Article:

Kazantzis, G. and Albarella, U. orcid.org/0000-0001-5092-0532 (2016) Size and shape of Greek Late Neolithic livestock suggest the existence of multiple and distinctive animal husbandry cultures. Journal of Archaeological Science, 9. pp. 630-645. ISSN 0305-4403

https://doi.org/10.1016/j.jasrep.2016.07.030

Elsevier Editorial System(tm) for Journal of Archaeological Science: Reports
Manuscript Draft

Manuscript Number: JASREP-D-16-00087R1

Title: Size and shape of Greek Late Neolithic livestock suggest the existence of multiple and distinctive animal husbandry cultures

Article Type: Research Paper

Keywords: Greece, Late Neolithic, Zooarchaeology, Husbandry, Domestic animals, Biometry

Corresponding Author: Dr. George Kazantzis, Ph.D. in Zooarchaeology

Corresponding Author's Institution: Archaeological Museum of Aeani, Kozani

First Author: George Kazantzis, Ph.D. in Zooarchaeology

Order of Authors: George Kazantzis, Ph.D. in Zooarchaeology; Umberto Albarella, Ph.D. in Zooarchaeology

Abstract: In this paper we discuss domestic livestock morphometric data from the Late Neolithic Greek regions of Macedonia and Thessaly. Six sites are considered, including a substantial and previously unpublished dataset from Promachon (Macedonia). The analysis of the size and shape of the animals indicates great variation between sites and regions, suggestive of the co-existence of multiple styles of husbandry. The site of Sitagroi stands out for its large and robust cattle and sheep, probably a consequence of its environmental setting, as well as the dynamism of its cultural and economic connections. In Thessaly, despite the existence of inter-site connections documented through the material culture, different sites maintained their independence in terms of husbandry choices.

Opposed Reviewers: Paul Halstead
University of Sheffield
p.halstead@sheffield.ac.uk

Valasia Isaakidou
University of Oxford
valasia.isaakidou@arch.ox.ac.uk

Covering Letter

Dear Editor(s),

This paper is partly based on the results of George Kazantzis' Ph.D. thesis, undertaken at the University of Sheffield, UK, during the academic years 2011-2014. The Ph.D. research focused on aspects of economy and animal use from the Late Neolithic site of Promachon in Macedonia, northern Greece using the animal bone assemblage as the main source of evidence. The faunal assemblage from this site provided a substantial, previously unpublished metrical dataset, useful for local and regional comparisons. The supervisor of George Kazantzis' Ph.D thesis and co-author of this paper, Umberto Albarella, collected pig metrical data from the contemporary to Promachon site of Makriyalos in Macedonia, northern Greece. This unpublished metrical dataset from Makriyalos is also considered in this paper, along with published metrical data from four contemporary sites from Macedonia (Sitagroi) and Thessaly (Ayia Sofia, Pevkakia and Zarkos).

It is important to note that this is the first time that a local and regional comparison of Greek Late Neolithic livestock size and shape is attempted. It is therefore anticipated that the arguments presented in this paper will form an important basis for future discussion on the nature of human-animal relationships during a crucial time-period in the prehistory of northern Greece and southeastern Balkans. What is equally important however, is that, given the general scarcity of studied and published metrical datasets from Late Neolithic Greek sites, this paper will hopefully demonstrate the importance of the collection of metrical data by current and prospective zooarchaeologists working on Greek prehistoric faunal assemblages.

Finally, it should be noted that this paper was initially submitted to the *Journal of Archaeological Science*, where it was not accepted. The Editor of the journal considered that its theme would be more appropriate for publication to the *Journal of Archaeological Science*: *Reports*.

Kind regards,

Dr. George Kazantzis
Zooarchaeologist
Ephory of Antiquities (Eph.A.) of Aeani
Archaeological Museum of Aeani
Kozani
Greece
georgekazantzis2004@yahoo.gr

Dr. Umberto Albarella
Reader in Zooarchaeology
Department of Archaeology
University of Sheffield
Northgate House
West Street
Sheffield S1 4ET
United Kingdom

u.albarella@sheffield.ac.uk

***Detailed Response to Reviewers**

Dear Chris,

Many thanks for the reviewers' comments. We have now dealt with them and have submitted a revised version of the paper. Ultimately we found that the criticisms were not as substantial as it might have looked at a first sight. Reviewer 1 is very positive, while Reviewer 2 has expressed more concerns. We have tried to accommodate their suggestions in the paper as much as we could but, as you can see from our responses below, there are several points on which we disagree, particularly with Reviewer 2. As much as we would like to appease them we cannot possibly include mistakes or changes to the approach that we disagree with. Having said that, some points were useful and we believe they have helped us to strengthen the paper.

Best wishes,

Giorgos and Umberto

Reviewer #1:

The research paper "SIZE AND SHAPE OF GREEK LATE NEOLITHIC LIVESTOCK SUGGEST THE EXISTENCE OF MULTIPLE AND DISTINCTIVE ANIMAL HUSBANDRY CULTURES" reports a detailed biometric analysis on faunal assemblages of Bos sp., Ovis aries and Sus sp. from six sites from the Thessaly and Macedonia regions. Biometric variables (size and form) are used as proxies for differences of livestock management among sites for each species, on a multiscale approach (intra-site, inter-site and interregional). The report is well written (good style), methodologically sound, the research question and the results are interesting and original, and it fits well within the scope of the Journal of Archaeological Science: Reports. I recommend its publication.

