. These three Empúries sub-populations can be seen more clearly in **Figure 4**, which shows several bivariate plots drawn using raw cattle metacarpal measurements. Data from late Iron Age and early Roman sites located near Empúries were again included for comparison. **Figure 4A** compared size variation, with the use of GL against Bd measurements. While the first and second sub-populations differed in the distal width, the second and third sub-populations were different from each other in both length and distal width. When we compared the size of the Roman metacarpals and the third to second century BC metacarpals, we noticed that both the length and the distal width clearly increased over time.

Figure 4B compares differences in gracility, with the plot of GL against SD measurements. This figure showed similar results to **Figure 4A**, with an increase of length and robustness across time. The three Empúries Roman sub-populations were also, once again, documented – the first sub-population was long and robust, the second long and gracile, and the third short and gracile. **Figure 4C** aimed to look at differences due to sex by plotting GL against Bp, with males more likely to be both longer in length and have a greater proximal width. This plot again showed high differences in length and width between the third and second century BC samples and the Roman samples. It also clearly showed the presence of the three Roman Empúries sub-populations, also documented in the other Roman sites. It might be assumed that the first sub-population were bulls, the second oxen and the third cows. However, as bulls have more robust bones than cows, and oxen (castrated bulls) have longer bones than both bulls and cows (Albarella, 1997; Guintard, 1998; MacKinnon, 2010), the distribution of **Figure 4C** does not match very well with sex differences.

3.2 Molecular analysis

Amplification of a 240 bp section of the control region was successful in seven of our 26 samples, with a further four samples yielding sequence data of less than 240 bp in length (**Table 1**). The sequences were aligned against a highly polymorphic region of the control region as

characterised by Troy et al. (2001) (**Table 4**). All archaeological samples gave sequences similar to those encountered in modern native cattle. The dominant feature among the archaeological samples was the predominance of the T3 haplotype (six samples). Three individuals had identical sequences to the T3 reference sequence (EM27, EM50 and EM57). In addition, a further three individuals grouped within T3 haplotypes, but with one or more nucleotide substitutions (EM22, EM28 and EM51). Three samples, where the full sequence could not be generated (EM21, EM51 and EM82), could only be classified as T/T3, due to the non-amplification of the diagnostic position at 16,255.

Two individuals belonged to haplogroup T1. Of these, one individual had an identical sequence to the T1 reference sequence (EM80), while the other exhibited a T1 haplotype (EM81). The Empúries samples were compared with mtDNA sequences from extant Iberian native *B. taurus* sequences from GenBank (**Table 2**) to compare modern and ancient cattle diversity. As can be seen from the median-joining networks (**Figure 5**), the Roman archaeological data show a large diversity, similar to the living cattle diversity.

Of the samples screened for sex typing, only a single individual (EM50) returned sufficient quality sequence to be characterised. This individual was a female, since the sequence traces displayed a T at the 243 SNP site.

3.3 Integrating osteometric and genetic data

Principal Component Analysis was carried out in order to link the morphological variability of the Empúries samples documented through osteometric analyses with the genetic diversity documented through molecular analyses (**Figure 6**). The description of the results was based on the first two components, which explained 97.4 % of the variation. The first component exhibited the greatest positive correlation with the length measurement (GL: 0.84 %), followed by width of the proximal epiphysis (Bd: 0.32 %) and width of the distal epiphysis (Bp: 0.32 %). Positive values were associated with the first and second Roman Empúries sub-populations (longer metacarpals), while negative values were associated with the second century BC Empúries metacarpals and the

Roman Empúries sub-population 3 (shorter bones). Despite the predominance of these three measurement variables, all of the above-mentioned six variables participated positively in the correlation, reflecting the overall size of the bones (Dd load with 0.18 %; Dp with 0.16 % and SD with 0.16 %). The second component contributed only 8.5 % of the total explained variation and, within this, the GL measurement contributed in a negative way (−0.53 %). In contrast, there was a high positive correlation with Bp (0.57 %) and also a significant correlation with Bd (0.38 %), mainly reflecting stockiness of the bones. The other variables also participated positively in this correlation (Dp load with 0.33 %; SD with 0.29 % and Dd with 0.21 %). Therefore, the positive values of this component originated from the first Roman Empúries sub-population, but also from the second century BC Empúries metacarpals (robust metacarpals), while negative values originated with the second and third Roman Empúries sub-population (gracile bones).

Those metacarpals where a genetic haplotype was generated were marked with filled circles. The metacarpals belonging to the T3 or T/T3 haplogroup (eight metacarpals) were grouped with the first and second Roman sub-populations (**Figure 6**; black filled figures). Conversely, the two metacarpals belonging to the T1 haplogroup were grouped with the third Roman sub-population (**Figure 6**; grey filled figures). The individual characterised as female corresponds to the larger black figure from the second Roman sub-population (**Figure 6**).

