Sheep and goat husbandry during the Early European Neolithic

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Word count:

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Abstract

Archaeozoological assemblages are important sources of information on past management strategies, which are influenced by cultural practices as well as the physical geography and climate. Sheep, goat and cattle arrived in Europe with early Neolithic migrants. Their distribution is believed to have been mainly influenced by the geography of European regions although individual species may have held symbolic importance for specific Neolithic cultures. Domesticated animal mortality data derived from dental eruption, wear and replacement can provide insights into slaughter management and consequently animal husbandry practices. Previous studies have focused on caprines (sheep and goat) collectively as a results of their morphological similarity. Here we present a species specific study of sheep and goat mortality data from early European and Anatolian Neolithic contexts using correspondence analysis. The results show that for sheep there were significant differences in slaughter management practices between regions, cultures and site types whereas for goats there was none. This initial examination into sheep and goat husbandry during the Neolithic suggest that cultural practices as well as regional geography played an important role in shaping management practices. Further species specific age-at-death determinations are is needed to investigate fully the evolution and development of present-day sheep and goat husbandry practices.

Keywords: Sheep, Goats, Neolithic, Europe, mortality data, correspondence analysis.

Introduction

Sheep (*Ovis aries*) and goat (*Capra hircus*) are an important component of modern livestock systems, producing renewable products such as milk, hair/wool, manure and traction as well as final products such as meat, skin, horn and bone. They are very morphological similar but, however, have different physiological and productive capacities (Haenlein 2007, Gillis, Chaix, and Vigne 2011, Halstead, Collins, and Isaakidou 2002). Sheep are naturally grazers, with short lactation lengths that produce high fat content milk ideal for cheese making. In comparison, goats are browsers and can exist in areas of rough grazing to such a degree that they have been used deliberately to remove unwanted vegetation in areas. They have a long lactation length earning them the synonym ‘the poor man’s cow’ (Haenlein 2007). Both species can survive in arid regions with infrequent water sources. Present day husbandry systems for these species vary greatly between southern and northern Europe. In the Mediterranean region, there is a focus towards systems that produce milk, lambs (<12 months) and wool. In the Balkans, transhumance with a focus on milk production is widely practised by stockherders who range from Northern Greece to Croatia and Serbia. In central and northern Europe, sheep were traditionally been used for wool and meat production. Specialised milk breeds for cheese production have been developed during the last century from traditional breeds with the capacity for good milk production such as Lacaune and East Friesian sheep and the Saanen Goat.

Direct morphological evidence for sheep and goat domestication has been identified at Pre-Pottery Neolithic (PPN) sites in the northern Levant and Zagros regions respectively, dating to the 9th millennium cal BC (Peters et al. 1999, Zeder 1999). From this point caprines formed an important cornerstone of prehistoric subsistence practices (Helmer, Gourichon, and Vila 2007, Arbuckle et al. 2014). They were the predominate species for Early Neolithic settlements of southern Europe; this is in part a reflection of their success in drier climates in comparison to cattle (Manning et al. 2013).

Neolithic cultures spread and were adopted by local hunter-gatherers groups along two main routes: following the northern Mediterranean seaboard to the west and major European rivers to the north. Along the Mediterranean seaboard, caprines dominated the Impressa and Cardial culture assemblages with some exceptions in south-eastern Italy (Rowley-Conwy et al. 2013). As Neolithic groups spread northwards into central and eastern Europe via the Balkans the proportions of sheep and goats kept at sites became more variable with an overall shift through time towards a greater reliance on the herding of cattle and pigs (Orton, Gaastra, and Linden 2016). This shift in focus towards cattle continued as the Neolithic spread further into Europe. Cattle were the predominate animal of the early Neolithic cultures such as the Linearbandkeramik of Central and Northern Europe. In some areas such as Southern Bavaria, caprines were more numerous than cattle (Lüning 2000). Moreover, Marciniak (2013) proposed that caprines may have used as the meat source with cattle being used for ritual consumption in LBK sites in southern Poland.

