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Livestock production, politics and trade: A glimpse from Iron Age and Roman Languedoc

Ariadna Nieto-Espinet^{a,b,*}, Silvia Valenzuela-Lamas^{a,b}, Delphine Bosch^c, Armelle Gardeisen

^a Archaeology of Social Dynamics, Institutió Milà i Fontanals, Consejo Superior de Investigaciones Científicas (CSIC-IMF), Barcelona, Spain

^b LabEx ARCHIMEDE, ANR-11-LABX-0032-01, CNRS- UMR 5140, Montpellier, France

^c Laboratoire de Géosciences, CNRS-Université de Montpellier, UMR-5243, Montpellier, France

ABSTRACT

Mobility is crucial in animal husbandry to overcome scarcity of food and the related over-grazing of pastures. It is also essential to reduce the inbreeding rate of animal populations, which is known to have a negative impact on fertility and productivity. Complex societies with a strong territorial component developed during the Iron Age in Southern France and across Europe. The impact of this phenomenon over animal husbandry is not yet fully understood, but a general small size of animals is attested in different parts of Europe at that time.

This paper presents the main zooarchaeological results (main domesticates species representation, mortality profiles, osteometry, pathologies) of two major Iron Age sites in Languedoc – La Monédière (Bessan) and Lattara (Lattes). In addition, the strontium isotopic ratios ($^{87}\text{Sr}/^{86}\text{Sr}$) of 44 sheep and 16 cattle teeth from these sites are provided together with some baseline isotopic data. La Monédière and Lattara represent good case studies to characterise the geographic range of meat provisioning in coastal urban centres in the mid Iron Age (6th–4th c. BC). Their archaeological record enables us to analyse whether different species may have had different mobility patterns. In addition the strontium ratios of 4 Roman cattle from these sites were analysed for comparative purposes. The results are contextualised with other archaeological and zooarchaeological data from Languedoc and neighbour Catalonia, and suggest that the socio-political context has a major influence on animal production.

1. Introduction

Animal mobility allows the mitigation of periods when limited pasture is available. It is also essential to reduce the inbreeding rate of animal populations, which is known to have a negative impact on fertility and productivity (e.g. Baker et al., 1945; Sutherland and Lush, 1962; Dickerson, 1973; Pedrosa et al., 2010; Berry et al., 2014). Complex societies with a strong territorial component developed during the Iron Age in Southern France and across Europe (e.g. Py, 1984; Johnson and Earle, 1987; Py, 1993; Brun, 1995; Asensio et al., 1998; Sanmartí and Belarte, 2001; Collis, 2003; López-Cachero, 2007; Kristiansen, 2016). This is perceivable in the archaeological record through different evidences. The settlement pattern changed from open-air settlements located on the plains to fortified villages located on hilltops with increasingly complex defensive structures (e.g. Dedet and Py, 1985; Beylier and Gailledrat, 2009; Gailledrat, 2010; Bagan et al., 2010; Gailledrat, 2014; etc). Other evidences are the growing presence of warrior equipment in the tombs and severed heads nailed to walls and gate spaces (e.g. Janin, 1992; Dedet 1992; Dedet 1995; Arcelin et al.,

2003; Beylier, 2012). In the case of the area of the Gulf of Lion, these changes are related to the spread of iron technology, which is thought to have favoured cereal production and demographic increase, which subsequently led to increased pressure over resources and territoriality (e.g. Garcia, 1987; Sanmartí, 2004; Gailledrat, 2014).

The impact of this phenomenon over animal husbandry is not yet fully understood, but a general small size of animals is attested in different parts of Europe at that time (e.g. Matolcsi, 1970; Bökönyi, 1974; Altuna 1980; Ijzereef et al., 1981; Méniel, 1984; Vigne, 1988; Audoin-Rouzeau, 1991; Lepetz, 1996; Peters, 1998; Breuer et al., 1999; Forest and Rodet-Belarbi, 2002; Frémondeau et al., 2017; Valenzuela-Oliver et al., 2013; Colominas et al., 2017; Valenzuela-Lamas and Albarella, 2017; Duval and Clavel, 2018). The reasons behind the small size of animals are not clear, and explanations include preference for smaller more manageable animals (Clutton-Brock, 1981), consequence of climatic changes (Davis, 1981), intensification of sub-adult breeding (Manning et al., 2015) and impact of socio-political context (Valenzuela-Lamas and Albarella, 2017; Valenzuela-Lamas et al., 2018).

This paper aims to contribute to this debate through the combination of archaeological, zooarchaeological and strontium isotopic data from two major Iron Age sites in the Gulf of Lion - La Monédière and Lattara. These sites constitute outstanding examples of the process of local elite emergence and redistribution of Mediterranean products towards the interior plain. Aspects discussed here include the characteristics of the settlement pattern, Mediterranean trade, herding practices, pathologies related to inbreeding, and strontium isotopic variability as a proxy of the catchment area/mobility of caprines (sheep and goats) and cattle from these sites. In this respect, strontium data from 44 Iron Age caprines and 20 cattle (16 dated from the Iron Age, 4 dated from Roman times) are provided.

1.1. Settlement pattern and trade in the area of Gulf of Lion during the Iron Age

Amphorae finds suggest that the lower valley of the Hérault river (present-day Languedoc, France) was an area of intense contacts between the local population and Mediterranean traders from the 7th c. BC onwards (e.g. Nickels, 1976, 1983; Ugolini and Olive, 1991a; Py and Roure, 2002; Ugolini, 2010; Mazière, 2004; Ugolini and Olive 2004; Gailledrat, 2014). This coincided in time with the spread of iron technology and the increase of fortified settlements on hilltops as well as some stone-built sites close to the littoral like La Monédière and Lattara (Py and Garcia, 1993; Garcia, 2004; Garcia, 2005; Beylier and

Gailledrat, 2009; Janin and Py, 2008; Janin and Py, 2012; Gailledrat, 2014) (Fig. 1). From the 6th c. BC, Greek influence is more apparent (Nickels, 1983, Gailledrat, 2014), and the colony of Massalia (present-day Marseille) was founded in the Eastern part of the Gulf. Nevertheless, Etruscan materials – most notably amphorae – were also well represented (Ugolini and Olive 2004; Mazière, 2004; Gailledrat, 2014; Curé, 2013). This is particularly evident at Lattara, one of the main trading ports in the region, located in the Eastern part of the Hérault valley.

From the 5th c. BC, Greek presence increased even further and the port-of-trade of Agathé (present-day Agde) was founded under the influence of Massalia (Nickels, 1983). This entailed some restructuration in its hinterland and some indigenous sites, like La Monédière, were abandoned (Beylier et al., 2018).

In this context of strong intensification following iron technology and Mediterranean trade, it is currently accepted that there was an increase on cereal and wine production (Alonso, 2000; Méniel et al., 2006; Wells, 2011; Alagich et al., 2018) that led to the development of trade and a market economy beyond the local or even the regional scale (Dietler, 2010; Janin and Py, 2012; Wells, 2011). In this context of intensification and Mediterranean trade, were domestic animals part of the maritime exchanges? Did territoriality and conflict – as evidenced by severed heads and the spread of weapons and fortifications – shaped animal husbandry somehow?

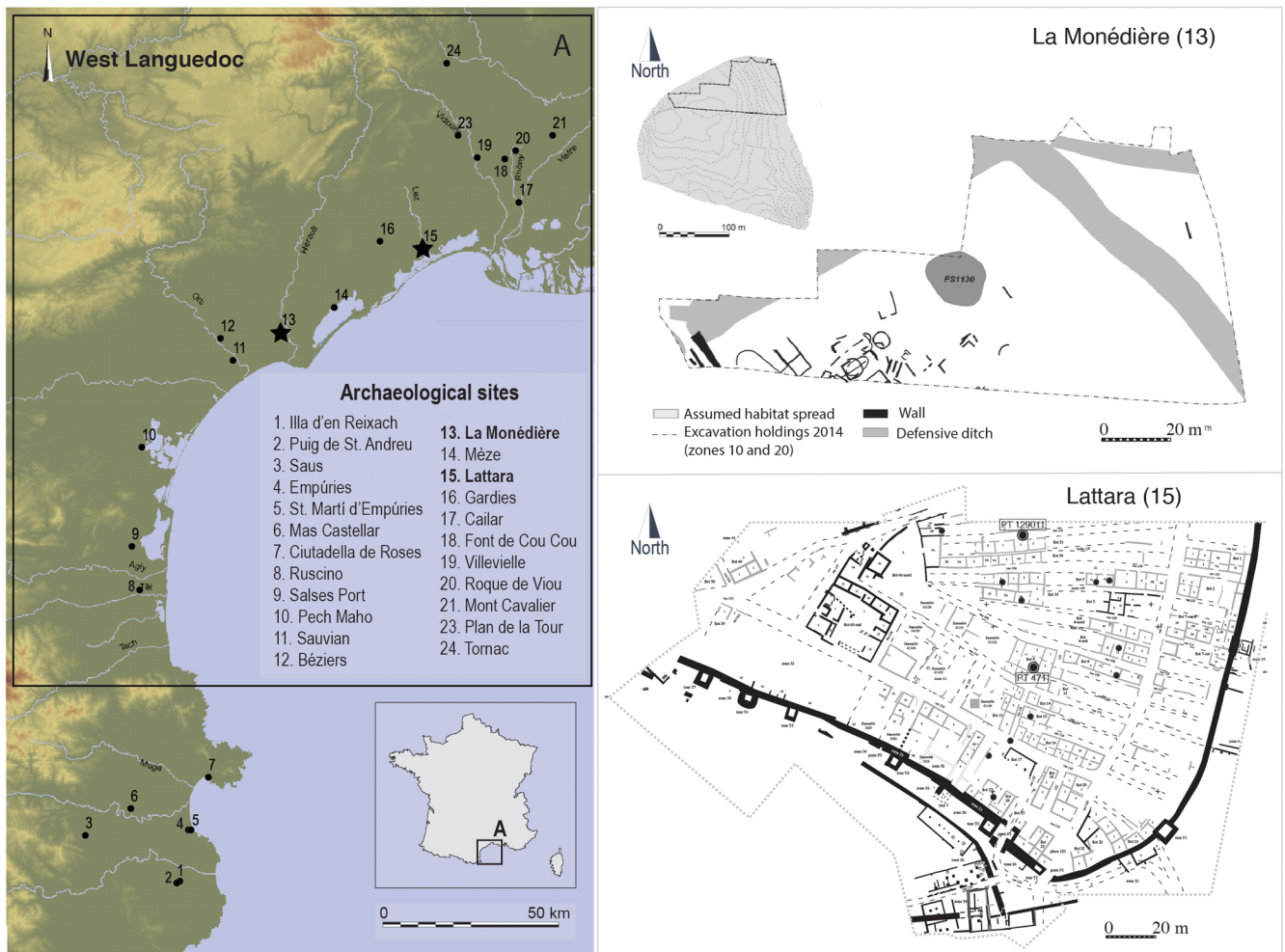


Fig. 1. A: Map with the location of the sites mentioned in the text (black points) and the studied sites (black stars). Source map: Hervé Bohbot (CNRS/UMR 5140). B: Plan of La Monédière (Bessan, Hérault): after Beylier et al. (2018: 6, Fig. 2), modified. C: Plan of Lattara (Lattes, Hérault), modified.