I have some minor comments for the authors.

1. I find the concept of "Husbandry Cultures" problematic, which in part could be due to belonging to a different archaeological tradition, and I apologize in advance for any misunderstanding on my behalf. Despite its many definitions, it could be said that Culture refers to a shared repertory of beliefs and knowledge and its objectifications (from spoken words to artifacts and institutions). Culture so defined is constantly actualized by people and allows for a wide breath of freedom, which is necessary for its adaptation to varying social and environmental constraints on different spatiotemporal scales. Therefore, differences in the zooarchaeological record could be described either as different husbandry cultures, or as variations of a single culture. The same goes for the statement about Thessalian sites as different despite environmental similarity, and that sites maintained different strategies as a choice (lines 687-697). Differences among sites probably reflect choices, but choice could be arbitrary or not, and the key question is if such choices were alternative solutions to similar or different combinations of goals, resources and external constraints. In conclusion, I would recommend the authors to define and justify their use of the Husbandry culture concept.

We are not really sure about the point raised by the reviewer. Their definition of 'culture' appears entirely consistent with the way we have used it and it is unclear why any further clarification is needed – it should be obvious that husbandry belongs to the realm of culture. However, to be absolutely clear, we have added a sentence in the conclusions which aims to clarify the concept even further.

2. A brief section on the Greek Late Neolithic would be helpful for international readers.

In the Introduction we have added a sentence, with some references, which elaborates further on the nature of the Greek Late Neolithic. If the editors want so, we can of course expand further – even much further – but this would increase the word count and we also suspect that a potted history of the late Neolithic in Greece would only distract from the main focus of the paper. However, we are happy to follow editorial guidance on this.

3. The paper should state which software package was used for the statistical analysis.

Done (see Methods section).

4. Using mean values from an archaeological site (Promachon) as a standard for the log ratio scaling technique implies a methodological issue. The goal of the log-ratio is to enlarge samples by scaling measurements from different elements to a common scale. To that end, a reference standard is derived

from a single animal -archaeological or modern- or from the mean of various animals. In either case it is desirable to work with measurements from complete skeletons -archaeological or modern- (see Meadow 1999, p. 295). If the assemblage is common refuse, the standard of each element becomes potentially independent from that of other elements because of differential accumulation and survivorship. I think that this does should not pose a problem for the present report as it focuses on comparisons of size among archaeological assemblages. Even so, the report should clarify if the standard is derived from articulated or independent elements. If it is from independent anatomical
elements, the aforementioned methodological issue should be acknowledged.

A paragraph has been added to clarify this methodological issue further (see Results section).

Reviewer #2:
1) The use of astragali GLl is fine, but I have some concerns about the use of Bd. This measurement is highly variable in my experience, and I am not convinced that it is an indication of "weight bearing" as indicated by the authors. Moreover, I am not entirely convinced that this measurement is useful for what the authors aim to achieve. They cite a paper of Johnstone and Albarella 2002. This is an unpublished paper, and this concerns me. I would suggest the authors revisit this aspect, by providing references from peer-reviewed papers to support this notion. This will have a major impact on their results and interpretation. This is a rather crucial point.

The reviewer believes that astragalus Bd is a highly variable measurement in their experience. However, we should rely on actual data to make these judgements. When coefficients of variation have been calculated astragalus Bd has been shown to be approximately in the same range of variability as astragalus GLl, and astragalus measurements in general in the same scale of variability (sometime less) than measurements from other anatomical elements. See for instance: Albarella U. & Davis S. 1996. *Mammals and Birds from Launceston Castle, Cornwall: Decline in Status and the Rise of Agriculture*. York, Circaea, 12 (1), pp.1-156. If required we can provide several more references. This is really, however, a non-issue, as astragalus Bd measurements are regularly used in the literature and, like all other width measurements, are associated with robustness. All morphometric literature is in agreement about that. See for instance the use of Bd measurements in classic and often cited articles such as: Payne and Bull 1988; Davis 1996; Davis 2000 (all cited in our paper). However, we have now changed the reference of Johnstone and Albarella (2002), with a more recent, fully peer-reviewed, version of that paper.

2) It would be necessary to include the sample size of specimens measured.

We regarded it as unnecessary as for all our diagrams sample size is clearly demonstrated by the scale of the histograms and number of points in scatterplots. We regarded this as more effective because of its visual impact.

However, we have now included sample sizes in all figure captions for the scatterplots, just to be even more explicit. Log ratio diagrams also include sample sizes.

3) Differences in environmental factors are not well considered as a potential factor in the size differences.

This reviewer seems to have overlooked our frequent references to environmental differences as possible causes for livestock morphometric differences. Here is an example: “It is worth pointing out that the environmental conditions between the two sites are substantially different. Promachon is located on the northernmost part of Macedonia, close to the mountainous and forested regions of the Balkans, with low winter temperatures and high precipitation levels, which may have been ideal for cattle pasture (Kazantzis 2015). Makriyalos is located on the southernmost part of Macedonia near the Thessalian plain; the site is fairly close to the sea with warmer and drier climatic conditions in comparison to Promachon, even during the winter”.