Individual domesticated species have different productive capacities, which have been exploited by herdsmen since domestication. Understanding the individual roles of sheep and goat since their domestication has been hampered by poor identification due to their morphological similarity (Boessneck, Müller, and Teichert 1964). In the last twenty years there has been methodological advances in identifying sheep and goat using dental morphology (Helmer 2000; Halstead, Collins, and Isaakidou 2002, Gillis, Chaix, and Vigne 2011, Zeder and Pilaar 2010). Animal teeth are an excellent source of information about past slaughter management and consequently husbandry practices. Here we present an analysis of species specific mortality profiles to investigate, compare and characterise species-specific husbandry practices during the early phases of the European Neolithic (7th to 5th millennium cal BC).

Material and Methods

Caprine age-at-death determination using eruption and replacement of dental remains was established by Ewbank et al. (1964) with occlusal wear stages based on Grant (1982) observations of caprines from English Iron Age sites. Species specific age-at-death methodologies specifically for eruption and wear stage have been developed for sheep devised by Silver (1963), Weinreb and Sharav (1964), Payne (1973, 1987) and Jones (2006) based on observations of modern sheep. For goats, Silver (1963), Noddle (1974), Bullock and Rackham (1982) and Deniz and Payne (1982) investigated eruption times and wear stages (Deniz and Payne 1982). There are slight differences between species in terms of eruption of the deciduous premolars (erupt later in goats), premolars and molars (erupt earlier in goats (Gillis 2012)). Many of the studies concerning goats were dominated with male goats, whose teeth have been observed erupted earlier than females (Deniz and Payne 1982).

Additional methods using the crown height and width were introduced by Ducos (1968) and re-examined by Gaastra (2016), the former was integrated into Payne's original age classes by Helmer, Gourichon, and Vila (2007). Mortality analysis of caprines in general and in case of this study, uses the age-at-death determination based on sheep, particularly that of Payne (1973). However, there is scope for the development of species-specific age-at-death methodologies in the future.

Because of the fragmented nature of archaeozoological remains and of the infrequent recovery of complete or large portions of mandibles, we included isolated teeth in the final count (deciduous premolar 4, premolar 4, molars 1-3). First and second molars can often be mistakenly identified as each other, to prevent this we took measurements (height and distance anterior/posterior) of known M1 and M2s and compared with loose M1and M2s. Isolated teeth found to belong to several age classes were divided between them according to the respective time length of the age classes according to Payne (1973).

Those sites studied by RG and JSG, sheep and goat were distinguished using methodologies established by Helmer (2000); Halstead et al. (2006); Balasse and Ambrose. (2005); Zeder and Pilaar (2010); Gillis et al. (2011).

The Dataset

We collected mortality data based on dental remains from 35 sheep profiles from 25 sites and 17 goat profiles from 18 sites (Figure 1; Table 1). RG studied and differentiated the caprine remains from 17 sites (La Draga (LAD), Font Juvenal (FON), Trasano (TRA), Füzseabony-Gubakút (FUZ), Apc-Berekalja (APC), Polgár-Piócási-dűlő (PIO), Polgár-Ferenci-hát (FER), Ludwinowo (LUD), Mold (MOL), Těšetice-Kyjovice (TES), Dillingen-Steinheim (WIK), Herxheim (HEX) and Bischoffsheim (BIS)). While JSG studied and differentiated the caprine remains from 3 sites (Spila Nakovana (SPI), Kneževi Vinograd (KNE), Belišće (BEL)). The remaining sties were collected from published sources detailed in SDATA1. The sites are representative of early Neolithic cultures from Anatolia, the Balkans, north-western Mediterranean, central Europe and Northern European plain. Sites/phases with a total less than 6 teeth per species were removed. On average the total sample size per site or site phase was 33 for sheep and 24.5 for goats.