4. Discussion

The morphological differences seen between the samples, not only in size but also in shape, cannot solely be explained by differences between males, females and castrates, or by an improvement of local cattle, as the change seen is not progressive through time. The larger individuals appeared during the first century BC and cohabited with the smaller individuals. The sex typing of one individual from the second sub-population as female, and the genetic characterisation of different haplotypes linked to different morphotypes (T/T3 associated to the first and second sub-populations and T1 associated to the third sub-population), corroborate the osteometric data. The results appear to reflect the simultaneous presence of novel cattle morphotypes in the commercial city of Empúries during its early Roman occupation. The large genetic diversity seen is suggestive of these cattle morphotypes arriving to Empúries from different origins during the first century BC, while the Roman city was still under construction.

Today, cattle milk breeds have thin and large bones in comparison to cattle meat breeds, which are characterised by robust bones and short extremities. Cattle used for traction are characterised by larger, more massive bones (Sañudo, 2011). This being the case, the morphological and genetic differences of Empúries cattle may reveal the importation of cattle from different regions for different purposes. Kill-off patterns from this area show that during the third and second centuries BC, cattle were slaughtered at both adult and juvenile ages, showing that meat, traction and milk were probably all used from these animals with no specialisation to any particular production. In contrast, during the Roman period, cattle were mainly slaughtered at adult ages, most likely to exploit traction and perhaps to obtain milk (Colominas, 2013). During the late Iron Age, the conformation of cattle was short and robust; a feature that today is mainly linked to cattle meat breeds. With the arrival of the Romans, not only do we see the continuation of this local stock, but we have also documented two other types of cattle, one with thin large bones, and another larger, more robust population. As mentioned above, these morphological characteristics are linked today with those cattle oriented towards milk production and traction respectively. Consequently, the

diversity seen in the Roman period could reflect the trade of specialised cattle varieties, more appropriate for milk production and traction than the local stock. Roman written sources show the existence of different varieties of cattle (Columella VI, 1 [1-3]; Varro II, 5 [10]) and there is also archaeological evidence of different types during that period in Italy (Mackinnon, 2010).

The trade of specialised products has already been documented at Empúries, with the arrival of perfumes, textiles, jewels, tableware and wine from the manufacturing centres of Italy, North Africa and the Eastern Mediterranean (Ramon, 2008; Tremoleda, 2012). The wreck Culip IV, a trading vessel of about 10 meters long, which sunk near Empúries during the Vespasian period (AD 69-79), is an example of the maritime traffic in these coasts during the Roman Empire. Its excavation produced evidence for a varied cargo, including red-slip wares from southern Gaul, lamps from Italy and oil from the south of the Iberian Peninsula (Nieto, 1989). This variety in goods from many regions led researchers to the hypothesis that the entire cargo was acquired from the port warehouses in Narbonne (Nieto, 1989). It is reasonable to assume that cattle would also have been acquired in Narbonne or in any other port of the Mediterranean basin. Written sources show the existence of different routes from east to west, such as the route between Liguria and Gaddes, following the coast and returning across Balearic Islands and Sardinia or Sicily (Arnaud, 2005). There were also north-south routes, such as between Narbonne and Carthago Nova following the coast (Arnaud, 2005).

Once all these products arrived to Empúries, they would have been redistributed in the surrounding territory via the road network. The surrounding area was occupied by several villas devoted to arable farming and livestock activities, such as Vilauba and Tolegassos, where imported products resulting from this inland distribution have been documented (Castanyer and Tremoleda, 1999; Casas and Soler, 2003). In these villas, cattle of large dimensions have been attested, showing that once cattle arrived to Empúries, they too were distributed between the villas to the surrounding territory along with the other imported goods.

5. Conclusions

The current available data do not allow us to say where the imported cattle originated from, and we do not know if this livestock trade was constant, as with ceramics, or sporadic, with perhaps only a few bulls brought in to breed with local cows. However, our study has shown that, as literary sources imply, a trade in cattle for productive purposes was practiced during the early Roman period. The implicit characteristics of livestock trade made it more complex than the trade of raw materials or manufactured products, as it would have involved the consideration of the journey time, the housing conditions of the animals and the necessity to feed them en route. Despite these difficulties, and if we take into account that the presence of larger cattle is documented in several new territories of the Roman Empire (Gallia, Britannia, Germania, Pannonia, Dacia and Hispania; Murphy et al., 2000; Forest & Rodet-Belarbi, 2002; Lepetz & Yvinec, 2002; Schlumbaum et al., 2003; MacKinnon, 2004; Oueslati, 2006; Gudea, 2007; Albarella et al., 2008; Boschin & Toskan, 2012; Colominas et al., 2014), we can venture that cattle trade was vital during the early Roman period but has been undocumented due to its invisibility in the archaeological record.