For Thessaly we have suggested that the environmental differences between sites are not so great to justify morphometric differences. This does not mean that we have not considered the environment, but simply that we did not regard it as the most likely explanation for the observed differences. Even for fodder access we mention that this may be related to variable environmental conditions. Potential environmental causes are mentioned no less than *seven* times in the paper, including in the abstract. To insist even more on the topic would definitely be an over-kill.

4) Since astragali don't fuse (as acknowledged by the authors), the (suggested) size differences could actually relate to age differences. This aspect is not given sufficient attention.

The answer to this reviewer's question is already in our text: "the astragalus rapidly reaches adult size and, once fully ossified, it exhibits limited size change, despite not having an epiphysis, as is constrained in an articulation and has limited room for growth (Albarella and Payne 2005; Payne and Bull 1988; Rowley-Conwy et al. 2012)".

To clarify the point further we have also added a new paragraph (see Methods section) in which we specify that we have only recorded fully ossified astragali.

5) In many cases, the differences are actually quite small. I am a bit concern that a lot is made of rather small differences. In some cases the differences amount to a few millimetres. If one considers that the two astragali from one single individual animal can vary with a few millimetres, and considering the small sample size, the results and interpretations seem like overstating the case.

There cannot be any reasonable expectation that differences between animals of the same species and roughly from the same period and region are any greater than that. In fact it is already remarkable that such differences exist. It is only between different species or, sometimes, wild and domestic forms that larger differences can be expected. The fact that some variability may exist between the left and right side in the same order of scale that we see between the groups we compare is irrelevant, because the comparison is based on populations rather than individual specimens. This is how biometry works at population level, and our observations are also supported by statistical testing. At the end of the day this is what statistics is for. Ultimately our approach is scientific rather than impressionistic.

6) It is by no means clear what the comparative postcranial remains are. Some explanations and justification would be helpful.

Once again the reviewer seems to have overlooked information that is included in the paper. The details are provided in SOM2. If the editor prefers that information to be included in the main body of the paper that is fine, but we assumed that this is what SOM is for. Please, let us know – happy to follow editorial preferences. We are now including a SOM3, in which full ranges of measurements of all species from all sites are provided for cross-reference.

7) It is highly possible that many of the astragali are from the same individual. This will obviously reduce the sample size even further.

A skeleton has only two astragali so it is not possible for "many of the astragali" to be "from the same individual". It is of course possible that a left and right astragalus do come from the same individual, but this is commingled material (rather than articulated skeletons, or partly articulated skeletons) that accumulated for centuries, so this possibility is remote. Moreover, this is how virtually all zooarchaeologists deal with biometrical analysis. One way to get round this problem is only use one side (left or right), but to reduce sample sizes by half in order to deal with a rather unlikely occurrence would not be sensible (and this is why hardly any zooarchaeologists use such approach). It must also be noted that in our recording system when two elements were regarded to derive from the same individual only one was recorded. We can make this specification in 'methods' if required, but it really seems rather unnecessary – there are so many details of this kind that can potentially be included in 'methods', but to list them all would really make for a very long and heavy going methods section. Concerning the question of sample size it must also be noted that our Macedonian samples are almost as large as they come for Neolithic sites. It is true that the Thessalian samples are smaller but they are mainly used for comparative purposes and they assume greater significance once compared with the Macedonian datasets.

8) Potential differences could also relate to different breeds. This aspect was not considered.

The concept of 'breed' is modern and it would be a serious mistake to apply it to prehistory. At most we can consider the existence of geographic types, which is what we do in the paper.

9) The settlement patterns at Drama: are these sites contemporary or do they follow chronologically? If this has not actually been demonstrated, then some of the statements are invalid.

From the context it should be obvious that we are dealing with roughly contemporary sites. To make it absolutely clear we have now specified that Dikili Tash is late Neolithic (the site has other phases but it is the late Neolithic one that is relevant to this paper)

10) I would suggest shortening the Results section somewhat, as there is a lot of repetition. It also reads a bit on the difficult side.

Please compare this with comments of first reviewer, who believes that the paper is very clearly written. We have gone through the text once again and we could not identify any repetitions in the Results section. This is information that we need to provide, so the only way we can shorten it is by moving sections to the SOM, but is this really desirable? We believe that readers will want to see the results fully explained in the main body of the paper.

Highlights

There is variation in livestock size and shape between sites and regions.

This can be linked to husbandry regimes and cultural and environmental differences.

Sitagroi has larger livestock and probably benefitted from the support of a network of local sites.

Thessalian sites had trade links, but practiced different husbandry styles.

Unlike Thessaly, wild boar is common in Macedonia, and probably did not crossbreed with domestic pig.