[FIGURE 1 HERE]

Figure 1, Map of site locations: Erbaba Höyük (EH), Ulucak Höyük (ULU), Spila Nakovana (SPI), Belišće (BEL), Blagotin (BLA), Seuşa-Cararea Morii (SEU), Foeni-Salaş (FOS), Polgár 10 (POL), Kneževi Vinograd (KNE), Font Juvenal (FON), La Draga (LAD), Trasano (TRA), Arene Candide (ARE), Füzseabony-Gubakút (FUZ), Apc-Berekalja (APC), Polgár-Piócási-dűlő (PIO), Polgár-Ferenci-hát (FER), Ludwinowo (LUD), Mold (MOL), Těšetice-Kyjovice (TES), Dillingen-Steinheim (WIK), Herxheim (HEX) and Bischoffsheim (BIS). Map was produced using ggmaps ((Kahle and Wickham 2013), satellite base map from Google maps Imagery © Terrametrics.

Table 1, Details of species identified, culture, region, climate and site type for studied sites.

Site	Code	Ovis/ Capra	Culture	Region	Climate	Site type	Citation
Ulucak Höyük	ULU	O	ENA	Anatolia	Csa	open	Çakırlar 2012
Erbaba Höyük	EH	O/C	LNT	Anatolia	Csa	open	Arbuckle 2008
Belisce	BEL	O	EN	Balkans	Dfb		Gaastra unpublished
Knezevi Vinograd	KNE	O/C	EN	Balkans	Dfb		Gaastra unpublished
Foeni-Salas	FOE	O	EN	Balkans	Dfa	open	Greenfield and Jongsma 2008
Seusa-Cararea Morii	SEU	O	EN	Balkans	Dfc		El Susi 2000.
Blagotin	BLA	O	EN	Balkans	Csb	open	Greenfield and Jongsma 2008
Mold	Mold	O/C	LBK	Central	Dfb	open	Gillis unpublished
Těšetice-Kyjovice	TES	O	LBK	Central	Dfb	open	Gillis unpublished
Polgar 10	POL	O	EN	Central	Dfb	open	Brighton et al. 2000.
Polgár-Piócási-Dűlő	PPIO	O	LBK	Central	Dfb	open	Gillis unpublished
Apc-Berekalja	APC	O	LBK	Central	Dfb	open	Gillis unpublished
Polgár-Ferenci-Hát	PFER	O/C	LBK	Central	Dfb	open	Gillis unpublished

Füzseabony-Gubakút	FUZ	O/C	LBK	Central	Dfb	open	Gillis unpublished
Luwinowo	LUD	O/C	LBK	NW Plain	Dfb	open	Gillis unpublished
Bischoffheim	BIS	O/C	LBK	NW Plain	Cfb	open	Gillis submitted
Rosheim	ROS	O/C	LBK	NW Plain	Cfb	open	Gillis unpublished
Hexheim	HEX	O/C	LBK	NW Plain	Cfb	open	Gillis in press
Dillingen-Steinheim	WIK	O/C	LBK	NW Plain	Cfb	open	Gillis unpublished
Font Juvenal	FON	O/C	ICW	Franco-Iberian	Cfb	cave/rockshelter	Gillis 2012
Arene Candide	ARE	O	ICW	Franco-Iberian	Csa	cave/rockshelter	Rowely-Conwy 1997
La Draga	LAD	O/C	ICW	Franco-Iberian	Cfb	open	Gillis 2012
Spila Nakovana	SPI	O	EN	Adratic	Dfb	cave/rockshelter	Gaastra unpublished
Transano	TRA	O/C	ICW	Adratic	Csa	open	Gillis 2012

The Anatolian sites Erbaba Höyük (Arbuckle 2008), Ulucak Höyük (Çakirlar 2012) date between 6700 to 6000 cal BC and represent the pre-pottery and pottery Neolithic cultural phases. Sites from the Balkans here are representative of the inland spread of the Neolithic. Early Neolithic sites of the inland Balkans are represented by the Starčevo-Körös-Criş (SKC) cultural complex (c.61/6000-55/5400 cal BC) and include the open-air settlements of Belišće (Serbia, Gaastra *unpub.*), Blagotin (Serbia, Greenfield and Jongsma Greenfield 2014), Seuşa-Cararea Morii (Romania, El Susi 2000), Foeni-Salaş (Romania, Greenfield and Jongsma Greenfield 2014). The Early Neolithic open-air settlement of Kneževi Vinograd (Gaastra 2016) dates to c.6015-5846 cal BC represents a local Early Neolithic cultural variant which is currently not well understood.