We consider that our new approach, focused on the combination of osteometry and genetics, has delivered new and valuable data about Roman trade, a key element of the economy of the Roman Empire. We have demonstrated that livestock was another traded commodity during the early Roman period at the trading post of Empúries. Our approach could be used at other sites and other time periods to study further the impact of trade through time. In addition, in assemblages where teeth are available, strontium isotope analysis could be used to uncover direct information about animal mobility. We hope that this study encourages other scholars to investigate the trade of Roman livestock as more comparative data from other Mediterranean coastal sites in the Roman Empire is needed.

Acknowledgements

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Tables

Table 1. Information about the samples studied and details of the mtDNA results.

chronology	% cattle	metacarpal sample	amplification success	fragment length	haplogroup
2nd c. BC	17%	EM47	negative	---	---
		EM51	positive	240bp	T3
		EM53	negative	---	---
1st c. BC	15%	EM30	negative	---	---
		EM80	positive	240bp	T1
1st c. AD	16%	EM21	positive	67bp	T/T3
		EM25	negative	---	---
		EM28	positive	240bp	T3
		EM29	negative	---	---
		EM46	negative	---	---
		EM50	positive	240bp	T3
		EM52	positive	175bp	T/T3
		EM55	negative	---	---
2nd c. AD	21%	EM22	positive	240bp	T3
		EM24	negative	---	---
		EM48	negative	---	---
		EM49	negative	---	---
		EM54	negative	---	---
		EM81	positive	203bp	T1
3rd c. AD	14%	EM20	negative	---	---
		EM26	negative	---	---
		EM27	postive	240bp	T3
		EM56	negative	---	---
		EM57	positive	240bp	T3
		EM58	negative	---	---
		EM82	positive	175bp	T/T3

Table 2. Information and genetic diversity values of the 1,131 modern native cattle used for comparison over the 240 bp fragment of D-loop.

country	breed	number of samples	% samples per haplogroup				number of haplotypes	haplotype diversity
			T	T1	T2	T3		
Spain	**Empúries**	**7**		**14.3**		**85.7**	**5**	**0.857 ± 0.137**
Spain	ALBERA	6				100	3	0.600 ± 0.215
Spain	ALISTANA	14		7.1		92.9	9	0.912 ± 0.059
Spain	AVILENA	7				100	3	0.667 ± 0.160
Spain	BERRENDA	33		3		97	8	0.780 ± 0.042
Spain	CARDENA ANDALUZA	7		14.3	14.3	71.4	7	1.000 ± 0.076
Spain	MONCHINA	5		40		60	4	0.900 ± 0.161
Spain	MORUCHA	5		20		80	5	1.000 ± 0.127
Spain	MOSTRENCA	21		19		81	9	0.886 ± 0.045
Spain	NEGRA SERRANA	5				100	2	0.600 ± 0.175
Spain	PAJUNA	9				100	5	0.722 ± 0.159
Spain	RETINTA	16		62.5		37.5	5	0.775 ± 0.063
Spain	TORO DE LIDIA	19	5.3	36.8		57.9	11	0.860 ± 0.071
Spain	TUDANCA	6	50			50	4	0.867 ± 0.129
	TOTAL	**153**	**2.6**	**17.6**	**0.7**	**79.1**		
Portugal	ALENTEJANA	48	4.2	43.7		52.1	14	0.885 ± 0.026
Portugal	AROUQUESA	28		14.3		85.7	15	0.889 ± 0.050
Portugal	BARROSA	31		3.2		96.8	16	0.929 ± 0.030
Portugal	BRAVA DE LIDE	16		12.5		87.5	6	0.683 ± 0.120
Portugal	CACHENA	16		25		75	8	0.800 ± 0.092
Portugal	GARVONESA	23		17.4		82.6	9	0.684 ± 0.106
Portugal	MARINHOA	16	12.5		18.75	68.75	10	0.917 ± 0.049
Portugal	MARONESA	29	6.9			93.1	8	0.650 ± 0.096
Portugal	MERTOLENGA	46	4.4	13	2.2	80.4	19	0.864 ± 0.043
Portugal	MIRANDESA	16		6.25		93.75	8	0.758 ± 0.110
Portugal	PRETA	25		12		88	15	0.940 ± 0.029
	TOTAL	**294**	**2.7**	**15.6**	**1.4**	**80.3**		