1.2. Archaeological context: La Monédière and Lattara

The site of **La Monédière** (Bessan, Hérault; from here onwards MON) is located about 6 km northwest of Agde, on the western bank of the Hérault river (Fig. 1). With an estimated area of about 4.5 ha, it occupied the end of an interfluvium of approximately triangular shape, elevated about ten meters above the fluvial plain. This small promontory, formed during the Riss glacial period, is composed of gravel, sand and colluviums that constitute the base of the protohistoric habitat. There are no evidences of occupation prior to the 6th c. BC, and the site was abandoned when the Greek colony of Agathe was founded (late 5th c.–early 4th c. BC). The abundance of amphorae and the situation of the site – close to the coast and in close contact with the interior area of the plain, rich in mineral resources (Garcia, 1993) – suggests that the settlement had a redistributive function closely related with the Mediterranean trade, both Etruscan and Greek (Gailledrat, 2014; Beylier and Gailledrat, 2017). New archaeological data confirmed the importance of the Mediterranean influence in the material culture and architecture of the site (Gailledrat, 2014; Beylier and Gailledrat, 2017; Beylier et al., 2018).

Lattara (Lattes, Hérault; from here onwards LSS) is located 6 km south of Montpellier, in a lagoon area at the mouth of the Lez River, in a small gulf. The settlement was a very important port-of-trade in the Mediterranean from the 7th century BC to the 3rd century AD (Janin and Py, 2008). From its foundation at the end of the 7th century BC some elements suggest the presence of exogenous communities in the site (possibly Etruscan; Lebeaupin and Séjalon, 2008; Gailledrat, 2014; Daveau and Py, 2015). But from the 5th century BC (475–450 BCE), imported pottery finds indicate a reorientation of the commercial activity of the city, now dominated by the Greek colony of Marseille. The site stands as the largest indigenous habitat in this area, with a surface area of about 9 ha and an estimate population between 4000 and 4500 inhabitants (Py and Garcia, 1993: 33).

2. Materials and methods

2.1. Archeozoology: taxonomy, mortality profiles, biometry, pathologies

The relative frequencies of cattle (*Bos taurus*), sheep/goat (*Ovis aries/Capra hircus*), and pigs (*Sus scrofa*) were quantified on the basis of the number of identified specimens (NISP). Although subject to several systematic biases, NISP offers a widely employed and easy to calculate method of assessing the relative frequency of different species (Lyman, 2008).

The analyzed assemblages have a significant number of animal remains in both settlements (Table 1). The material originates from habitat contexts or from specialized deposits linked to economic activities. In the case of the Monédière, unpublished data from the archaeozoological studies from habitat areas are presented for the first time (Nieto-Espinet, 2016, 2017). For Lattara some unpublished data are coupled to those previously published (Gardeisen, 1999, 2003, 2008, 2010; Gardeisen, in this paper).

The anatomical and taxonomic identifications and classifications of the materials based on the reference collections of the Laboratory of Archaeology of the University of Lleida (Spain) and the Laboratory of

Archaeology of the CNRS-UMR 5140 (Montpellier, France). This was completed with diagnostic criteria from different atlases and catalogues for distinction between sheep and goat (Boessneck, 1980; Payne, 1985; Fernandez, 2001; Halstead et al., 2002).

The age of slaughter was estimated for cattle and caprines (sheep and goats) from the degree of epiphysation of long bones (Barone, 1986), as well as tooth eruption and wear (Silver, 1980; Bull and Payne, 1982; Gardeisen, 1997; Blaise, 2010). The mortality profiles were calculated using a bayesian method that considers both long bones and mandibular ageing data (Valenzuela-Lamas and Pozo-Soler, 2011). In a similar approach to that of Helmer and Vigne (2004), the histograms height shows the 'intensity' of killings by age group, the total number is expressed with the histogram area, and the line shows the survival curve expressed in percentage. For the interpretation and restitution of livestock management we considered different baseline works, most notably Redding, 1981, 1984; Payne, 1973; Halstead, 1998; Helmer and Vigne, 2004; Vigne and Helmer, 2007; Blaise, 2005, 2010. These studies complement Payne's specialized management models as, in most cases, the prehistoric communities are likely to have had a mixed management model rather than a specialised one (Helmer and Vigne, 2004; Helmer et al., 2007; Blaise, 2010).

In order to contextualise the results from MON and LSS we compared NISP frequencies and biometric data from other contemporary sites in Hérault region and neighbour present-day Catalonia – an area strongly connected with Southern France. Each site was georeferenced to analyse the correlation between animal husbandry and ecology.

Osteometric analysis was based on 426 caprine measurements – from which 275 from Lattara, 33 from La Monédière and 118 from other sites in France (n = 39) and north Catalonia (n = 79) – and 325 cattle data – 197 from Lattara, 50 from La Monédière and 46 from other sites in France and 32 from North Catalonia. Only limb bone length measurements following standards established by Von den Driesch (1976) were taken into account. Changes in animal size were assessed using size-index scaled Log Standard Index values (LSI) (Meadow, 1999). Published standards were used for cattle (Nieto-Espinet, 2018) and caprines (Davis, 1996). Log ratios offer a useful method for investigating animal size, because they allow measurements from different elements to be pooled into a larger sample of indices for each dimension (length and width). However, this method can lead to the overrepresentation of specimens that yield several measurements, a problem that is quickly compounded if a skeleton or articulating limb is included. To avoid over representation of articulating remains, our LSI analyses included only one measurement per specimen and one specimen from an articulating group of bones following the protocol described in Trentacoste et al. (2018). Bone widths were considered separately from lengths in order to assess two-dimensional change.

2.2. Strontium isotopic analysis

Strontium isotope ratios ($^{87}\text{Sr}/^{86}\text{Sr}$) in tooth enamel can be used to analyse mobility patterns across geological landscapes as strontium substitutes for calcium in animal tissues (e.g. Comar et al., 1957; Toots and Voorhies, 1965; Chamberlain et al., 1997; Price et al., 2002; Bentley, 2006). $^{87}\text{Sr}/^{86}\text{Sr}$ ratios vary geographically, primarily based on the distribution of local bedrock. In general, the older and more felsic a

Table 1
Percent NISP of main domesticates of La Monédière and Lattara settlements.

Sites	Chrono	Dom	Wild	Total	%Dom	%Wild	Cattle	Pig	Sheep Goat	Total	%Cattle	%Pig	% Sheep Goat
Monédière	6 th BC	779	13	792	98.4	1.6	104	74	596	774	13.4	9.6	77.0
Monédière	6-5th BC	1999	140	2139	93.5	6.5	354	194	1437	1985	17.8	9.8	72.4
Monédière	5th BC	464	31	495	93.7	6.3	65	47	344	456	14.3	10.3	75.4
Lattara	5 th BC	2016	138	2154	93.6	6.4	861	175	942	1978	43.5	8.8	47.6
Lattara	4th BC	2966	439	3405	87.1	12.9	863	506	1527	2896	29.8	17.5	52.7
Total		8224	761	8985	91.5	8.5	2247	996	4846	8089	27.8	12.3	59.9

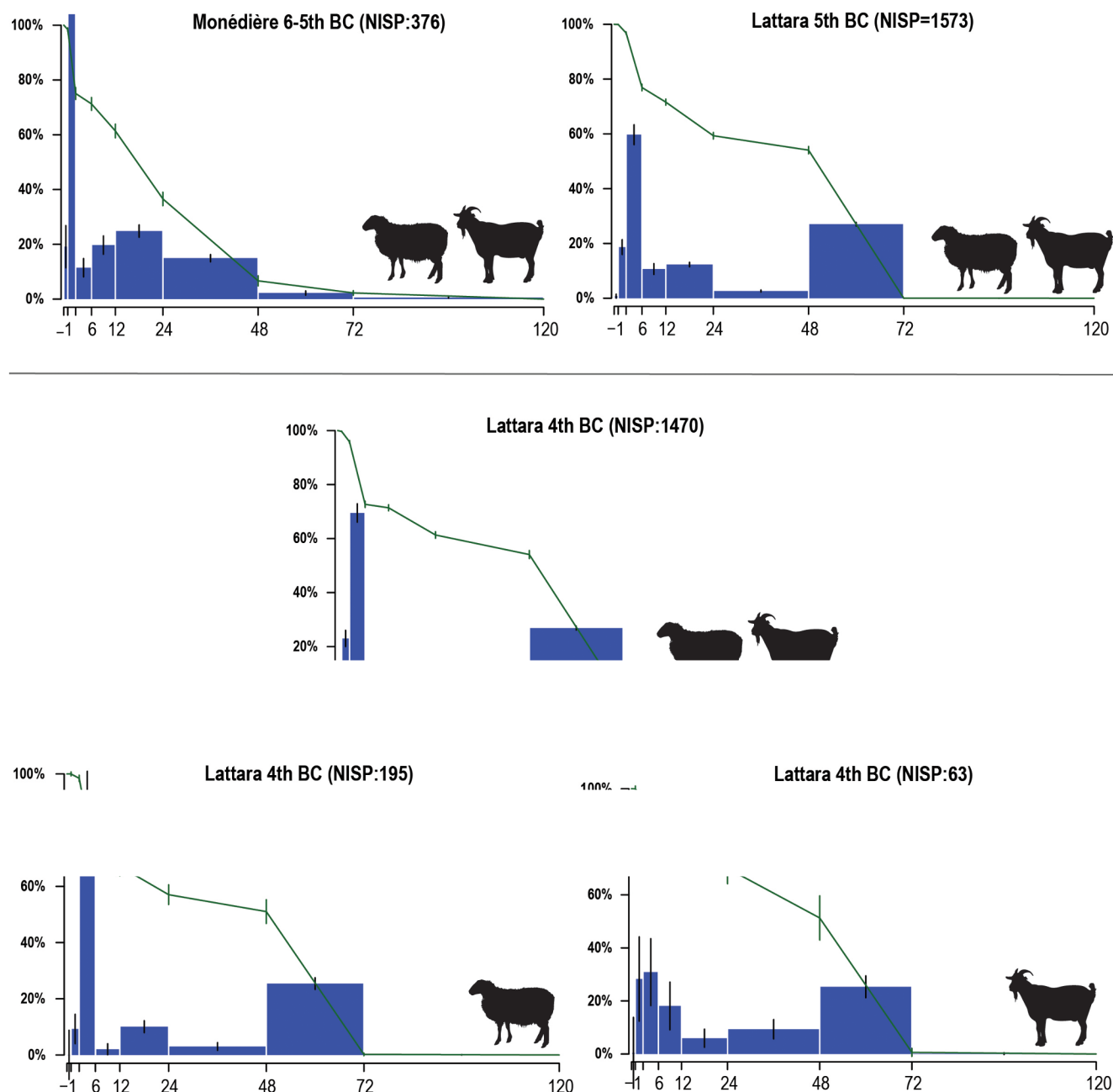


Fig. 2. Mortality profiles of sheep/goats at La Monédière and Lattara.

rock formation is, the higher the proportions of ^{87}Sr (Faure and Mensing, 2005). The $^{87}\text{Sr}/^{86}\text{Sr}$ ratio from vegetal samples can be used to produce maps of bioavailable strontium ratios (Sillen et al., 1998; Hodell et al., 2004; Evans et al., 2010; Copeland et al., 2011) that then enable geographic sourcing. In addition, strontium isotope ratios from tooth dentine reflect the ones of the burial environment while dentine is susceptible to diagenetic alteration (Budd et al., 2000; Evans et al., 2007; Price et al., 2002). For this reason, dentine can also be used as a proxy of the strontium ratio present in the archaeological site (e.g. Viner et al., 2010; Minniti et al., 2014).