Adriatic sites are the maritime cave site of Spila Nakovana (Croatia, Gaastra *unpub.*) and open air site of Trasano (Italy, Gillis 2012), contains material from the *impresso/impressa* culture (c.6000-5500 cal BC). Franco-Iberian sites are represented by *cardial* sites (Font Juvenal (France, Gillis 2012), La Draga (Spain, Gillis 2012), Arene Candide (Italy, Gillis 2012) which date from 6400 to 4800 BC cal. All the sites are open-air settlements apart from Font Juvénal and Arene Candide, which are cave/rock shelters.

Four sites from Hungary represent the LBK. One of them belongs to the LBK in Transdanubia (TLP; Apc-Berekalja) and the remaining sites belong to the so-called Alföld Linear Pottery (ALP; Füzseabony-Gubakút, Polgár-Piócási-Dűlő and Polgár-Ferenci-Hát). The LBK phenomenon in Hungary was distributed mainly to the west of the Danube whereas the ALP lies east of the Danube. This culture differs in pottery styles from TLP/LBK although it has many similarities with TLP and LBK phenomenon [40]. Furthermore, the ALP and TLP cultures are dated to the Hungarian Middle Neolithic and follow the Starčevo (Transdanubia) and the Körös (Hungarian Plain).

From the Balkans, Neolithic cultures spread northwards into Northern Hungarian basin. The Transdanubia (TLP; Apc-Berekalja) and Alföld Linear Pottery (ALP; Füzseabony-Gubakút, Polgár 10, Polgár-Piócási-dűlő and Polgár-Ferenci-hát). The former is believed to be the progenitor of the Linearbandkeramik cultural phenomenon. The ALP lies east of the Danube differs in pottery styles from TLP/LBK although it has many similarities with TLP and LBK phenomenon [40]. The ALP and TLP cultures are dated to the Hungarian Middle Neolithic (5600 to 4600 cal. BC) and follow the Starčevo (Transdanubia) and the Körös (Hungarian Plain). These sites have been included into central region.

Sites from the central region of Europe are Mold (Austria, *Gillis unpub.),* Těšetice-Kyjovice (Bohemia, *Gillis unpub*) dating to the LBK culture (5500 to 4900 BC). Sites of the NW European plain are Ludwinowo (Poland, *Gillis unpub*), Dillingen-Steinheim (Germany, *Gillis unpub*), Herxheim (Germany, *Gillis unpub*), Bischoffsheim (France, *Gillis unpub*) and belong to the LBK culture, dating from 5500 to 4900 cal. BC.

Climate reference codes were given to each site based on the revised Köppen's classification (Peel, Finlayson, and McMahon 2007) to attribute each site one of the following five *climate* types: Temperate without dry season and hot summer (Cfa) and warm summer (Cfb); Temperate dry summer with hot summer (Csa) and warm summer (Csb); Cold without dry summer with warm summer (Dfb). As several climatic oscillations have been recorded during the Early Neolithic time periods under consideration in this study (e.g. Fiorentino et al. (2013); Feeser et al. (2016)), these reference codes are incorporated only as an approximate representation for the climatic zones of sites used in this study.

Statistical methodology

Common methods to compare mortality data such as, Chi² (Helmer et al. 2005) and Mann-Whitney U-test (Greenfield and Arnold 2015) none of these techniques adequately assesses the high level of sampling uncertainty in age-at-death data due to numerous factors, such as differential preservation and recovery and particularly small sample sizes associated with early Neolithic assemblages. Correspondence analysis (CA) is a descriptive statistical analysis that can be used to elucidate the 'correspondence' between datasets to generate hypotheses. CA plots both rows (here, number of teeth distributed across 7 age classes for each site) and the columns (age classes) (Benzécri 1973). Thus it can on the one hand clearly illustrate, which age classes are the most common within a dataset. While on the other hand the grouping of sites can elucidate relationships between sites and the association with particularly age classes.