Table 3. Descriptive statistical parameters and Kruskal-Wallis *p* values for the osteometric data used in **Figures 2 and 4** by time periods. Significant

values, with a *P* value of ≤ 0.025, are shaded in grey.

metacarpal measurements	Summary						Kruskall-Wallis test results			
	n	min.	max.	mean	SD	V	1st c. BC	1st c. AD	2nd c. AD	3rd c. AD
3rd - 2nd c. BC	54	-0.06	0.05	-0.01	0.026	0.0006	4.00E-05	2.59E-09	4.16E-09	8.03E-10
1st c. BC	26	-0.05	0.07	0.02	0.031	0.0009	---	0.9335	0.6515	0.6213
1st c. AD	57	-0.04	0.11	0.03	0.030	0.0009		---	0.6016	0.4898
2nd c. AD	77	-0.06	0.12	0.03	0.038	0.0015			---	0.9044
3rd c. AD	64	-0.05	0.13	0.03	0.037	0.0013				---

Table 4. Variation in mitochondrial control region sequences.

The variable positions in control region sequences of archaeological cattle samples aligned to the European consensus haplotype (T3). Differences are indicated, with a period (.) denoting identity. Sequence codes from **Table 1** are given in the first column and only variable sites are shown. The sequence positions from the BOVMT GenBank sequence are given above each column (accession number V00654; Anderson et al. 1982). The common and putatively ancestral Middle Eastern and European consensus sequences are denoted T and T3, with T1 and T2 denoting the consensus sequences from Africa and the Middle East/Europe, respectively. All ancient sequences generated as part of this study are shown in bold type, and each sample has been assigned to one of the four main haplogroups by means of its relative position in the median-joining networks (**Figure 5**).

| sequence code	16028	16032	16033	16042	16043	16050	16051	16057	16058	16063	16068	16074	16077	16082	16085	16086	16093	16096	16104	16108	16113	16119	16122	16139	16142	16158	16185	16193	16196	16201	16215	16222	16231	16233	16235	16237	16238	16239	16247	16255	assignment to haplogroup
T3	T	T	A	T	A	C	T	G	C	C	T	T	T	G	T	G	G	C	C	T	T	T	T	C	T	G	G	C	G	G	G	G	C	G	G	G	G	C	G	T	**T3**
	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	C	T
	.	.	.	.	.	.	T	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	C	T1
	.	.	.	.	.	.	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	A	.	.	.	.	.	.	.	.	C	T2
EM52, EM82	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	?	?	?	?	?	?	?	?	?	?	?	**T/T3**
EM21	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	**T/T3**
EM50, EM27, EM57	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**T3**
EM51	.	.	.	.	.	.	.	.	.	T	.	C	.	.	.	.	T	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**T3**
EM28	.	.	.	.	.	.	.	.	.	.	.	.	.	A	.	A	A	.	.	.	.	.	.	.	.	.	.	.	.	.	G	.	.	.	.	.	.	.	.	.	**T3**
EM22	.	.	.	.	.	.	.	.	.	.	.	.	.	.	A	.	.	.	.	.	.	.	.	.	.	.	.	.	G	.	.	.	.	.	.	.	.	.	.	.	**T3**
EM80	.	.	.	.	.	.	T	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	C	**T1**
EM81	?	?	?	?	?	?	?	?	?	.	C	C	C	.	.	.	.	.	.	.	.	.	C	.	.	.	.	A	.	.	.	.	.	.	.	.	.	.	.	C	**T1**