Size and shape of Greek Late Neolithic livestock suggest the existence of multiple and distinctive animal husbandry cultures

Abstract

In this paper we discuss domestic livestock morphometric data from the Late Neolithic Greek regions of Macedonia and Thessaly. Six sites are considered, including a substantial and previously unpublished dataset from Promachon (Macedonia). The analysis of the size and shape of the animals indicates great variation between sites and regions, suggestive of the co-existence of multiple styles of husbandry. The site of Sitagroi stands out for its large and robust cattle and sheep, probably a consequence of its environmental setting, as well as the dynamism of its cultural and economic connections. In Thessaly, despite the existence of inter-site connections documented through the material culture, different sites maintained their independence in terms of husbandry choices.

Keywords: Greece, Late Neolithic, Zooarchaeology, Husbandry, Domestic animals, Biometry.

1. Introduction

Biometry constitutes one of the most important tools that zooarchaeologist have for the investigation of past patterns of human behaviour. It can inform us on many archaeological issues, ranging from animal domestication to husbandry practices, feeding regimes and the introduction of new breeds and improved livestock (Albarella 1997; 2002; Davis 1996; 2000; Rowley-Conwy 1999; Zeder 2008; Albarella et al. 2007).

Biometry has been used by European zooarchaeologists on a regular basis, but less so in Greece. For the Neolithic, the use of biometry is linked with the intensity of zooarchaeological research in different regions, with Thessaly a greater focus of research than Macedonia (Kazantzis 2015). This is the result of an archaeological perception of the Neolithic cultures of Macedonia as largely derivative from, and marginal to, those of Thessaly (Fotiadis 2001). This has led Macedonia to be discussed in the context of a Thessalian, rather than a local Macedonian Neolithic (Andreou et al. 1996; Perlès 2001). Only in the past 20 years has the Macedonian Neolithic been placed in its original, regional context.

From the 1960's, many Neolithic excavations in Thessaly have been staffed with a variety of different specialists, including zooarchaeologists (Trantalidou 2001). When it comes to data analysis there has, however, been a tendency for zooarchaeologists to confine the use of biometry to a limited range of issues, such as the origins of cattle domestication (Boessneck 1962; Bökönyi 1989; Becker 1999), the use of secondary products (Bökönyi 1986) and the crossbreeding of wild and domestic forms (Becker 1991; 1999; Bökönyi 1989; Gejvall 1969). The investigation of these issues was facilitated by the inclusion of raw metric data in publications. Nevertheless, temporal and regional comparisons of different metrical datasets between Neolithic Thessalian sites were attempted only by von den Driesch (1987)[1]. Faunal reports from Neolithic Macedonian sites tend to provide only summary statistics of measurements. An exception is represented by the work of Bökönyi (1986) at the Late Neolithic Macedonian site of Sitagroi, which provides a full range of tooth and postcranial measurements. A lack of availability of raw data is therefore one of the reasons why metrical datasets between Neolithic sites from Macedonia have not been previously compared.

A further issue, which has not been adequately investigated, is the ambiguous status of pigs. In almost all sites from Macedonia and Thessaly, pig bones were - and still are - by default attributed to domesticates, while the identification of their wild counterparts is limited to cases of particularly large specimens (Kazantzis 2015). This is also the case for domestic cattle and its wild progenitor, the aurochs. This obviously represents a potential problem, since it means that the significance of wild boar and aurochs has not been properly evaluated.

This paper will focus on a regional comparison of the size and shape of the main domesticates between Late Neolithic (6^{th}-5^{th} Millennium BC Cal) sites from Macedonia and Thessaly. For Greece, it constitutes the first attempt to identify local and regional patterns of livestock management in this dynamic period of change in the prehistory of southeastern Europe (Bailey 2000; Kotsakis 1999; Renfrew 1972). In Greece, in particular, the Late Neolithic is characterised by a considerable expansion in the number of settlements and a burst of innovations in the material culture sphere (c.f. Andreou et al. 1996; Fotiadis 2001; Halstead 1989a; 1989b; Kotsakis 1999; Pappa 2008). It is important to see how such changes can be compared with developments in stock-keeping strategies.

The exploration of livestock morphometry in Late Neolithic Macedonia and Thessaly will be used to clarify issues such as:

- whether livestock was properly kept and nourished
- differences in animal herding and livestock management between sites and regions

[1] In addition, Becker (1991) briefly compares the size of sheep, red deer and fallow deer between Zarkos and a number of Thessalian sites (Pevkakia, Argissa, Ayia Sofia and Kastanas), while Halstead (1992) compares ranges of measurements of domesticated and wild species between Dimini, Argissa, Zarkos, Ayia Sofia and Pevkakia.

- the degree in which economic and other cultural considerations contributed to animal husbandry management
- the contribution of wild boar and aurochs to the life of late Neolithic communities located in different areas.

This will ultimately provide important insights regarding husbandry practices at both local and regional levels, assisting us in the understanding of the nature of human-animal relationships during the Late Neolithic of northern Greece.

2. Materials and Methods

Published and unpublished metrical data of cattle (*Bos* sp.), sheep (*Ovis aries*) and pig (*Sus* sp.) from six Late Neolithic sites from Macedonia and Thessaly are used for regional comparisons (**Table 1**) (**Figure 1**). Goats (*Capra hircus*) are uncommon and therefore, due to the restrictions of small sample size, they are not considered in this analysis.