Small sample sizes inherent in archaeological assemblages, particularly for the early Neolithic can lead to misrepresentation with correspondence analysis. Consequently, Gerbault et al. (2016) proposed using the Dirichlet distribution in combination with CA. This distribution permits generation of random deviates of the true population frequencies given the observed age-at-death frequency distribution and an appropriate prior. Thus creating a cloud around the original data point thus providing an indication of the potential distribution of individual sites based on number of teeth within individual age classes. The use of the Dirichlet function here therefore helps generate robust interpretations of the dataset.

The CA coordinates represent the distances between rows and columns respectively. To test trends visualised within the CA biplots, statistical tests on the mean value of CA coordinates generated for each sites, such as ANOSIM (analysis of similarities) using the vegan R package (Oksanen et al. 2017) can be used. The ANOSIM is a non-parametric test used in ecology and is based on a ranked dissimilarity matrix. It provides a means of test significant difference between two of more categories. The test statistic R varies within the range $[-1, 1]$ when R is close to 1 suggests dissimilarity between groups, whereas when R is close to zero suggests distribution between groups and when it is below zero suggests dissimilarity within groups. All analyses and biplots were produced using the free platform R program (V3.03.3; R Team 2017) using R studio (R Studio Team 2016). The R packages used were: ggplot2 (V1, (Wickham 2009)), ca (Nenadic and Greenacre 2007), LaplacesDemon (V16.0.1, (Statisticat 2016)) and MASS (V7.3-37, (Venables and Ripley 2002)).

Results

We carried out 5000 simulations for each site sheep/goat profile following the Gerbault et al. (2016) methodology for caprines. Correspondence analysis was then carried out on for the sheep and goat datasets. The summary of the columns and mean row coordinates are available in the supplementary data. For sheep (Figure 2a), the correspondence analysis had a global inertia of 0.71 with the F1 and F2 axis explaining 30% and 21.9% respectively of the total variation. The global inertia for the goats CA (Figure 2b) was 0.91 where F1 and F2 was explained 24.9 and 21.9%. The age class 0-2M dominates both CA due to the low representation in this age class, which has been seen in other CA analysis (Helmer et al. 2007). Overall the CA analysis for sheep is explained by the opposition on the F1 axis between age classes 2-6 months and 6-12 months (-ve coordinates) versus 2-4 years (yrs; +ve coordinates). Whereas the CA for goats is explained by the opposition on the F1 axis between age classes 1-2yrs (-ve coordinates) versus 2-4 yrs and 4-6yrs (+ve coordinates).

[FIGURE 2 HERE]

Figure 2a) Sheep correspondence analysis biplots; 2b) Goat correspondence analysis biplots, with 5000 Dirichlet simulations for each site. The colour of points refers to individual sites and the site code are labelled with the corresponding colour. The size of the age class lettering reflects the contribution of each age class to the axes.

Analysis of similarity (ANOSIM, permutations =5000) was carried out on the mean CA coordinates for the Dirchelet simulations for each site using climate, culture, region and site type as grouping factors (Table 2). For goats, no significance was found for any or the categories nor was there any correlation between coordinates and longitude and latitude (Figure 3e-h). For sheep, the ANOSIM was significant for culture, site type and region. The R statistic is low but suggests that there is dissimilarity between groups. Further Kruskal-Wallis tests, confirm that there is a significant difference between site type (chi^2=6.5, p=0.01) and region (chi^2=11.02 p=0.05).

	Culture	Climate	Site type	Region
Goat F1	0.02/0.4	-0.07/0.7	-0.06/0.4	0.02/0.4
Goat F2	0.08/0.2	-0.06/0.7	0.5/0.1	0.06/0.3
Sheep F1	0.2/0.005*	-0.003/0.4	0.5/0.006*	0.2/0.01*
SheepF2	0.03/0.2	0.02/0.3	0.03/0.4	0.04/0.2

Table 2, The results of the ANOSIM (R statistic/ probability) test on the CA coordinates for F1 and F2 for sheep and goats for cultural group, climate, site type and region. * indicates statistical significant.