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Figure legends

Figure 1. Location of Empúries, late Iron Age and early Roman sites cited in the text, plus a plan of the Roman city (Museu d'Arqueologia de Catalunya-Empúries).
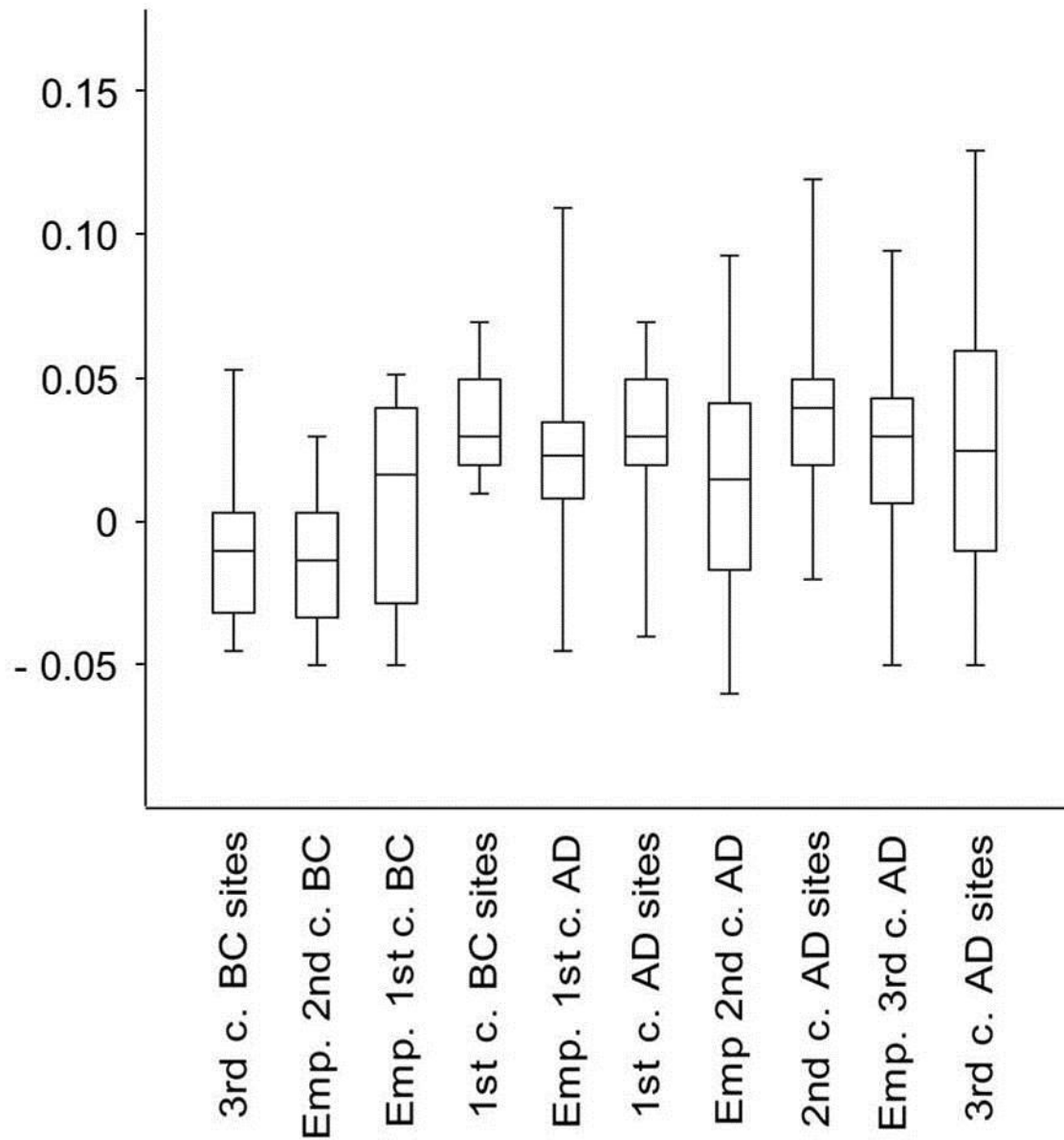
Figure 2. Log-ratio diachronic comparison of cattle metacarpal measurements from Empúries and late Iron Age and early Roman sites located near Empúries (**Figure 1**). The central line of the box