In order to assess the geographic origins of cattle and caprines (sheep and goats) in LSS and MON during the Iron Age, a total of 64 teeth were analysed: 9 cattle and 35 caprines from MON, and 7 cattle and 9 caprines from LSS, all dated between the 5th and the 4th c. BC according to pottery finds and contextual evidence. In addition, 4 Roman cattle (3 from LSS and 1 from MON) were analysed for

comparative purposes.

We mainly selected third lower molars that were fully erupted and formed (closed roots) to facilitate data comparison as they are easily identified even when isolated. However, it was not always possible so 29 lower molars were also considered for sheep and goats and, in some cases, the wear stage corresponded to an early stage of tooth formation. In addition, an effort was made to sample teeth from the same side (right/left) in order to ensure that the analysed teeth corresponded to different individuals.

In order to have some comparative strontium isotopic data around the archaeological sites we analysed one sample from tooth dentine, one long bone sample and 6 present-day tree leaves.

The sampling and cleaning protocol for the archaeological samples and present-day tree leaves followed the ones described in Valenzuela-Lamas et al., 2016 and Valenzuela-Lamas et al., 2018. A transversal slice from the protoconid of each archaeological tooth was cut using a

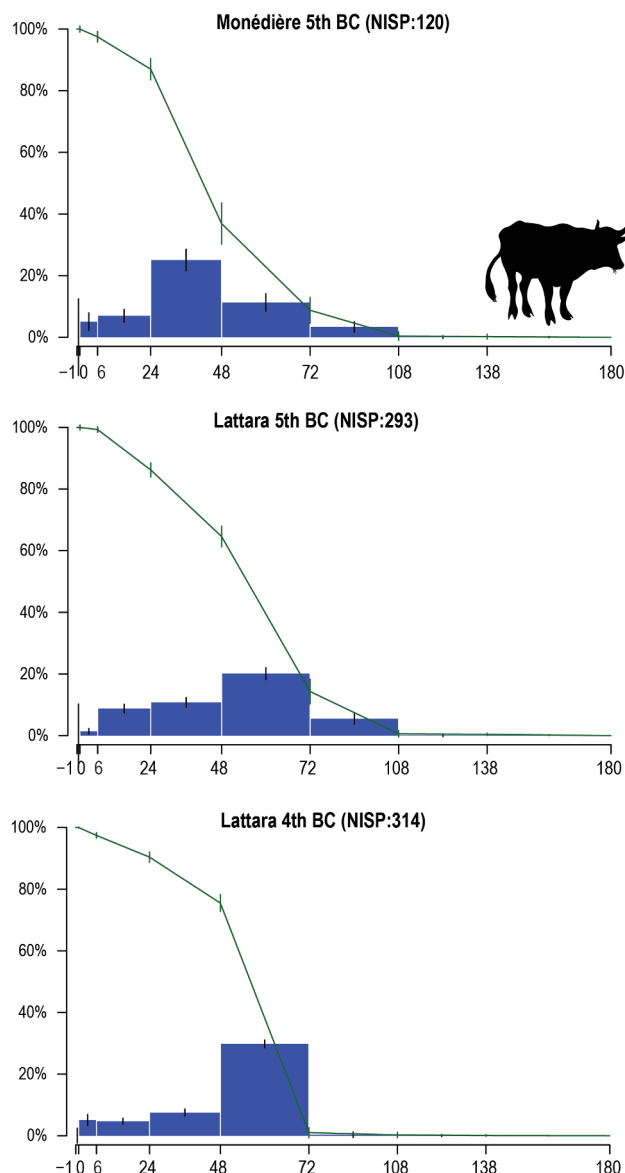


Fig. 3. Mortality profiles of cattle at La Monédière and Lattara.

dentist drill with a diamond cutter disc just above the enamel root junction (2–3 mm). The samples were then mechanically cleaned with a rotation drill to remove all the dirt, tartar and dentine. Further cleaning, strontium collection and isotopic analysis was developed at Géosciences Laboratory (CNRS, Montpellier, France) following standard protocols to Delphine Bosch (in Valenzuela-Lamas et al. 2018: 5). Strontium isotopic ratios were obtained using the Neptune + Thermo Scientific Multi-Collector Inductively-Coupled-Plasma Mass Spectrometer (MC-ICP-MS) at the AETE-ISO platform (OSU OREME) from the University of Montpellier. Total chemistry blanks were less than 20 pg and thus negligible for this study. The samples were alternatively run with international NBS 987 standards using a sample-standard-bracketing measurement protocol wherein standards were run every 3 unknowns. The ^{88}Sr beam intensity for all standards and samples ranges from 8 V to 15 V. $^{87}\text{Sr}/^{86}\text{Sr}$ isotopic ratios were internally normalized from the instrumental bias using a value of 0.1194 for the $^{86}\text{Sr}/^{88}\text{Sr}$ ratio. Then the corrected ratios were normalized to the NBS 987 standards which gave a mean value of 0.710245 with a reproducibility of ± 0.000004 (2 s, n = 8) during the course of this study.

3. Results

3.1. Frequency of the main domesticates (%NISP) at La Monédière (MON) and Lattara (LSS)

The NISP counts from the two sites show that the domestic species represent about the 90% of the zooarchaeological record at both MON and LSS (Table 1). Bone remains from wild species are very scarce, although the frequency of wild species is higher at LSS in the levels dated from the 5th and 4th c. BC compared to the *oppida* located inland (Columeau, 1991, 2001, 2002; Gardeisen, 2008: 189). Both sites (MON and LSS) display a notable continuity in their meat diet during the Iron Age (Gardeisen, 2010; Gardeisen, 2003). MON has a high frequency of caprines (72–77%) and a low frequency of bovine remains (13–14%) during the whole occupation of the site (6th–5th c. BC) (Table 1). In contrast, caprines represent 47% of NISP remains at LSS and bovines constitute 36–39% NISP, while pigs are 12–16% of NISP at LSS and only 9% at MON.

3.2. Mortality profiles at La Monédière (MON) and Lattara (LSS)

Both sites register the presence of both sheep and goats, with a higher frequency of sheep compared to goats. At MON, the mortality profiles of sheep and goats were put together to improve the robustness of the results. Given the predominance of sheep remains at MON, it is likely that the mortality profile mainly reflects sheep management (Fig. 2). The main peak is centred on the culled-off very young animals (0–2 months). This fits well with the 'A milk type' mortality profile according to Halstead (1998) and Helmer and Vigne (2004), which exemplifies intensive milk exploitation. It must be noted that the exploitation of milk does not require the slaughter of the very young animals (a limited access to it would be enough see e.g. Halstead, 1998; Helmer and Vigne, 2004; Vigne, 2005; Helmer et al., 2007; Vigne and Helmer, 2007), but it facilitates intensive milking. In this productive model, females are usually culled-off when milk production decreases, between 48 and 72 months. The profile at La Monédière is also compatible with this kind of management (Fig. 2). Despite the intensity of slaughters in the early stages, the majority of individuals were slaughtered in the meat optimum and when they reached their maximum weight as demonstrated by the mortality curve and histograms area. Wool exploitation would be also possible as it can start in the first-second year of life up to 48–84 months (Torrent, 1986).

At LSS, the joint mortality profiles (sheep and goats together) were found to be centred on the slaughter of young animals (2–6 months) and 'old' adults (48–72 months), both in the 5th and the 4th century BCE (Fig. 2). The young caprines correspond to weaned animals that provide tender meat (type A meat following Helmer and Vigne, 2004), and the 'old' adults likely correspond to animals in decreasing reproductive capacity. Previous works suggested that the mortality profile could correspond to an intensive production of wool (Gardeisen and Raux, 2000: 105). When considering sheep and goats separately (Fig. 2), it is clear that sheep lead the observed tendency (the number of sheep remains is significantly higher) but, interestingly, goats seem to follow a similar profile, in which most animals are slaughtered older than 48 months.

Cattle mortality profile at MON suggests that slaughter was focused on fully-grown animals (24–48 months), followed by animals aged between 48 and 72 months (Fig. 3). In contrast, cattle mortality profile for the 5th c. BC at LSS indicates a strong focus on animals between 48 and 72 months, followed by animals between 24 and 48 months. This tendency is even clearer for the 4th c. BC.

3.3. Animal size at La Monédière (MON) and Lattara (LSS)

Fig. 4 shows the log values for lengths and widths for cattle at MON and LSS (top). Length values at both sites are generally smaller than the