Promachon is an open-air (also known as flat-extended) site dated to the Late Neolithic (Koukouli-Chrysanthaki et al. 2007; 2014). The site is located at the northernmost edge of the Aegean world, in the Serres basin, close to the Balkans. The faunal material from this site constituted the subject of a doctoral research (Kazantzis 2015). Measurements were taken on teeth and on fused, fusing and unfused specimens, as suggested by Zeder (2008). These generally follow von den Driesch (1976), with some additional measurements from Albarella and Payne (2005), Davis (1992) and Payne and Bull (1988). In this paper, however, we only use metrical data from fully fused specimens.

The tell site of Sitagroi (Bökönyi 1986) is fairly close to Promachon and it is one of several known Neolithic settlements located in the plain of Drama (Renfrew et al. 1986). Due to restrictions of small sample size, the Late Neolithic sheep measurements were combined with those from the Final Neolithic.

Makriyalos is a Late Neolithic open-air site (Pappa and Besios 1999), located in the southernmost part of Macedonia, close to the Thessalian plain. From Makriyalos, we use unpublished pig metric data originally collected by Umberto Albarella and Keith Dobney, courtesy of Paul Halstead. Unpublished metric data for cattle and sheep from Makriyalos are not included in this paper. They have, however, been provided by Paul Halstead to be used as part of Kazantzis' doctoral research (Kazantzis 2015).

Few Late Neolithic sites from Thessaly have an adequate number of measurements for regional comparison, but an exception is represented by the open-air site of Ayia Sofia (Driesch and Enderle 1976). To increase sample size, measurements from the Late Neolithic deposits of the tell site of Zarkos (Becker 1991) were combined with those of the Early Bronze Age. Overall, three PhD publications focus on the faunal material from Pevkakia (Amberger 1979; Hinz 1979; Jordan 1975), but the data used in this paper exclusively come from Jordan's thesis as it is the only one focusing on the Late Neolithic. Due to restrictions of small sample size the measurements from the Late Neolithic (Dimini era) deposits were combined with those of the Final Neolithic (Rachmani era).

Table 1: Sites from Macedonia and Thessaly considered in this paper (see also Figure 1).

N	Site	Region	Cultural periods	Metrical data – Sources
1	**Promachon**	Macedonia	Late Neolithic	Kazantzis (2015)
2	**Sitagroi**	Macedonia	Late Neolithic - Final Neolithic	Bökönyi (1986)
3	**Makriyalos**	Macedonia	Late Neolithic	Albarella and Dobney (unpublished data)
4	**Ayia Sofia**	Thessaly	Late Neolithic	Driesch and Enderle (1976)
5	**Pevkakia**	Thessaly	Late Neolithic - Final Neolithic	Jordan (1975)
6	**Zarkos**	Thessaly	Late Neolithic - Early Bronze Age	Becker (1991)