represents the median of the data, and the lower and upper limits of the box, the first and third quartiles. The whiskers correspond to the rest of the data.
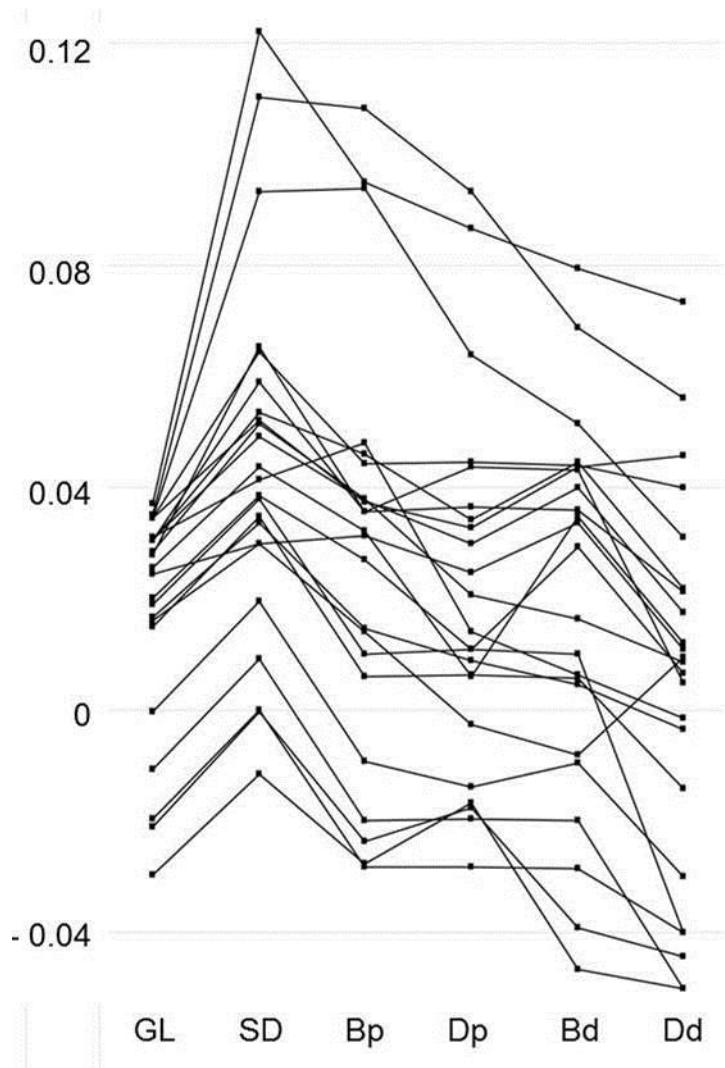
Figure 3. Log-ratio diagram of dimensions of Roman cattle metacarpals from Empúries.
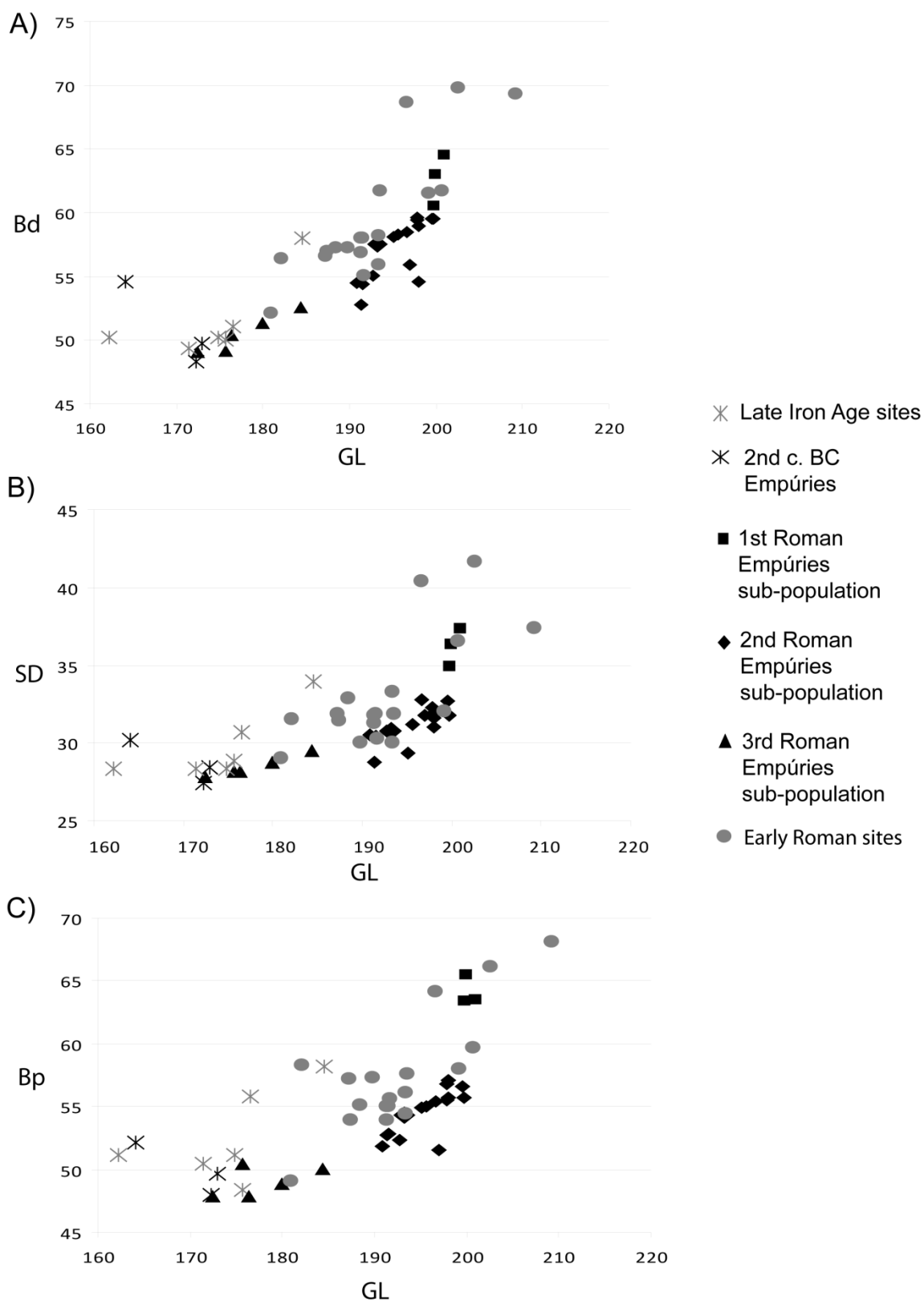
Figure 4. Scatter plots of: A) length (GL) against distal width (Bd); B) length (GL) against minimum width of the diaphysis (SD); and C) length (GL) against proximal width (Bp) measurements for the cattle metacarpals from Empúries and later Iron Age and early Roman sites located near Empúries (**Figure 1**).
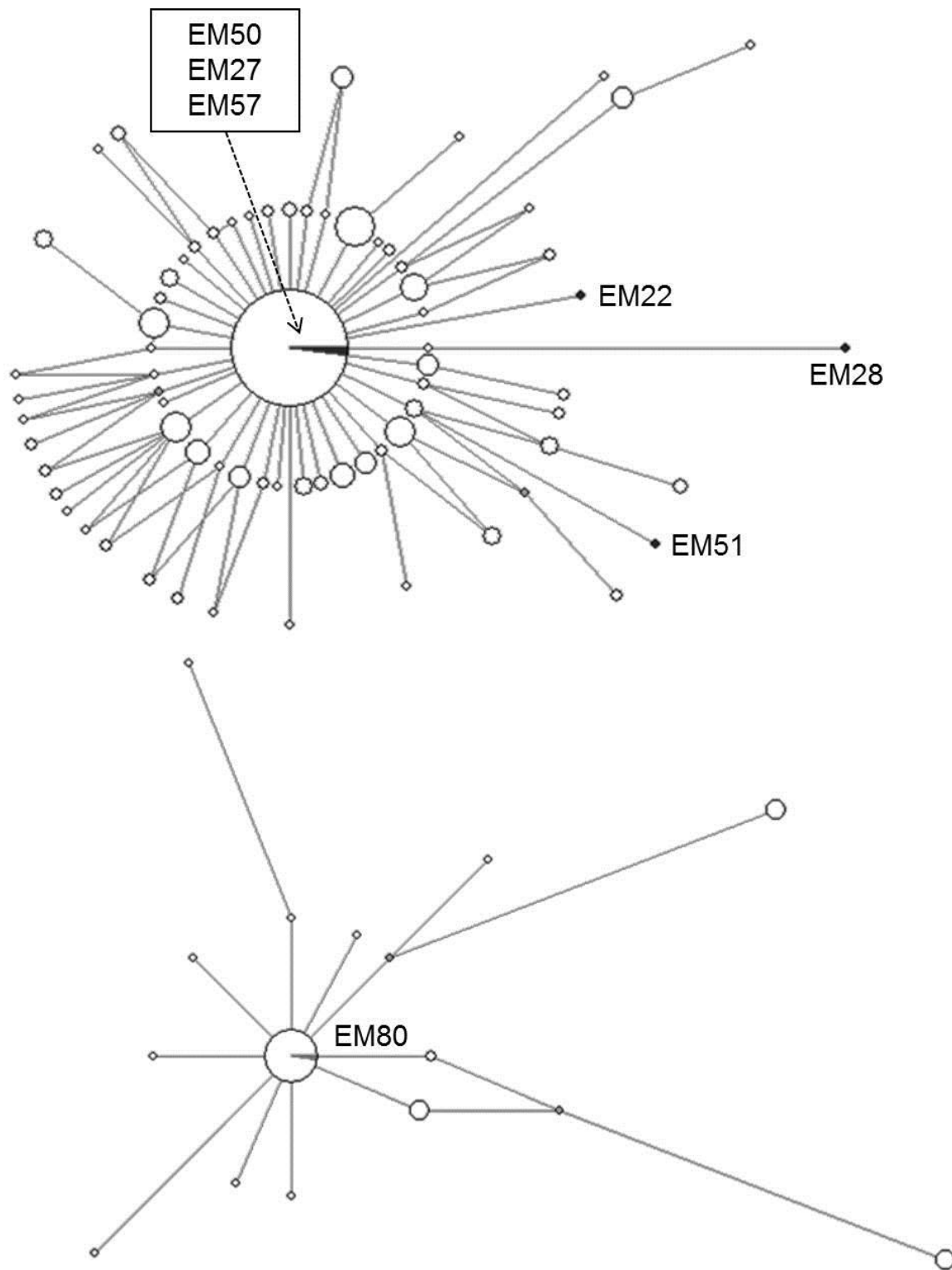
Figure 5. Median-joining networks comparing Empúries samples with extant native Iberian breeds. The top network shows all modern T3 sequences with the six T3 Roman samples where 240bp could be recovered (EM22, EM27, EM28, EM50, EM51 and EM57) while the bottom network