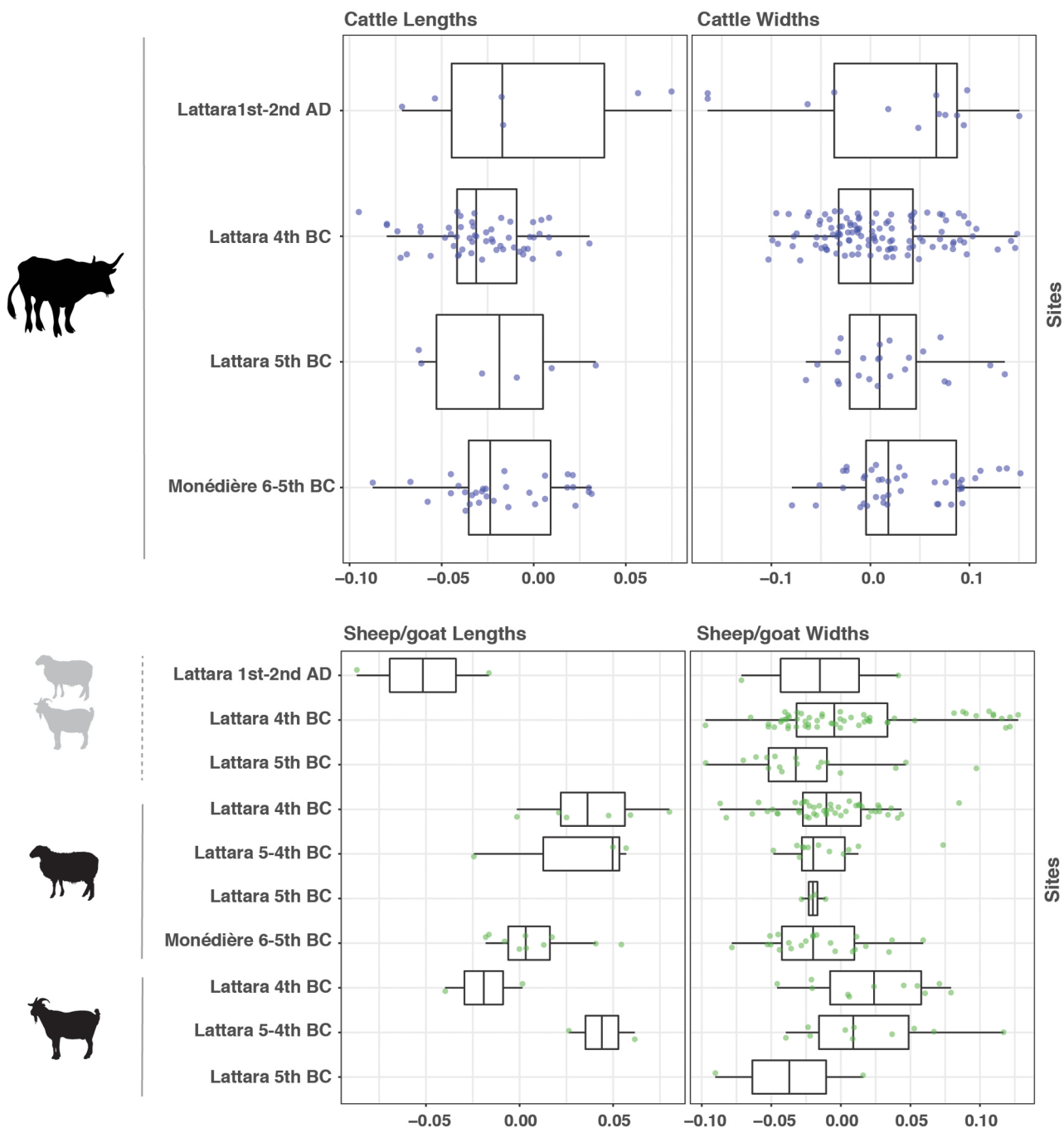


Fig. 4. Distribution of sheep/goat and cattle bone length LSI values at La Monédière and Lattara.

Early Bronze Age cow from Catalonia used as a reference (Nieto-Espinet, 2018), especially cattle from the 4th century BC at LSS. Nevertheless, some length measurements are bigger than the reference cow, especially at MON. In contrast, width measurements are generally bigger thus suggesting that Iron Age animals at MON and LSS were robust compared to the reference Early Bronze Age cow. In addition, width measurements at MON display a bimodal distribution, while they are continuously distributed at LSS. When comparing LSS and MON, the size differences on cattle lengths were found not to be statistically significant, whereas they were statistically significant on width measurements ($p = 0.005$). Overall, cattle from the 4th century BC at LSS were significantly smaller (or slender) compared to 6th–5th century cattle at MON (see Tables 1 and 2 in supplementary material). In addition, Roman cattle were found to be significantly bigger than the Iron

Age ones (see Tables 6 and 7 in supplementary material).

Concerning caprines (Fig. 4), sheep and goat measurements were considered separately whenever possible. Regarding goats, a sudden length decrease is attested at LSS from the 5th to the 4th century BCE, although more data would be needed to check the robustness of these results. This contrasts with the more stable size of sheep at the same site, although the length dataset is equally small. Sheep lengths at MON are smaller compared to LSS, but the differences between populations were found not to be statistically significant. Regarding widths, the biggest values are found at 4th century BC caprine remains from Lattara, but this probably results from the presence of both species, sheep and goats (i.e. goat width measurements are bigger compared to widths obtained on bones identified as unequivocally sheep). When comparing the different assemblages (Table 3 and 4 in supplementary material),

4th century BCE goat widths from LSS were found to be significantly bigger than the rest of data – excepting 5th–4th goats from LSS – and caprine widths from LSS were found to be different between the 5th and the 4th century BC. Given the presence of both species in these datasets we cannot assess the origin of the size difference (e.g. it could result from a higher presence of goat measurements in 4th century BC caprine dataset). Nevertheless, the differences were found to not be statistically significant and, therefore, we combined the data for a regional scale comparison.

3.4. Paleopathology at La Monédière (MON) and Lattara (LSS)

Pathologies can inform about dietary or work stress as well as inbreeding, among others (Argant et al., 2013; Nieto-Espinete et al., 2014: 95). The pathologies observed on cattle and caprine remains at MON and LSS related to dietary stress and inbreeding are reported here (e.g. fractures or pathologies with an infectious origin were not included). This totals 19 pathologies at MON and 16 at LSS (Table 10 in [supplementary material](#)).

Despite their low frequency compared to caprines and pigs, cattle both at MON and LSS concentrate the highest number of pathologies ($n = 15$ and $n = 12$ respectively). Pathologies were mainly observed on teeth, metapodials and phalanges (see Table 10 in [supplementary material](#) for details). Other than exostoses on 7 remains, 4 upper third molars (M3) at MON had a singular wear pattern (Fig. 5). At LSS, a cattle bilobate M3 with a reduced hypoconulid was recorded together with a caprine lower M3 with an abnormal hypoconulid wear (Fig. 5). In addition, hypoplasia was observed on 3 teeth at MON.

Concerning the anomalous wear of the upper M3, a preliminary study presented at the Fifth Animal Palaeopathology Working Group Conference in Stockholm (May/June 2013) by Thierry Argant, Richard Thomas and James Morris, showed that high frequencies of the trait appear to occur in France in the Iron Age and at the beginning of the Roman period, and again in the medieval period. Some authors have interpreted the presence of this anomalous wear as a problem of occlusion caused because the cattle were maintained in smaller breeding groups, so that an uncommon genetic trait was more likely to be expressed in at least some herds (e.g. O'Connor, 2000; Argant et al., 2013; Nieto-Espinete et al., 2014: 95). Some examples observed in herds of extant cattle give strength to this hypothesis. This is the case of a feral herd of cattle in Chillingham (UK), which has remained very stable since the late medieval period, with a small herd size (50–100 individuals) and highly inbred. In this case, the anomalous M3 wear frequency is 23%. This approximates the percentages for the cattle of MON with almost 16% of the teeth with this type of wear (Fig. 5). Other pathologies related to inbreeding also include high frequencies of acetabular notches and absence of second premolars (Argant et al., 2013). No absence of second premolar was detected for the moment at MON, but this genetic abnormality was found in a LSS goat's mandible (Fig. 5 and Table 10 in [supplementary material](#)). The presence of these pathological elements suggests that the flocks of LSS and MON could be subject to inbreeding rates.

3.5. Strontium isotopic ratios ($^{87}\text{Sr}/^{86}\text{Sr}$) at Hérault valley, La Monédière (MON) and Lattara (LSS)

Table 2 and Fig. 6 present the strontium isotopic ratios ($^{87}\text{Sr}/^{86}\text{Sr}$) obtained on the 8 baseline samples. The bone and tooth dentine samples from La Monédière provided isotopic ratios around 0.7093–0.7094, and the present-day leaves collected at Lattara ranged between 0.7081 and 0.7095. These results are compatible with other studies providing strontium isotopic ratios from Pliocene and Miocene sediments (e.g. Knipper et al., 2014; Brönnimann et al. 2018; Valenzuela-Lamas et al. 2018). The bioavailable strontium variability 25 Km around the sites was found to range from 0.7095 to 0.7111, which comprises Jurassic and Cretaceous bedrocks.

Table 3 and Fig. 7 (see also [Figure Supplementary Fig. 1](#)) show the strontium isotopic ratios ($^{87}\text{Sr}/^{86}\text{Sr}$) from the 20 cattle enamel and the 44 caprine (sheep and goats) enamel samples from Iron Age and Roman La Monédière (MON) and Lattara (LSS). The 9 Iron Age cattle from MON provided strontium isotopic ratios between 0.7081 and 0.7179, and the 7 Iron Age cattle samples from LSS ranged between 0.7078 and 0.7108. The Roman individual from MON gave a ratio compatible with the local baseline (see Table 3) and the Roman cattle from LSS provided ratios between 0.7107 and 0.7195. The diversity of strontium ratios – understood as the difference between the maximum and the minimum value – provided a span of 0.0097 in Iron Age cattle from MON, 0.0029 in Iron Age LSS ones, and 0.0087 in the three Roman cattle from LSS.

The strontium ratios obtained on the 35 caprine teeth from MON ranged between 0.7076 and 0.7108, and the 9 caprine samples from LSS gave strontium ratios between 0.7079 and 0.7098 (Table 3). Same as with cattle, caprine samples from MON display a wider diversity of strontium ratios compared to LSS (0.0031 vs. 0.0018). Nevertheless, the differences in the diversity of cattle and caprine strontium signatures between the two sites were found not to be statistically significant. Conversely, the three Roman cattle from LSS were found to likely correspond to a different population (Table 5 in [supplementary material](#)).

3.6. Frequency of the main domesticates and animal size in a broader context

We compared the frequency of the main domesticates and osteometric cattle and caprine data at other sites in Languedoc and neighbour areas (northern present-day Catalonia). Mortality profiles and pathologies as well as strontium isotopes could not be compared because the lack of published data.

Fig. 8 shows the relative frequencies (%NISP) of the main domesticates at several sites in Languedoc and northern Catalonia. NISP frequencies at MON (Fig. 8 top) are similar to the contemporary indigenous *oppida* located on the littoral plain (zone 2) and the ones located inland (zone 3). They are characterised by high frequencies of caprines, generally over 60%. In contrast, LSS has a higher percentage of bovines, like other sites located on the coastal wetlands and swamps (zone 1). These sites display cattle frequencies between 30 and 50%. This pattern (higher percentage of cattle remains in the sites located on coastal wetlands and swamps) is also found in northern Catalonia, although cattle remains are generally lower, between 20% and 30%. The application of a regression test from a linear model (Chambers and Hastie, 1992) revealed that there is indeed a correlation between coastal wetlands (zone 1) and higher proportions of cattle compared to caprines ($p = 0.01$). Similarly, a correlation was found between high frequencies of caprine remains and scrubland and dry hills (zone 3; $p = 0.01$).

Most assemblages dated from the 4th c. BC have higher percentages of pig remains and lower percentages of caprines compared to the previous ones (Fig. 8 bottom). In addition, sites located on coastal wetlands and swamps have higher cattle frequencies than the sites located on scrubland and dry hill, characterised by higher caprine frequencies.