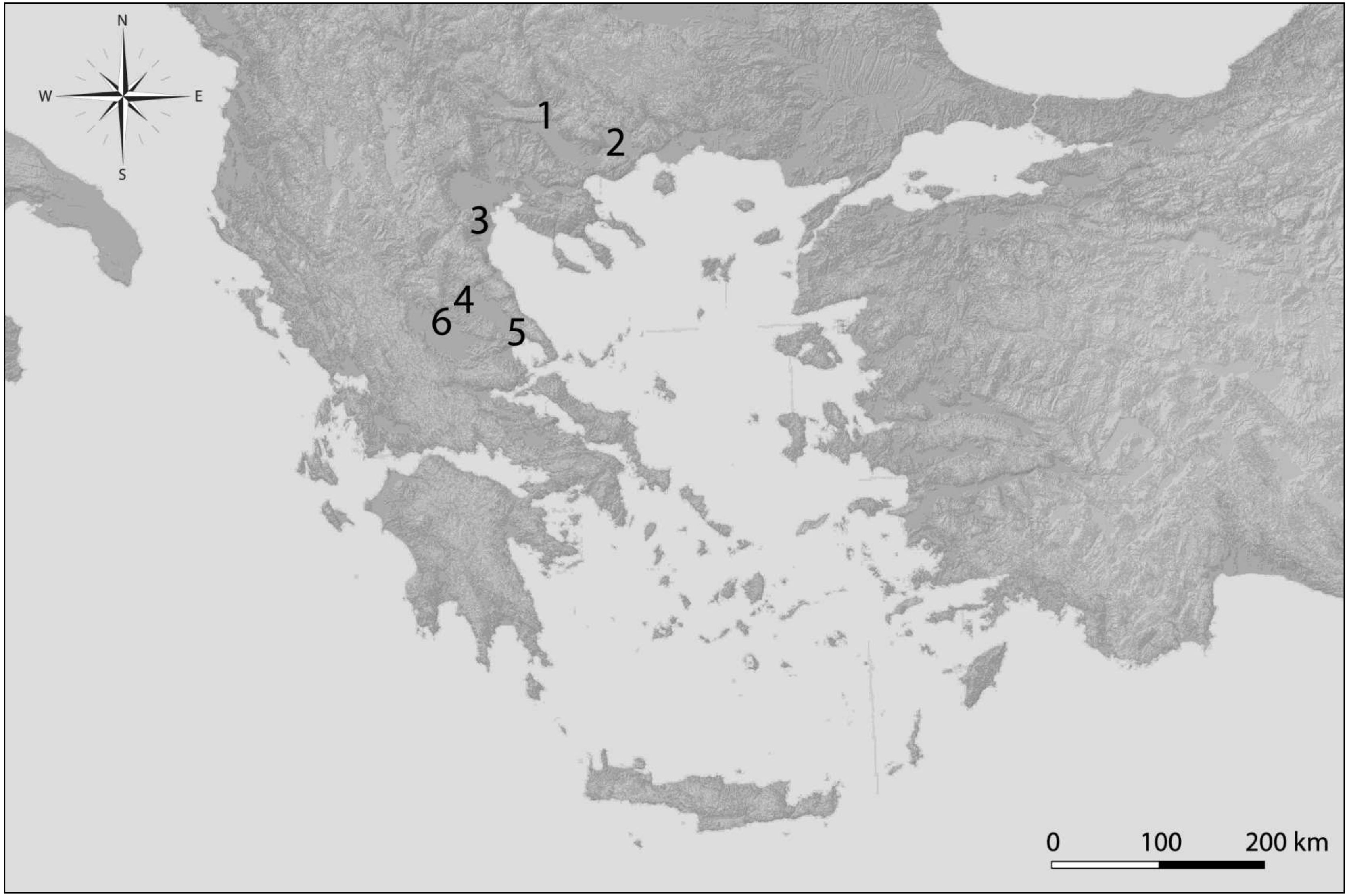

Figure 1: Map of sites mentioned in text. 1. Promachon; 2. Sitagroi; 3. Makriyalos; 4. Ayia Sofia; 5. Pevkakia; 6. Zarkos.

Measurements used by the zooarchaeologists who conducted faunal research in these sites generally follow von den Driesch (1976). However, different researchers chose to take different measurements and this limits somewhat comparability (see **Supplementary Online Material 1** for more details). **Supplementary Online Material 2** presents a table with the list of measurements used in this paper, while **Supplementary Online Material 3** presents the full ranges of postcranial and tooth measurements from all sites under study.

In this analysis there will be a heavy reliance on astragalus measurements, firstly because it is a compact and dense element, which tends to survive well, therefore providing good metric sample sizes. Secondly, the astragalus rapidly reaches adult size and, once fully ossified, it exhibits limited size change, despite not having an epiphysis, as is constrained in an articulation and has limited room for growth (Albarella and Payne 2005; Payne and Bull 1988; Rowley-Conwy et al. 2012). To minimise age-related variation, at both Promachon and Makriyalos we only measured fully ossified astragali. Though such approach is not explicit in the older datasets that we use for comparative purposes, it is unlikely that that immature/porous astragali were measured, as in the past there was no tradition to measure juvenile bones (cf. von den Driesch 1976).

Astragalus measurements are plotted for each species, first between the three Macedonian and then the three Thessalian sites. Then, we compare astragalus measurements between the two regions (Macedonia and Thessaly). For pigs, we also plot distal humerus and distal tibia measurements, as there are sufficient sample sizes. The distal tibia in particular, is a valuable bone in providing information about the actual average body size of a certain population, as it is not particularly affected by sex variation or post-fusion growth (Albarella and Payne 2005; Albarella et al. 2009; Payne and Bull 1988; Rowley-Conwy et al. 2012). The chosen measurements of the distal humerus (BT and HTC) are less affected by post-fusion growth than the commonly taken Bd (Albarella and Payne 2005; Albarella et al. 2006; Rowley-Conwy et al. 2012), which means that age plays a less confusing role in their interpretation. However, the humerus is likely to be substantially affected by sex variation (Payne and Bull 1988).

The significance of the statistical difference between samples was evaluated using an ANOVA t-test. Statistical analysis was carried out by using an IBM SPSS Statistics software package. In addition to the use of individual measurements, we have also applied a scaling index technique (Albarella 2002; Meadow 1999), by calculating log ratios of measurements compared to a standard (Albarella and Payne 2005; Payne and Bull 1988; Simpson et al. 1960).

3. Results

3.1. *Bos* sp.

3.1.1. Macedonia

We compare the size of cattle astragalus between Promachon and Sitagroi by plotting the greatest length of the lateral half of the astragalus (GLl) against the distal breadth of the astragalus (Bd) (**Figure 2**). The diagram also includes a single astragalus from Sitagroi, which was identified by Bökönyi (1986) as aurochs (*Bos primigenius*): this plots away from the main distribution, on the upper right corner of the diagram. Conversely, there are no large outliers in the Promachon distribution. This suggests that all cattle astragali from Promachon are likely to derive from a single population, presumably domestic. The diagram shows that domestic cattle astragali at Promachon and Sitagroi have similar lengths, but astragali from Sitagroi have a relatively greater distal breadth (Bd). The distal breadth (Bd) is a measure of the width of the joint surface and it is therefore related to the weight-bearing ability of that particular joint (Johnstone and Albarella 2015). A relatively larger Bd therefore suggests the presence of more robust animals.