The significant result for region lies between the Balkans and Franco-Iberian regions and the other regions (Figure 3a). This is also seen between coordinates from ICW and other early Neolithic cultures (Figure 3b). In terms of slaughter management strategies, -ve coordinates are associated with age classes 2-6 months and 6-12 months whereas +ve coordinates are associated with adult age classes. These results for sheep suggest that in areas such as, the Balkans and Franco-Iberian peninsula, animals are mainly slaughtered before 12 months. This is also reflected for cultural groups where SKC and ICW sites are dominated by animals slaughtered before 12 months although for SKC sites there is also sites where adults were predominantly slaughtered. In the Balkan/Franco-Iberian regions, cave sites are often used as seasonal camps for birthing stations or dairies within a short-ranged pastoral system. This appears to be reflected in the results where we find at cave sites animals are mainly slaughtered or die before 12 months. For climate types (Figure 3d), there is little difference between climatic zones suggesting that sheep management was not influenced by specific climatic conditions.

[Figure 3]

Figure 3, Boxplots for F1 sheep and goat F1 coordinates: a) Sheep F1~ Region; b) Sheep F1~Culture; c) Sheep F1~ Site type; d) Sheep F1~Climate; e) Goat F1~ Region; f) Goat F1~Culture; g) Goat F1~ Site type; h) Goat F1~Climate

Discussion

Sheep and goats are often herded together but have different productive capacities, such milk quantity and quality, which at present are exploited by pastoralists and stock herders around the world. However it is not clear whether these productive differences were exploited from the beginning of the Neolithic. A number of models for specific products have been proposed for meat, milk and wool based on ethnographic observations (Payne 1973, Redding 1981, Helmer et al. 2005). There have been a number of criticisms for models focused on single products as they assume to some extent the productive uniform capacity between modern breeds and prehistoric animals (Halstead 1998). Intensive selective breeding has increased the capacity for animals to produce greater quantities of milk/wool and develop muscle/fat faster (Haenlein 2007). Mixed production models are probably more appropriate for early prehistoric stock herders, although specialisation towards one species has been uncovered at sites dating from the PPNB onwards (c.f. Vigne REF). Equifinality may also be a problem where mortality data may be reflect excavation and sampling protocols rather than the result of slaughter practices (Halstead 1998). Here we discuss the results in light of ethnographic studies of European sheep and goats as a loose framework well as considering the effect of age-at-death methodologies on mortality analysis.

Sheep

Our results suggest that there were differences in slaughter practices between cultural groups and regions. In southern Europe and North-west Mediterranean SKC and ICW cultures slaughtered animals were between 6-12 months and to a lesser extent 2-6 months in comparison to LBK where animals were slaughtered in general as adults. Lambs offer a source of fat rich fast growing meat. A slaughter focus on the age class 6-12 months has in past been proposed as indicative of older lamb slaughter (Helmer et al. 2007), whereas animals younger than 6 months are traditionally slaughtered in many areas of the Mediterranean countries part as a cultural preference for tender meat and the result of post-lactation slaughter associated with dairy production (Boyazoglu and Morand-Fehr 2001; Haenlein 2001).

The cheese and yoghurt from sheep and goat milk is particularly economically important for modern Mediterranean and Balkan countries where 55% of the world’s sheep milk is currently produced (Boyazoglu and Morand-Fehr 2001). Ethnographic examples have shown that lambs and kids can be removed without affecting the flow of milk (Halstead 1998) however sheep do require lambs to stimulate milk ejection from the aveoli to the cistern at the beginning of the lactation period

(Balasse 2003). If milk is being exploited, the weaning age varies between 3 to 6 months and is dependent on the intensity of the production and whether milk or lamb meat is the focus of the operation. The traditional Mediterranean management, where sheep milk is highly prised, the lambs are separated and weaned at one month so that full milking can take place for five months (Halstead 1998).