Cattle size at MON and LSS (Fig. 9) is also coherent with other sites in Languedoc and neighbour areas, both in widths and lengths. Most length values from the Iron Age are smaller than the Early Bronze cow used as a reference (Nieto-Espinete, 2018). This is especially visible at the Greek colony of Emporion in the levels dated from the 6th–5th centuries BC, both on lengths and widths. In contrast, width values are generally larger, thus suggesting a robust aspect for Iron Age cattle in the area of the Gulf of Lion. In this case, the Mann-Whitney U test (Tables 6 and 7 in [supplementary material](#)) indicates that these differences are significant. Some large animals were present at Lattara in the 3rd century BC (Fig. 9). But the global cattle size increase is not statistically significant until the 1st century BC (Tables 6 and 7 in

Sites	Number of teeth with pathologies			Total number of teeth by species			% Incidence rate by species			Incidence in total teeth			
	Cattle	Pig	Sheep Goat	Cattle	Pig	Sheep Goat	Cattle	Pig	Sheep Goat	Affected teeth	Total teeth	% Affected	% Unaffected
Monédière 6-5th BC	7	2	2	44	36	150	15,9	5,6	1,3	11	230	4,8	95,2
Lattara 5-4th BC	1	0	2	54	68	205	1,9	0,0	1,0	3	327	0,9	99,1

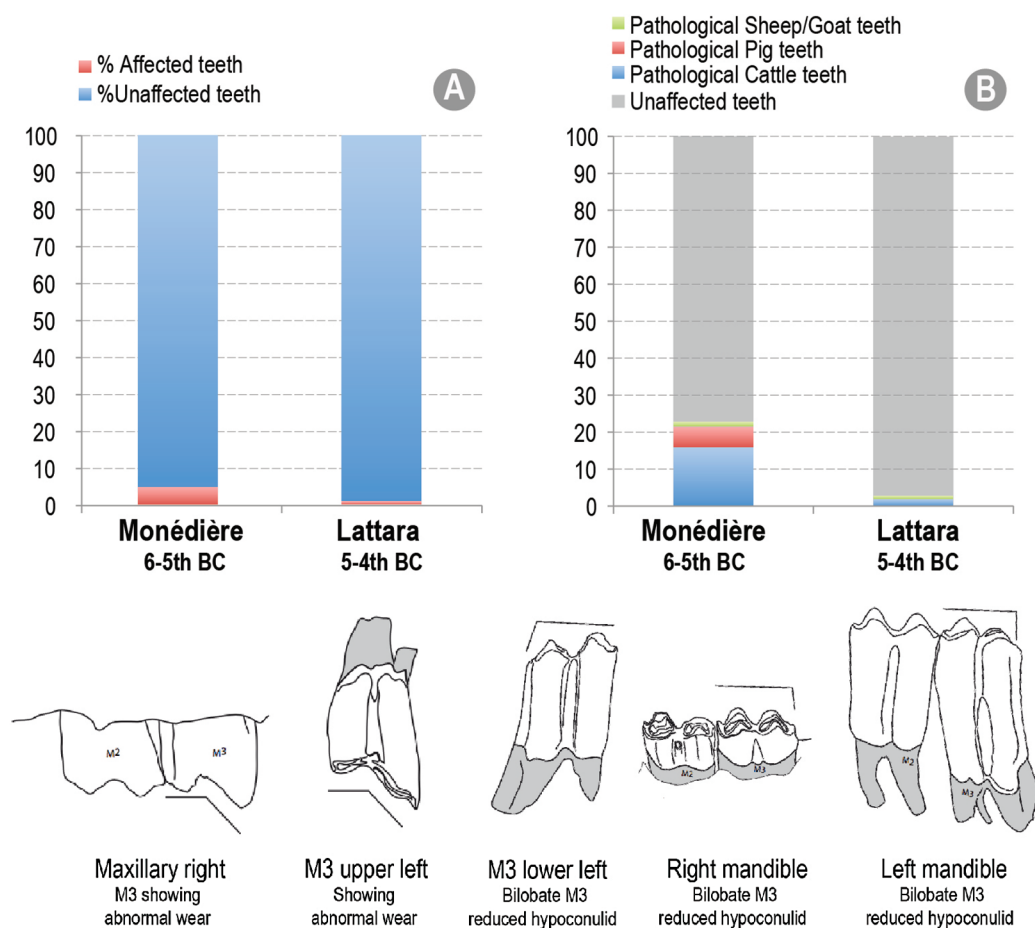
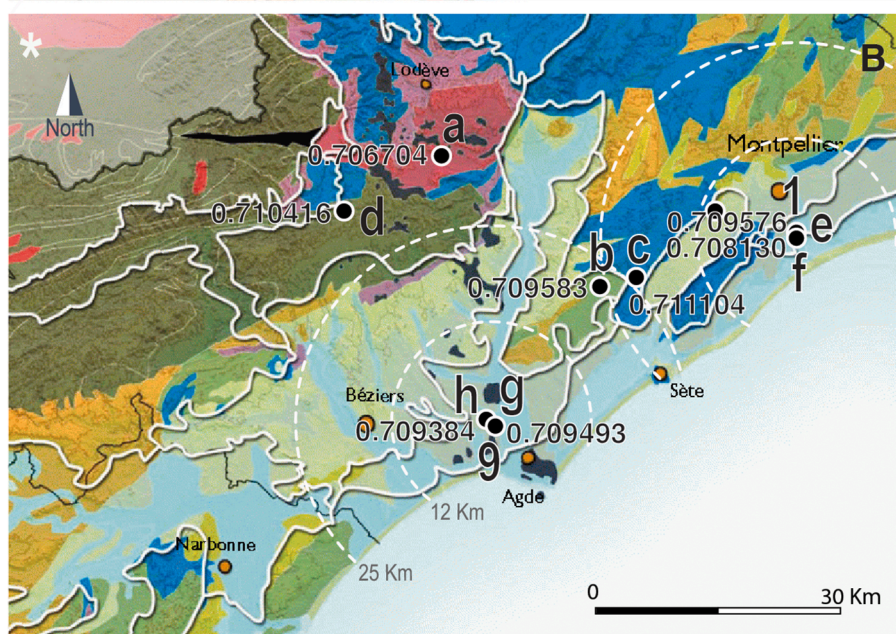
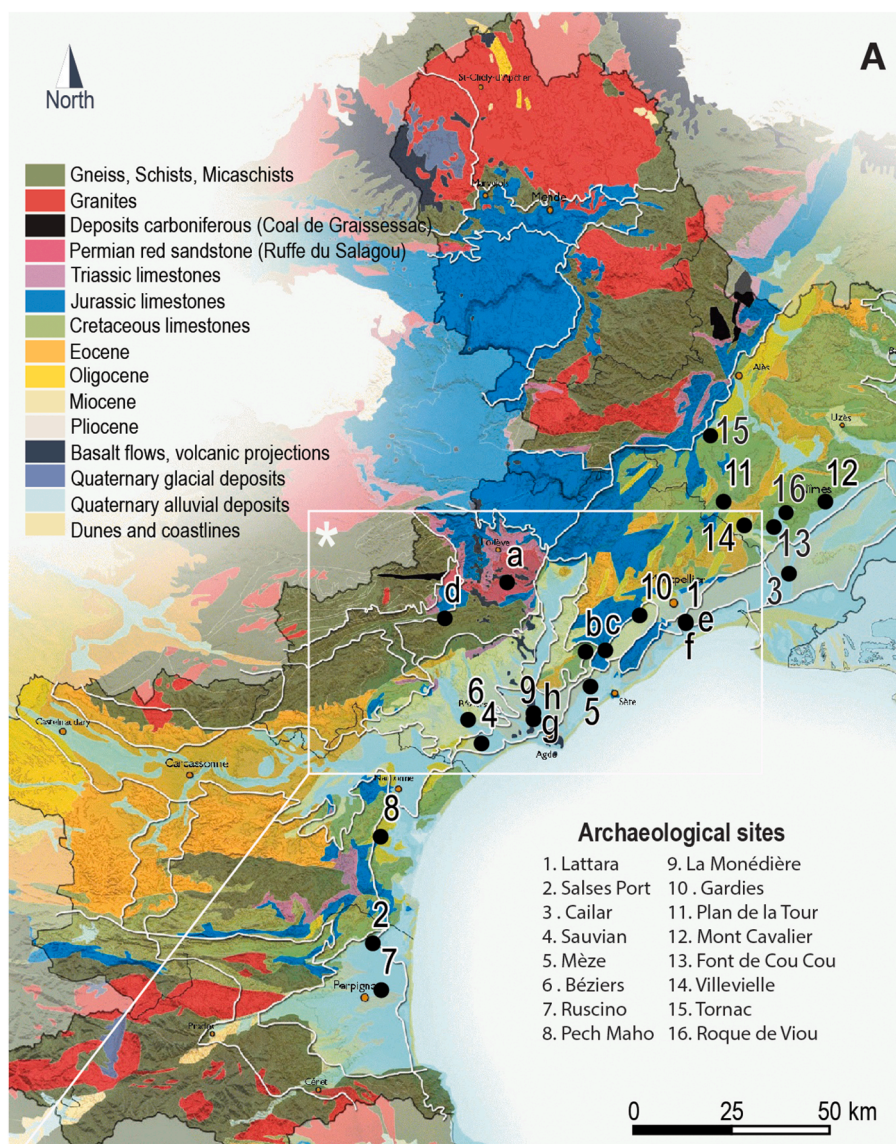


Fig. 5. On top: Dental pathologies identified at the settlements of La Monédière and Lattara. Data are expressed in number of affected teeth and percentage of the total number of dental pieces (isolated teeth, mandibles and maxilla) per site; **A:** Degree of incidence of dental pathologies at each site; **B:** Degree of affection by species with percentage of teeth affected by each species; **Bottom:** Illustrations of the dental pathologies identified in the sheep/goat and cattle of La Monédière and Lattara. After Argant et al. (2013), modified.

Table 2

Strontium isotopic ratios ($^{87}\text{Sr}/^{86}\text{Sr}$) obtained on modern tree leaves and sheep bones from different geologic formations. Coordinates ETRS89 UTM31N.

code	Sample code	W	N	Municipality	Era	Epoch	Bedrock	sample type	Species	$^{87}\text{Sr}/^{86}\text{Sr}$	error (± 2s)
a	M37	43.663170	3.343710	Celles	Cenozoic	Quaternary	Basalte	tree leaf	<i>Quercus ilex</i>	0.706704	0.000007
b	M38	43.502553	3.590682	Villeveyrac	Mesozoic	Cretaceous	Calcareous	tree leaf	<i>Pinus</i> sp.	0.709583	0.000007
c	M39	43.505669	3.652922	Poussan	Mesozoic	Jurassic	Calcareous	tree leaf	<i>Quercus ilex</i>	0.711104	0.000017
d	M40	43.580919	3.146213	Faugères	Palaeozoic	Ordovician	Gneiss, Schists, Micaschists	tree leaf	<i>Quercus ilex</i>	0.710416	0.000008
e	L10	43.56978	3.907409	Lattes St. Sauveur	Cenozoic	Holocene	Alluvial deposits	tree leaf	<i>Pinus</i> sp.	0.709576	0.000003
f	L11	43.566410	3.906950	Lattes St. Sauveur	Cenozoic	Holocene	Alluvial deposits	tree leaf	<i>Populus</i> sp.	0.708130	0.000003
g	MON-12_B	43.352739	3.427054	Bessan	Cenozoic	Holocene	Alluvial deposits	bone fragment	cattle	0.709493	0.000004
h	MON-13_B	43.352559	3.426070	Bessan	Cenozoic	Holocene	Alluvial deposits	dentine	cattle	0.709384	0.000004



(caption on next page)

Fig. 6. A. Location of sites in Hérault mentioned in the text (with numbers) and the sampling locations (with letters) of modern tree leaves and archaeological bones used to assess the bioavailable strontium of the different geological formations surrounding the sites. B. Detail map only with the sampling locations of modern tree leaves in the area of the department of Hérault. Source map: DREAL Languedoc-Roussillon/Agence Folléa-Gautier, paysagistes DPLG. Atlas des paysages du Languedoc-Roussillon-Synthèse régionale-Mars 2010 (source on-line: [http://paysages.languedoc-roussillon.developpement-durable.gouv.fr/synthese\)/partie1.html](http://paysages.languedoc-roussillon.developpement-durable.gouv.fr/synthese)/partie1.html).