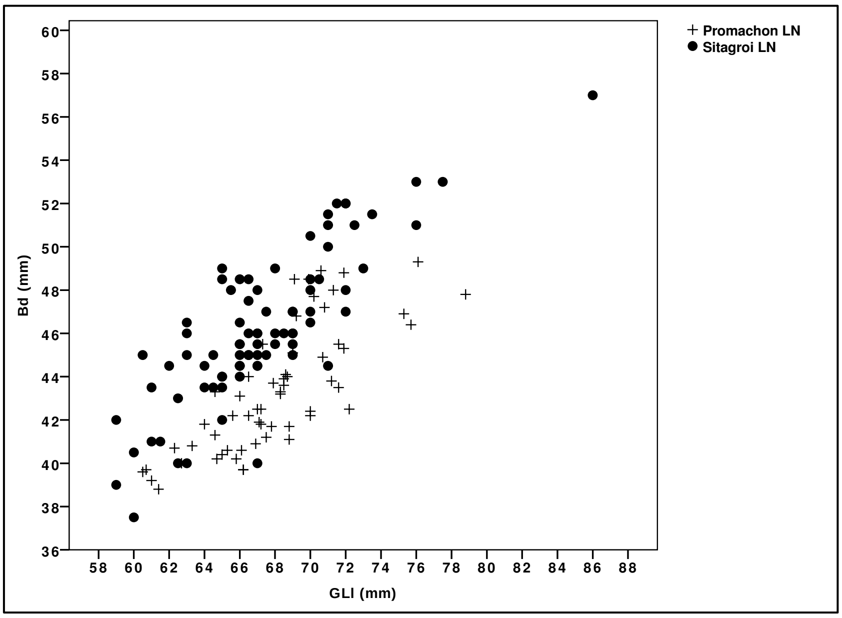

Figure 2: Cattle astragalus. Comparison between Promachon (N = 59) and Sitagroi (N = 81).

An ANOVA t-test indicates that there is no significant difference in the greatest length of the lateral half (GLl) of the astragalus between the two sites, but there is a highly significant difference in the distal breadth (Bd), with Sitagroi astragali having a much greater mean distal breadth (μ= 46 mm) than the Promachon astragali (μ= 43.4 mm) (**Table 2**).

Table 2: Probability results of the difference between sample means as conducted through an ANOVA t-test. ** = highly significant; * = significant.

Local and regional comparisons	ANOVA t-test							
	***Bos* sp.**		***Ovis aries***		***Sus* sp.**			
	Astragalus		**Astragalus**		**Astragalus**		**Tibia**	
	GLl	**Bd**	**GLl**	**Bd**	**GLl**	**Bd**	**Bd**	**Dd**
Promachon-Sitagroi	.129	.000**	.000**	.000**	.288	.864	.442	.092
Ayia Sofia-Pevkakia	.301	.367	.971	.167	.025*	.313	-	-
Pevkakia-Zarkos	.214	.117	.081	.027*	-	-	-	-
Ayia Sofia-Zarkos	.049*	.184	.236	.050*	-	-	-	-
Macedonia-Thessaly	.154	.002**	.051	.544	-	-	-	-

To obtain large enough samples of measurements, log ratios were also calculated. **Figure 3** shows the log ratio diagrams for the three dimensions (lengths, widths and depths respectively) of cattle postcranial bones from Promachon and Sitagroi in order to see how different measurements are distributed according to the standard. The standard that we use for the calculation of the log ratio is the mean value from Promachon. Unlike the use of an articulated skeleton, a standard deriving from a commingled assemblage does not imply that the measurements will necessarily be related to each other (Meadow 1999). Chances that different anatomical elements from an archaeological assemblage derive from entirely different populations are, however, minimal, and the archaeological standard has the advantage of relying on a larger sample size (Albarella 2002). This is why archaeological standards are increasingly commonly used in the literature (e.g. Albarella and Payne 2005; Wright and Viner-Daniels 2015).

The log ratio analysis suggests that measurements of all three dimensions from Promachon have broadly unimodal distributions, with no large outliers. On the other hand, there are a few large outliers from Sitagroi (right hand side of the three histograms), which suggests the presence of a few aurochs specimens.

The log ratio diagrams also indicate that cattle bones from Sitagroi were of similar length to cattle bones from Promachon, but they were larger both in width and depth (note Sitagroi means plotting on the right hand side of the standard = mean from Promachon). Altogether the log ratio analysis supports the results obtained from the astragalus, indicating greater robustness of the cattle from Sitagroi.