Previous multi-proxy analysis of organic residues from ceramics and mortality data analysis has demonstrated that milking was practised from the beginning of the Neolithic in North-western Mediterranean (Debono Spiteri et al. 2016). Furthermore, cave sites may have played an important role in milk production and were used as a part of a pastoral systems where animals were brought to cave sites for surrounding pasture resources and temporary birthing stations. Transhumant practices have long been a tradition in the Balkans and Greece. For example, the Vlach communities, who ranged from Greece to Czechoslovakia and built special housing on summer pastures for milking ewes and processing milk (Ryder 1999). Previous analysis of caprines from cave and open sites in Southern France has shown that sites were used complementary with cave sites acting as seasonal birthing stations (Bréhard, Beeching, and Vigne 2010, Helmer and Vigne 2004, Vigne and Helmer 1999).

If we accept that the slaughter focused towards animals aged 2-6 months is the result of post-lactation slaughter with also later slaughter (6-12 months) the result of staggered slaughter to provide meat throughout the year. Then our results from sites of the Balkans and Mediterranean seaboard would suggest that sheep were used for dairying in these regions, which would correlate with previous analysis by Debono Spiteri et al. (2016). We do not suggest large-scale sheep milking that is seen at present, as it is labour intensive and for good milk returns requires the evolution of specialised breeds (Redding 1981). However, as sheep’s milk is very rich in fat and excellent for cheese making it is not unreasonable to postulate that early Neolithic farmers exploited this resource seasonally on a small scale. In comparison, stockherders of the LBK appear to have slaughtered the animals as young adults and adults, perhaps as a reflection that milk was provided mainly by cattle (Gillis et al. 2017) and sheep provided a source of meat only.

Goats

Greenfield and Arnold (2015) have suggested that goats were managed for milk from the beginning of the Neolithic in the Balkans. Goats can be easily milked without need of the presence of their infants and their milk is more digestible than cow’s milk (Haenlein 2007, 2004). Goats also have long productive lives as well as long lactations (198-285 days, Gillis 2012). Consequently, adult age classes particularly those greater than 4 years could support a dairy hypothesis. Young slaughter (0-6 months) could also be a reflection of dairying with infants being removed early in the lactation period.

The CA biplot was structured by the opposition of 1-2 years and 2-6 years, a reflection of the age classes associated with the largest samples from La Draga and Polgár-Piócási, with age class 6-12 month playing an important role. There are some indication of differences between sites of the same region or similar regions, such as the opposition between La Draga and Font Juvenal (FON), with the latter site situated close to age class 2-4/4-6 years. This can also be seen between Füzseabony, Polgár-Piócási and Apc with the former site is associated with age class 6-12 months while the remaining two are more closely associated with 2-4/4-6 year. LBK sites from central and north-western plain regions, such as Wikenpoint (WIK), Bischoffsheim (BIS), Herxheim (HEX1) and Mold (MOL) are centred on age classes 6-12 months and 2-4/4-6 year.

The interpretation of the results is hampered by the sample sizes, as well as other methodological issues that will be discussed later. Two of the sites, Polgár-Piócási-Dűlő (PIO) and Füzseabony (FUZ) have large samples sizes (>50) and if omitted the mean sample size is 16.5. These sites, as well as La Draga (LAD), plot separately from each other (Figure 2b) with La Draga plotting close to age class 1-2 years, Füzseabony close to age class 6-12months and Polgár-Piócási associated with 2-4/4-6years. This suggests when there are sufficient samples sizes it is possible to distinguish specific management strategies.

Unlike the results from the sheep, there is no obvious groupings of sites as a result of culture, climate or region as previous seen in the ANOSIM tests and boxplots. The lack of significance between region, climate and culture may be the result of low samples sizes and also be a reflection of a low number of goats kept. Previous ethnographic studies of Near Eastern societies have shown that goats are generally managed for household production (Redding 1981). There are other methodological reasons that may have affected the final results, such as the effect of age on criteria characterising sheep or goat (Orton pers. comm.) and age-at-death methodology.