Table 3
Strontium isotopic ratios ($^{87}\text{Sr}/^{86}\text{Sr}$) obtained from the archaeo

Site	SU	Sample code	S _f				e	⁸⁷ Sr/ ⁸⁶ Sr	error (± 2s)	Chronology	period
Monédière	10,443	MON-10_B	ca					0.709535	0.000004	– 450/-425	IA
Monédière	11,190	MON-11_B	ca					0.709146	0.000005	– 450/-425	IA
Monédière	10,556	MON-2_B	ca					0.708739	0.000005	– 500/-450	IA
Monédière	20,093	MON-3_B	cattle	lower M3	enamel			0.709393	0.000010	– 525/-450	IA
Monédière	10,581	MON-4_B	cattle	lower M3	enamel			0.714934	0.000006	– 550/-450	IA
Monédière	11,205	MON-5_B	cattle	lower M3	enamel			0.708151	0.000003	– 450/-425	IA
Monédière	20,024	MON-6_B	cattle	lower M2	enamel			0.709343	0.000008	– 200/-50	RR
Monédière	10,707	MON-7_B	cattle	upper M3	enamel			0.708689	0.000005	– 500/-400	IA
Monédière	10,758	MON-8_B	cattle	upper M3	enamel			0.709213	0.000003	– 550/-500	IA
Monédière	10,616	MON-9_B	cattle	upper M3	enamel			0.717909	0.000008	– 500/-450	IA
Lattes St. Sauveur	os-27757-9	LS5-1_B	cattle	lower M3	enamel			0.708594	0.000006	– 450/-425	IA
Lattes St. Sauveur	os-51121-27	LS5-3_B	cattle	lower M3	enamel			0.709759	0.000005	– 425/-400	IA
Lattes St. Sauveur	os-51075-1	LS5-5_B	cattle	lower M3	enamel			0.708722	0.000005	– 425/-400	IA
Lattes St. Sauveur	os-51121-28	LS5-7_B	cattle	lower M3	enamel			0.707892	0.000008	– 425/-400	IA
Lattes St. Sauveur	os-27757-5	LS5-9_B	cattle	lower M3	enamel			0.710728	0.000006	– 450/-425	IA
Lattes St. Sauveur	os-50301-7	LS5-11_B	cattle	lower M3	enamel			0.710804	0.000009	– 425/-400	IA
Lattes St. Sauveur	os-51019-1	LS5-13_B	cattle	lower M3	enamel			0.708635	0.000011	– 425/-400	IA
Lattes St. Sauveur	os-30294-5	LS5-15_B	cattle	lower M3	enamel			0.718899	0.000006	75/90	ERE
Lattes St. Sauveur	os-30292-11	LS5-41_B	cattle	lower M3	enamel			0.719532	0.000008	75/90	ERE
Lattes St. Sauveur	os-30291-3	LS5-63_B	cattle	lower M3	enamel			0.710799	0.000009	75/90	ERE
Lattes St. Sauveur	53301-22	L1	s/g	lower M3	enamel			0.708824	0.000007	– 450/-425	IA
Lattes St. Sauveur	51121-53	L2	s/g	lower M2	enamel			0.708740	0.000003	– 425/-400	IA
Lattes St. Sauveur	51092-53	L3	s/g	lower M2	enamel			0.709805	0.000008	– 425/-400	IA
Lattes St. Sauveur	53022-26	L4	s/g	lower M2	enamel			0.707982	0.000003	– 450/-425	IA
Lattes St. Sauveur	53038-28	L5	s/g	lower M3	enamel			0.708975	0.000003	– 450/-425	IA
Lattes St. Sauveur	53228-74	L6	s/g	lower M2	enamel			0.709087	0.000002	– 450/-425	IA
Lattes St. Sauveur	53224-5	L7	s/g	lower M3	enamel			0.708497	0.000003	– 450/-425	IA
Lattes St. Sauveur	50404-2	L8	s/g	lower M2	enamel			0.708914	0.000004	– 425/-400	IA
Lattes St. Sauveur	53022-28	L9	s/g	lower M3	enamel			0.708916	0.000003	– 450/-425	IA
Monédière	10605-unf8	M1	s/g	lower M2	enamel			0.708950	0.000005	– 500/-450	IA
Monédière	11436-FS1130-3	M2	s/g	lower M2	enamel			0.708644	0.000007	– 475/-450	IA
Monédière	11436-FS1130-2	M3	s/g	lower M2	enamel			0.710115	0.000006	– 475/-450	IA
Monédière	11436-FS1130-1	M4	s/g	lower M2	enamel			0.709802	0.000008	– 475/-450	IA
Monédière	10849-2	M5	s/g	lower M2	enamel			0.708363	0.000004	– 500/-450	IA
Monédière	10714-2	M6	s/g	lower M2	enamel			0.709307	0.000003	– 525/-450	IA
Monédière	10714-1	M7	s/g	lower M2	enamel			0.707691	0.000003	– 525/-450	IA
Monédière	10,971	M8	s/g	lower M3	enamel			0.708666	0.000008	– 575/-450	IA
Monédière	10849-1	M9	s/g	lower M2	enamel			0.709193	0.000004	– 500/-450	IA
Monédière	20,024	M10	s/g	lower M2	enamel			0.709191	0.000005	– 525/-425	IA
Monédière	10461-1	M11	sheep	lower M3	enamel			0.708188	0.000004	– 475/-450	IA
Monédière	10461-2	M12	goat	lower M2	enamel			0.710842	0.000010	– 475/-450	IA
Monédière	11,092	M13	s/g	lower M3	enamel			0.707844	0.000004	– 550/-500	IA
Monédière	11,366	M14	s/g	lower M3	enamel			0.709459	0.000008	– 525/-400	IA
Monédière	10,181	M15	s/g	lower M3	enamel			0.708661	0.000004	– 575/-550	IA
Monédière	11,022	M16	s/g	lower M2	enamel			0.708986	0.000003	– 540/-500	IA
Monédière	20,012	M17	sheep	lower M2	enamel			0.709197	0.000004	– 525/-425	IA
Monédière	11,202	M18	s/g	upper M3	enamel			0.710568	0.000006	– 550/-400	IA
Monédière	11,227	M19	sheep	lower M3	enamel			0.709880	0.000004	– 475/-450	IA
Monédière	10413-1	M20	sheep	lower M2	enamel			0.710531	0.000007	– 525/-475	IA
Monédière	10413-2	M21	sheep	lower M2	enamel			0.708956	0.000003	– 525/-475	IA
Monédière	11,190	M22	sheep	lower M3	enamel			0.708842	0.000004	– 450/-425	IA
Monédière	11,203	M23	goat	lower M3	enamel			0.710750	0.000005	– 550/-500	IA
Monédière	10,847	M24	sheep	lower M2	enamel			0.708284	0.000005	– 475/-425	IA
Monédière	10970-1	M26	sheep	lower M2	enamel			0.709017	0.000006	– 550/-500	IA
Monédière	10970-2	M27	sheep	lower M2	enamel			0.708977	0.000004	– 550/-500	IA
Monédière	10970-3	M28	sheep	lower M2	enamel			0.708982	0.000009	– 550/-500	IA
Monédière	10970-4	M29	goat	lower M2	enamel			0.709595	0.000006	– 550/-500	IA
Monédière	11,190	M30	goat	lower M2	enamel			0.707856	0.000005	– 450/-425	IA
Monédière	11041-1	M31	sheep	lower M2	enamel			0.708075	0.000004	– 575/-500	IA
Monédière	11041-2	M32	sheep	lower M2	enamel			0.709506	0.000004	– 575/-500	IA
Monédière	10,922	M33	s/g	lower M3	enamel			0.708948	0.000003	– 575/-400	IA
Monédière	11,119	M34	goat	lower M2	enamel			0.708386	0.000004	– 600/-500	IA
Monédière	11,028	M35	sheep	lower M2	enamel			0.708772	0.000004	– 500/-400	IA
Monédière	10,369	M36	s/g	upper M3	enamel			0.707901	0.000004	– 475/-450	IA

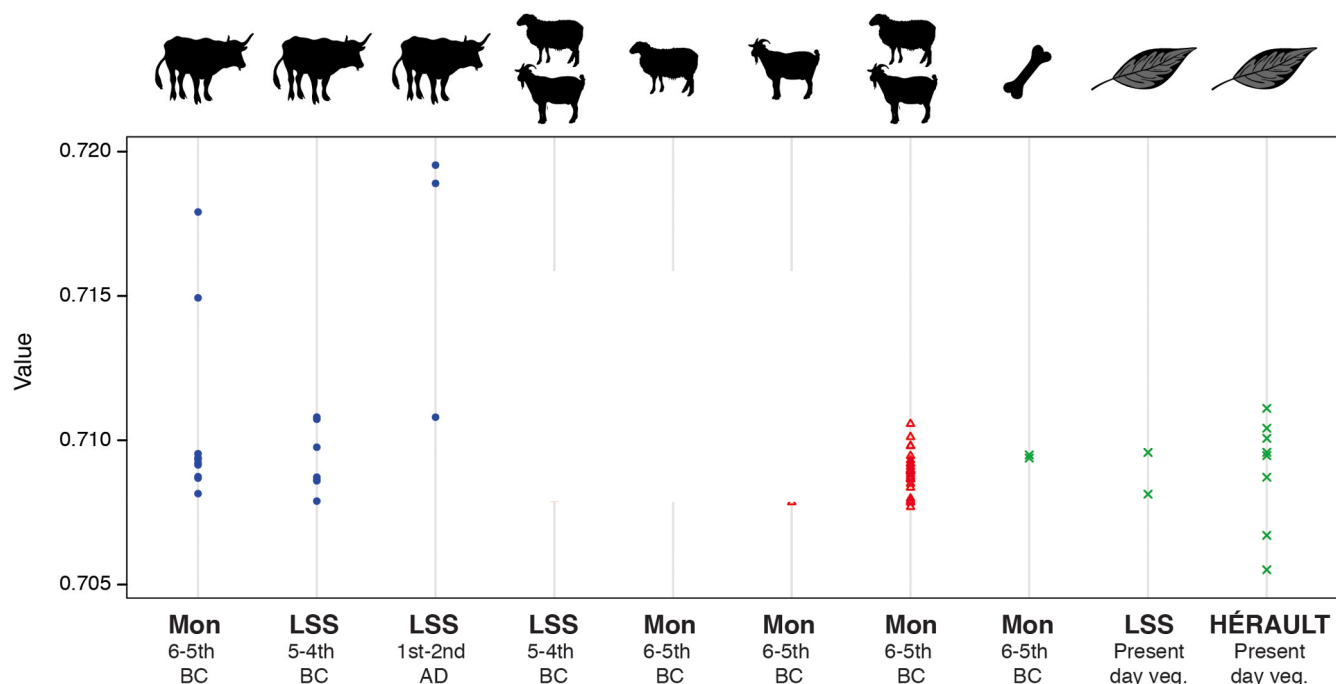


Fig. 7. Strontium isotopic ratios ($^{87}\text{Sr}/^{86}\text{Sr}$) obtained from archaeological cattle and sheep and goats enamel from La Monédière and Lattara and baseline samples from the archaeological sites and Héroult department.

supplementary material). This is most evident on Early Imperial assemblages at present-day Montpellier and Port Arianne.