shows the location of EM80, one of the T1 sequences found at Empúries (only 203bp of EM81 could be amplified).
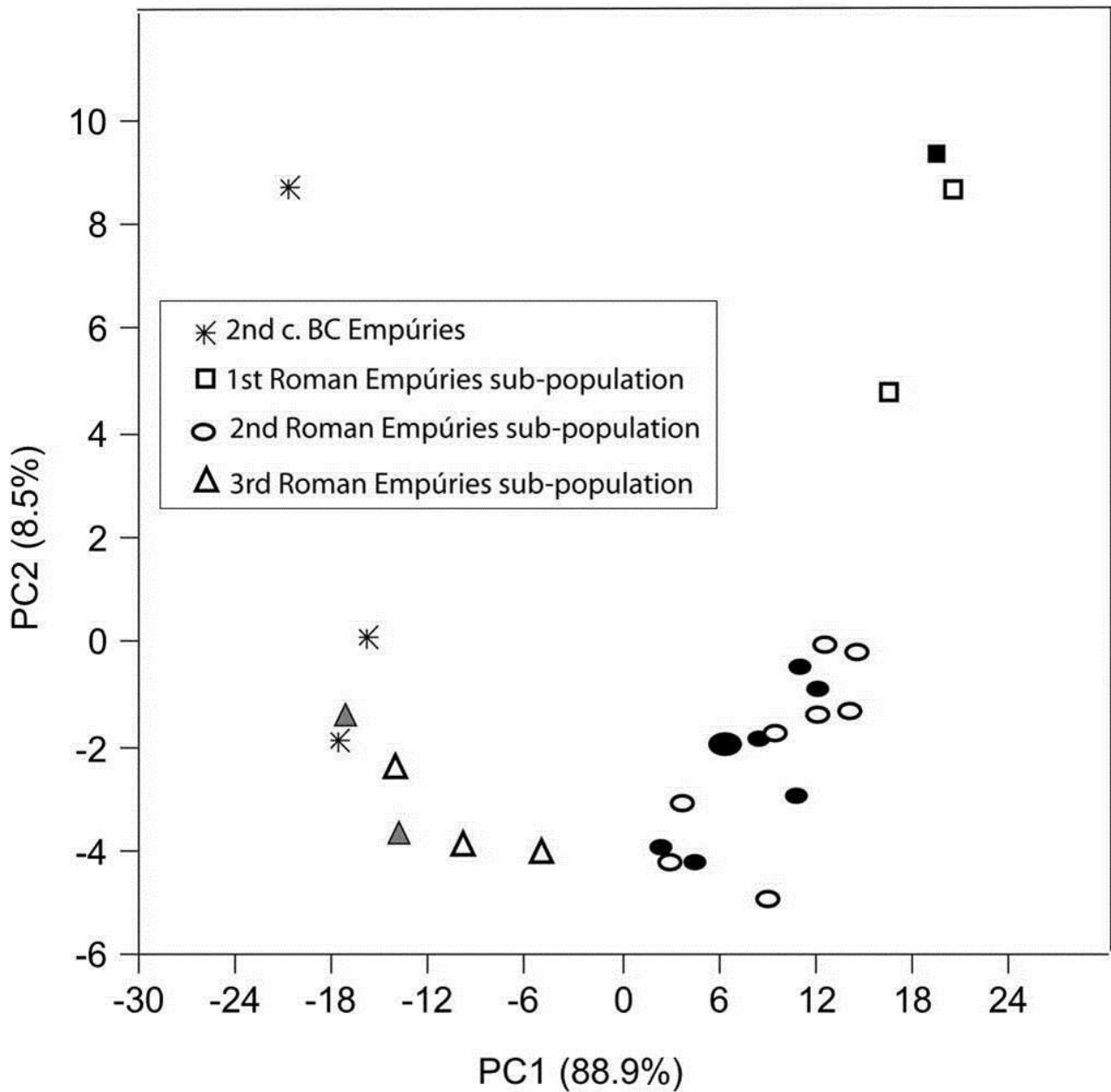
Figure 6. Principal component analysis of cattle metacarpal measurements from Empúries. The two metacarpals typed to the taurine haplogroup T1 are shown in grey, while those typed to the taurine haplogroup T3 or T/T3 (n = 8) are shown in black. The larger black circle corresponds to the sample characterised as female.