We previously highlighted was the use of age-at-death methodology based on sheep, which could skew age-at-death determination. Comparison between species specific age determination methodologies has shown there is a slight differences between sheep and goats dental eruption. The molars on average erupt 1-2 months later in goats than in sheep whereas the deciduous premolars erupted later in sheep. There may also be differences between sexes in terms of eruption and wear stages with males having increased dental wear (Deniz and Payne 1982, Mellado et al. 2007). These differences in eruption and wear stages can have an impact on mortality analysis. For example, age class 6-12 months, 1-2 years and 2-4 years was defined by the eruption of M1, M2 and M3 respectively in sheep. Using this methodology - given that goat molars on average erupt later - would produce incorrect age estimates. Further studies are needed on large cohorts of goats to extend and establish goat specific age determination methodologies.

Conclusions

Sheep and goat are similar morphologically but are currently exploited differently as a result of their different productive capacities and environmental tolerances. Mortality data from archaeozoological remains can provide an insight into prehistoric slaughter management practices. Ethnographic evidence indicates that the age of slaughter of kids and lambs is related to the demands of market or family consumption, regional traditions, and the replacement needs of the herd. For older animals this is closely associated with productive capacity in terms of breeding and milk production of adults, particularly females. The results from the analysis of species specific mortality data from early Neolithic contexts here suggest that sheep were managed differently between regions and cultural groups. The data suggests in southern European contexts it was primarily young animals that were slaughtered, which reflects dairy husbandry as well as a cultural preference for young tender meat. In regions, such as central Europe and the north-west plain, cattle appear to have replaced sheep and goat as the primary dairy producers. These husbandry practices may be related to cultural preferences and practices as well as the geography and hydrology of the region being ideal for cattle. For goats, it was not clear whether they managed for specific purposes, such as milk production, nor were there significant differences between cultural groups or regions. This may be related to the fact that only small numbers of goats being kept. In addition, there is a need for species specific age-at-death determination methodologies.

To further investigate the evolution and development of sheep and goat husbandry, future analysis is required to further increase the number of species specific mortality datasets and extend this study to other periods of the Neolithic. Here we have taken a large corpus of species specific data from several regions unlike previous analysis which has focused on one region or site (c.f. Greenfield and Arnold 2015). There are still a number of methodological issues that need to be resolved, such species specific age-at-death determination methods. However, this initial examination offers tantalising glimpse into early goat and sheep husbandry practices and how the first farmers of Europe adapted these domesticates to new environments and moulded husbandry practices in response to cultural tastes and preferences.

Acknowledgements: RG research into ICW caprines was carried out during a PhD funded by the LeCHE (Marie Curie Initial Training Networks (FP7-ITN-215362-2)) and for LBK caprines during a postdoc funded by the European Research Council NeoMilk project awarded to Prof. R.P. Evershed (Grant no: FP7-IDEAS-ERC/324202) hosted by MNHN, Paris and the paper was written during her current postdoc with the Graduate School, CAU, Kiel. RG would like to thank to those who allowed access to material during the NeoMilk and LeCHE project: Dr Rose-Marie Arbogast (UMR7044, Université de Strasbourg, France); Prof Jean Guilaine and Isabelle Carrère (CNRS-UMR 5608, Université Le Mirail, France); Dr Giovanni Radi (Università di Pisa, Italy); Dr Maria Saña Segui (Universitat autònoma de Barcelona, Spain); Dr Andrea Zeeb-Lanz (Lansesarchäologie Speyer, Germany); Drs Ivana Vostrovská and Eliška Kazdová (Masaryk University, Czech Republic); Prof. Erich Pucher (Museum of Natural History, Austria); Dr László Domboróczki, Sándor Tanyi and Kristóf Rácz (István Dobó Castle Museum, Hungary); Prof. Pál Raczky, Dr Alexandra Anders and Dr Péter Csippán (Institute of Archaeological Sciences, Hungary); Dr. Henriette Obermaier (Staatssammlung für Anthropologie und Paläoanatomie München); Dr Joachim Pechtl (kelten römer museum Manching, Germany); Prof Arkadiusz Marciniak (Instytut Archeologii UAM, Poland). She would also like to thank Prof Mark Thomas (UCL, UK) and Dr Pascale Gerbault (University of Westminster, UK) for statistical advice. JSG post doc was funded by the European Research Council project EUROFARM (FP/20072013; ERC Grant Agreement no. 313716), led by MVL and hosted by UCL.

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