Caprine size appears to be more stable through time, although some variations occurred (Fig. 9). Iron Age caprines from Lattara seem to be larger than the contemporary ones from present-day Catalonia. The Mann-Whitney U test (Tables 8 and 9 in supplementary material) revealed that these differences are not significant although this may be consequence of the low sample size. Empúries had a large degree of caprine length variability, something that it is not attested on widths (Fig. 9). In addition, the indigenous site of Mas Castellar de Pontós had caprines with bigger width values compared to Empúries (Mann-U p value = 0.001). As stated above, there was a significant increase of width values at LSS from the 5th to the 4th c. BC, and the Mann-Whitney U test confirmed that this increase was statistically significant (p value = 0.009). Perhaps the most significant result is that, in contrast with cattle, caprine size seemed not to change much in Roman times in this area.

4. Discussion

The comparison of Iron Age NISP frequencies from Languedoc suggests that each site adapted animal husbandry to their most immediate environment, especially in early chronologies (6th–5th c. BC). This led to higher frequencies of caprine remains at the *oppida* located on scrubland and dry hills, and higher presence of cattle at the sites located on the coastal wetlands and swamps as previous works had pointed out (Al Besso et al., 2013; Forest, 2013). This has an echo today in this area, as the local cattle breed (Camargaise) is reared in a free-range regime on the coastal wetlands and swamps the whole year (Fig. 10). In contrast, sheep graze on the dry inland area for which they are better adapted, as they are more sensitive to humidity and bacteria (Vincent and Holder, 2008; Dupieux, 1998; Thulliez and Magueur, 2018). From the 4th c. BC, the higher frequency of pig remains at most sites may be related to the increase of urbanisation and/or the convenience of an animal that does not compete with agricultural land. It also suggests a more intensive meat production as observed at Iron Age sites from present-day Catalonia dated from the 4th and especially the

3rd c. BC (e.g. Iborra, 2004; Valenzuela-Lamas, 2008; Nieto-Espinet, 2012; Colominas, 2013).

The focus and the intensity of meat production are also attested on mortality profiles. Cattle cull-off pattern at MON suggests a strong focus on meat production and the slaughter of adult animals the reproductive capacity of which started to decrease (Fig. 3). In this sense, the low number of animals older than 72 months suggests that cattle devoted to labour were not usually slaughtered for their meat at the end of their productive life. At LSS, cattle were kept alive for a longer period compared to MON, and most animals were killed between the 48 and 72 months of life (Fig. 3). This may reflect better nourishment conditions, longer reproductive life, or perhaps a stronger focus on secondary products. Same as in MON, the absence of senile animals suggest that workforce animals were not usually consumed at LSS.

Caprine mortality profiles suggest a strong focus on milk exploitation together with meat and, most probably, wool and hair, although these later products were not driving the overall management (Fig. 2). In any case, management at MON is clearly different to the one attested at LSS, which seems very specialised on young caprines and adults older than 48 months. Conversely, MON shows a profile centred on milk and prime meat. In both cases, exploitation seems to be intensive, with a quick renewal of animals before their productive capacity started to decrease. This has been also attested at French Neolithic sites (Helmer and Vigne, 2004; Blaise, 2005, 2010; among others), and other Neolithic sites in Greece (e.g. Helmer, 2000a), the Near East (p.e. Helmer, 2000b) and Iron Age sites in present-day Catalonia (e.g. Colominas, 2004: 223; Valenzuela-Lamas, 2008; Nieto-Espinet 2012: 387–389). In previous studies, Gardeisen and Raux (2000) suggested that the slaughter of older adults increased in the 4th–3rd c. BC at LSS, and they related this increase to a stronger focus on secondary products. Some archaeological materials such as the *faiselles* together with the loom weights and spindle whorls recovered across the site testify of the use of milk and its derivatives (Feugère, 1992: 294) as well as wool work at domestic level (Raux, 1999; Gardeisen and Raux, 2000).

Both cattle and caprines have different mortality profiles at MON and LSS, and mature animals predominate at LSS. Based on ethnographical parallels, Stein (1987) proposed that producers and



The different types of landscapes

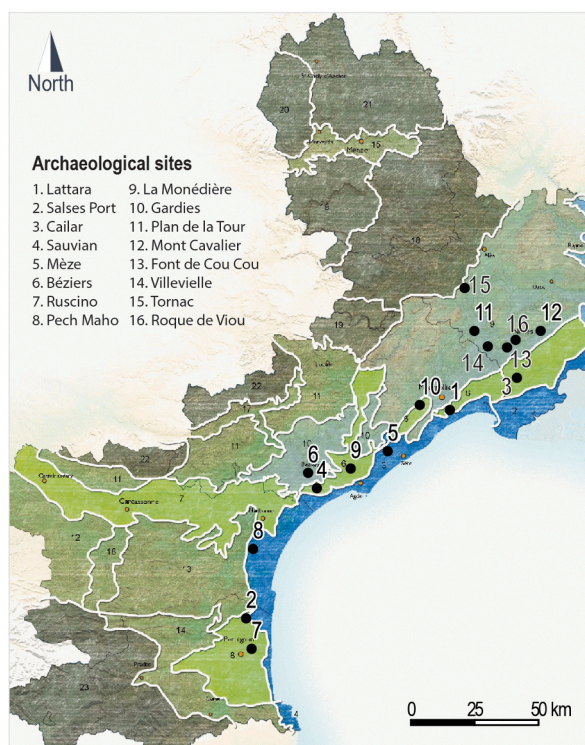
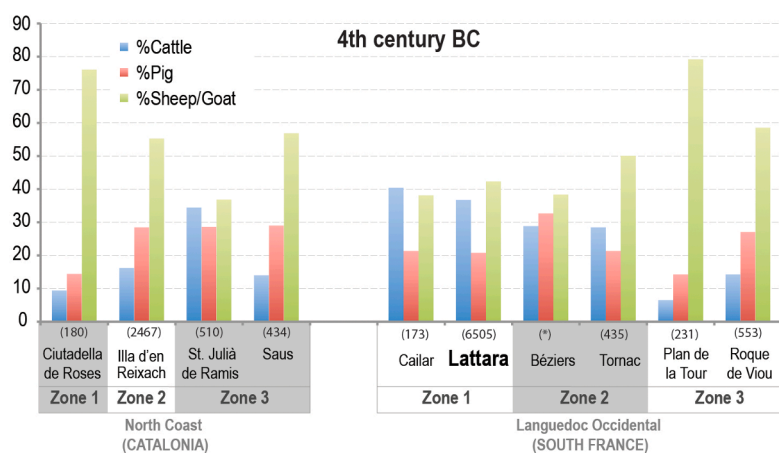
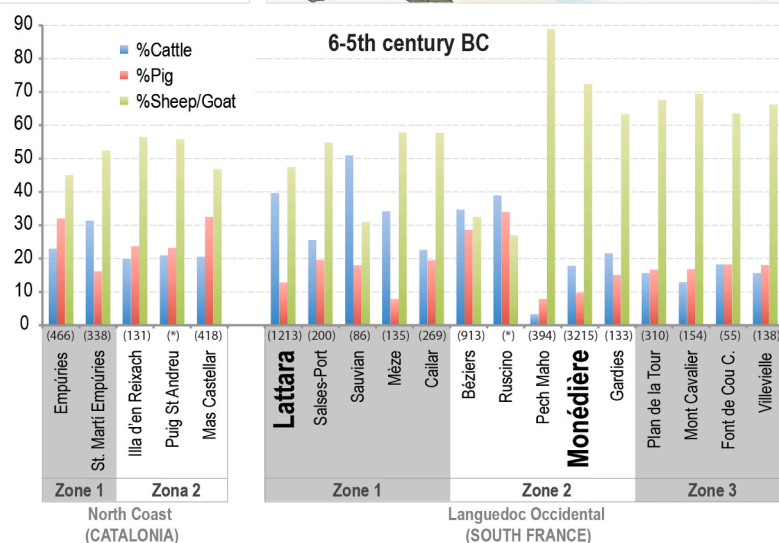


Fig. 8. Comparison of the distribution of the main domesticates in Middle Iron Age (6th to 4th BC) sites in North Catalonia (Sant Martí d'Empúries: [Casellas, 1999a](#); Illa d'en Reixac: [Casellas, 1999b](#); Ciutadella de Roses: [Monteró, 2000](#); Mas Castellar: [Colominas, 2013](#); [Colominas et al. 2017](#); Puig de Sant Andreu and Empúries: [Molist et al., 1987](#)) and Western Languedoc (Salses and Mèze: [Columeau, 1997a, 1997b](#); Sauvian: [Ugolini and Olive, 1998](#); Béziers: [Ugolini and Olive, 1991b](#); Cailar: [Gardeisen, 2002](#); [Creuzieux, 2009](#); Pech Maho: [Columeau, 2004](#); and for the other sites see references in [Gardeisen, 2010: 426](#); [Albesso et al., 2013: 140–142](#); [Sejalón et al., 2012: 22](#)). (n) The number in brackets refers to the NISP of the main domesticates; (*) the asterisk in brackets refers to the sites with only main domesticates percentages available. Source map: DREAL Languedoc-Roussillon/Agence Folléa-Gautier, paysagistes DPLG. Atlas des paysages du Languedoc-Roussillon-Synthèse régionale-Mars 2010 (source on-line: <http://paysages.languedoc-roussillon.developpement-durable.gouv.fr/synthese>).



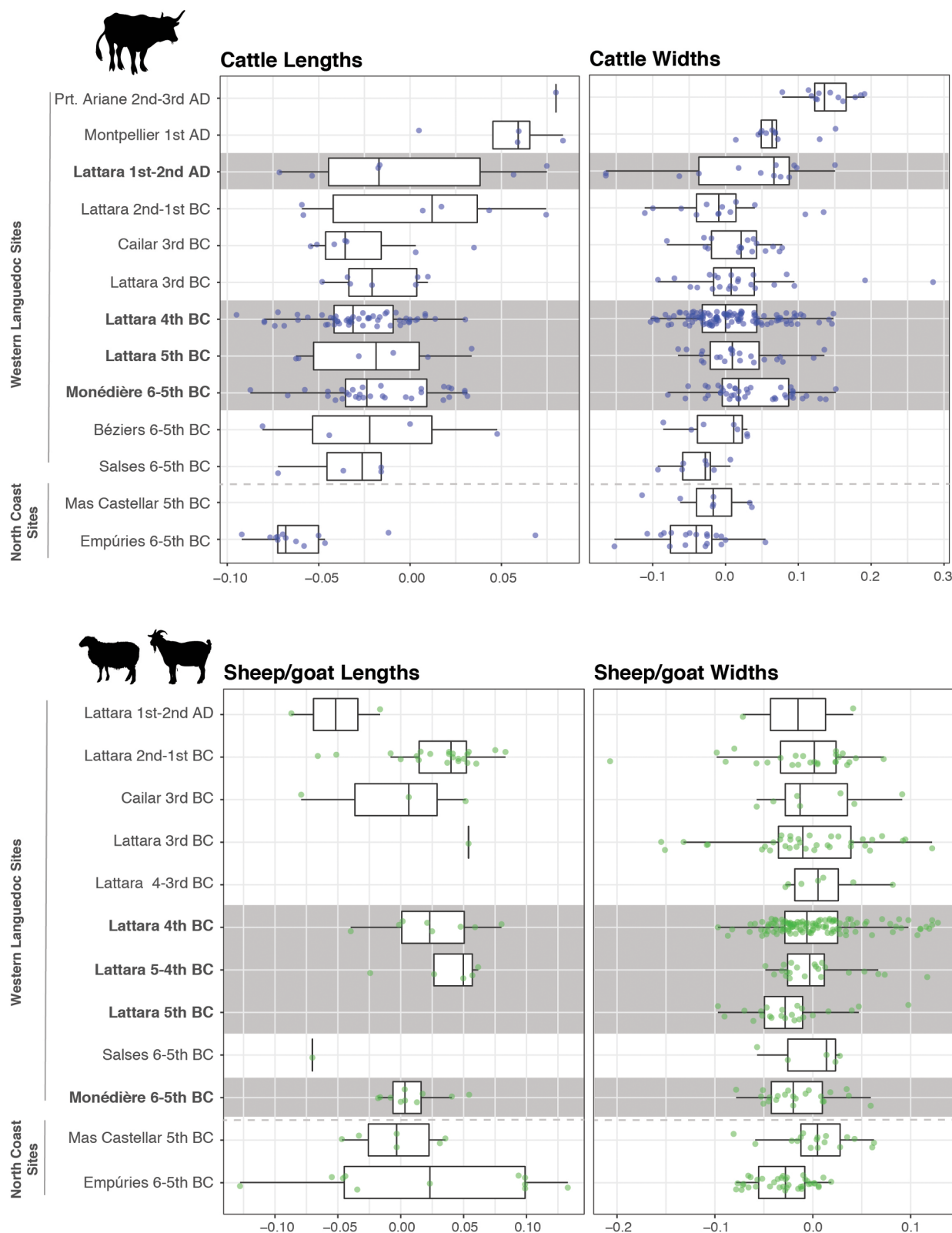


Fig. 9. Comparison of bone lengths and widths measurements (LSI values) for sheep/goat and cattle at the sites of La Monédière and Lattara together with other sites of the North Coast of present-day Catalonia and Western Languedoc (Creusieux, 2009; Valenzuela-Lamas, unpublished; Columbeau, 2000a: 115; Ugolini et al., 1991: 141–143; Columbeau, 1997: 18).

consumers had different patterns of meat consumption. In a producer site, young animals (mainly males aged between 12 and 36 months) would be sold for slaughter and the best reproducers would be kept to ensure herd sustainability. Consequently, the meat consumption

pattern of producers would have a peak on young animals (before the optimum meat) and another one on adults aged between 72 and 84 months, when the reproductive capacity of the animals starts to decrease. A consumer economy would be characterised by the high



Fig. 10. A-B-C: The breed from Camargue or “Raço di biòu” to a type of breeding that has remained very extensive. The Camargue is located in the Rhone delta, with typical landscapes shaped by the river. The diversity of Camargue's landscapes, which include ponds, canals, flooded prairies, paddies, and salt flats. In this area around 18,000 to 20,000 bulls are raised in more than 150 herds, of which at least half have more than 100 heads. URL: http://www.parc-camargue.fr/index.php?pagendx=app_173. **D:** Nearly 20,000 sheep roam in the Languedoc and the Cevennes (in the picture flocks of sheep in the Cevennes, South France). URL: <https://www.la-croix.com/Journal/estives-Cevennes-bergers-sont-labri-2017-09-20-1100878201>. **E:** Present day flocks of sheep in the Corbières (South France), a dry massif south of the Carcassonne-Narbonne line, URL: <http://www.albas-corbieres.fr>. **F:** Present day flocks of sheep in the Garrigues (Gard). URL: <http://www.pascale-menetrier-delalandre.com/moutons-caussenarde-des-garrigues-a92788485>.

presence of animals in optimum meat (12–36 months) and the absence of young and seniles. The mortality profiles at MON at LSS do not fully correspond to either of these models, but MON ones suggest focus on milk production and meat consumption, and the high proportion of mature adults at LSS seems to better correspond to a pattern that may be selling the animals at their optimum meat. As observed at LSS seem inappropriate with the idea of an urban site depending on its hinterland, but may fit with a lively Mediterranean of-trade dependent from a bigger site (Marseille in this part).

Iron Age cattle at both MON and LSS, as well as at Languedoc and neighbour present-day Catalonia, were small compared to Neolithic cattle from these areas (e.g. Forest, 2013). Cattle size decrease happened across Europe from Neolithic times onwards, and numerous studies point out that size only increased in the Late Iron Age and Roman times (see references in Valenzuela-Lamas and Albarella 2017 for a review, and also Duval and Clavel (2018) for an updated synthesis for France). This has also been attested in the region studied here, although a high diversity of sizes coexisted at LSS in the 1st c. AD (Fig. 9). In contrast, caprine size remained more stable through time. Roman caprines at LSS may have been smaller than Iron Age ones, but the differences were found not to be significant (Tables 8 and 9 in supplementary material).

As stated in the introduction, the reasons for cattle size diminution are not clear, but the presence of pathologies related with herds with high ratios of inbreeding and malnutrition at MON and LSS, together with the strontium isotopic ratios recorded (most of them compatible with local geology), may provide some hints to understand this process. In the case of MON, the pathologies observed on cattle teeth include hypoplasia and anomalous wear on M3 related to malocclusion (Table 2 and Fig. 5). Hypoplasia is known to reflect malnutrition and physiological stress during the period of tooth formation (Upex and Dobney, 2012), and anomalous M3 wear has been related with herds maintained in small breeding groups (O'Connor, 2000; Argant et al., 2013; Nieto et al., 2014: 95). In the case of LSS, a cattle bilobate M3 with the reduced hypoconulid was identified, together with a caprine lower M3 with abnormal hypoconulid wear (Table 2). The reduction of hypoconulid has also been related with inbreeding and malnutrition (O'Connor, 2000). The presence of these pathologies indicates that some animals suffered from inbreeding and nutritional stress both at

MON and LSS. In this sense, Argant et al. (2013) state that malocclusion and bilobate third molars are especially present during the Iron Age in

addition to other prehistoric and historical periods. Strontium isotopic analysis ($^{87}\text{Sr}/^{86}\text{Sr}$) on 20 cattle and 44 caprines at LSS revealed low variability of strontium ratios among animals dated from the Iron Age (Fig. 7). Two cattle at MON have strontium ratios not compatible with any geology immediately surrounding the sites, which indicates the presence of some animals further away, probably from a granitic bedrock area. In contrast, caprines with high strontium signatures were recorded despite the significantly higher number of teeth sampled and the presence of both M2 and M3 - and therefore different mineralisation periods. While the possibility cannot be excluded that cattle and caprines analysed originated from other areas with similar geology, the homogeneity of strontium values argues against this. The results obtained are compatible with local and small scale herding coupled to occasional exchange of animals as observed on other Iron Age sites (e.g. Owslebury, UK, Minniti et al 2014; Turó de la Font de la Canya, Spain, Valenzuela-Lamas et al 2018) rather than frequent long-distance trade of animals.

Another evidence suggesting local herding is the high correlation between the immediate ecological environment of the sites and animal production (Fig. 8).

Consequently, the combination of different lines of evidence (NISP frequencies, pathologies, strontium isotopes) suggests that livestock was mainly bred locally during the Iron Age in this area, and mainly 'prestige' goods (e.g. Greek wine, Etruscan and Greek fine ware) arrived from distant sources (Dietler, 2010; Janin and Py, 2012). Nevertheless, transport of living animals towards other places overseas, or the shipping of preserved meat as exchange for the imported goods cannot be excluded.

Local breeding of livestock may reflect the local socio-political context during the Iron Age. The significant change in settlement pattern from the Late Bronze to the Iron Age - from open-air sites to fortified settlements - together with the presence of warrior equipment and weapons in some tombs and severed heads at some sites is thought to reflect increased warfare and territoriality (e.g. Dedet and Py, 1985; Dedet 1995; Janin, 1992; Arcelin et al., 2003; Beylier and Gailledrat, 2009; Bagan et al., 2010; Gailledrat, 2014). Perhaps, even if long-

distance maritime trade flourished during the Iron Age across the Mediterranean, long-distance terrestrial movements of livestock were difficult in Languedoc at this time.

Conversely, the three Roman cattle from Lattara had a much higher strontium isotopic variability, which could reflect a wider circulation of animals. Cattle were clearly bigger in Roman times in the Gulf of Lion as demonstrated in numerous studies (e.g. Forest and Rodet-Belarbi, 2002; Forest, 2013; Duval and Clavel, 2018; Colominas et al., 2014, see also Fig. 9). More data are needed for this region, but the results are also compatible with the ones observed at Roman Owslebury (UK, Minniti et al. 2014). This suggests that animal size, mobility and economic system may be correlated, as previously suggested (Valenzuela-Lamas and Albarella, 2017).

5. Conclusions

This work presents the main zooarchaeological results from two major Iron Age sites in present-day Languedoc – La Monédière (Bessan) and Lattara (Lattes) – and contextualises them in their regional environment. In addition, strontium isotopic ratios ($^{87}\text{Sr}/^{86}\text{Sr}$) of 44 caprines (sheep and goats) and 16 cattle were analysed to assess the geographic range of livestock rearing during the Iron Age at these sites. Four Roman cattle were also included as a comparison. The zooarchaeological results showed that meat diet at these two urban sites focused on caprines and cattle. Moreover, a strong link between animal husbandry and immediate ecological environment was observed, and several pathologies related with inbreeding and malnutrition were recorded both at La Monédière and Lattara (i.e. anomalous wear on the third molar, bilobate third molar, hypoplasias). Iron Age cattle in Languedoc were small compared with Neolithic and Roman ones, as attested across Europe at this time, and caprine size was found to be more stable. Most animals dated from the Iron Age had strontium isotopic ratios compatible with the ones present in a 25 Km radius from the sites. Conversely, the Roman cattle from Lattara corresponded to individuals raised on a higher diversity of geological areas, thus suggesting wider circulation of animals in Roman times.

The results are coherent with other archaeological data and provide a comprehensive insight of animal husbandry in Iron Age Languedoc. Local breeding of livestock may reflect the local socio-political context of warfare and territoriality (as shown by fortifications, weapons and severed heads). This probably increased inbreeding and perhaps malnutrition of animals, and favoured smaller cattle, less demanding in water and fodder. While 'prestige goods' (e.g. wine, fine ware) were imported from distant places, terrestrial movement was probably difficult compared to Roman times, in which large-scale production and trade also involved wider circulation of living animals.

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Appendix A. Supplementary data

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