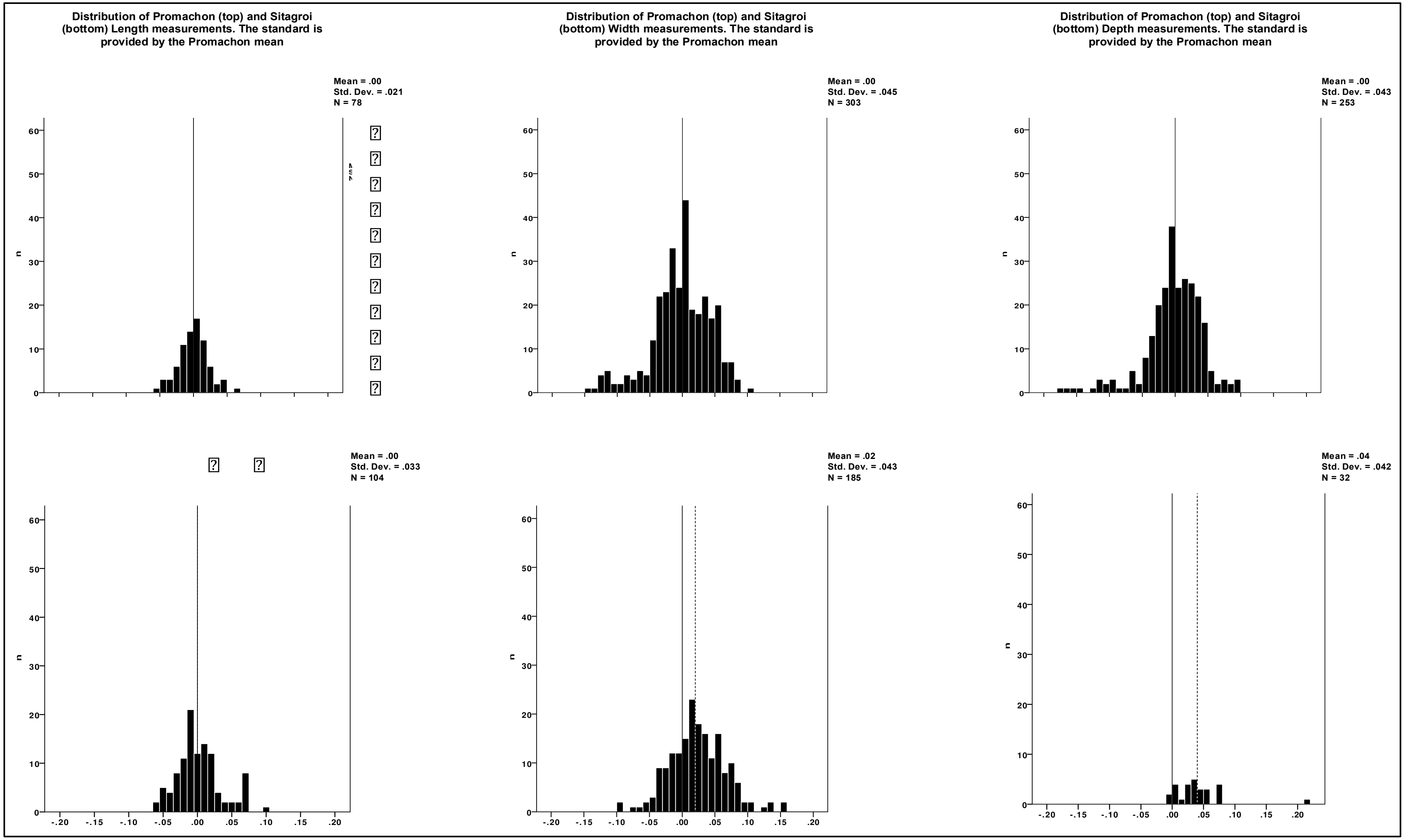

Figure 3: Distribution of Promachon (top diagrams) and Sitagroi (bottom diagrams) cattle postcranial length, width and depth measurements using the log ratio technique (Simpson et al. 1960). The standard is provided by the Promachon mean. Only fully fused postcranial bones from Promachon were considered. The mean of Sitagroi length, width and depth measurements is marked by a black dashed vertical line, and the standard measurement by a black vertical line at .00. The scale of the vertical axis is fixed to emphasize differences in sample sizes.

3.1.2. Thessaly

For this region the attribution of cattle specimens to the domestic and wild forms, as published in the literature, was made *a priori* (i.e. on the basis of a general impression of size at the time of the recording) rather than on the kind of biometrical analysis undertaken above. The aurochs is given as present at Pevkakia (Jordan 1975) and Zarkos (Becker 1999), but not Ayia Sofia (Driesch and Enderle 1976). However, no astragali from Pevkakia and Zarkos were identified as aurochs, which means that the following scatterplot (**Figure 4**) includes only astragali regarded to be domestic by the original authors of the studies.

Sample sizes are small, which means that interpretation needs to be cautious. Nonetheless, cattle astragali from Ayia Sofia are, on average, distinctively larger than from the other two sites. Most cattle astragali from Zarko are smaller, but two large specimens plot on the upper right corner of the distribution, resembling in size those from Ayia Sofia. Sexual dimorphism could explain the clustering of the Zarko distribution, but this seems unlikely to be the only explanation as the astragalus is not very sexually dimorphic (Payne and Bull 1988).

ANOVA T-tests (**Table 2**) indicate that there is a marginally significant difference in the greatest length of the lateral half (GLl) of the astragalus between Ayia Sofia and Zarko, with the Ayia Sofia astragali having a much greater length (μ= 68.3 mm) than the Zarko astragali (μ= 61.9 mm). Clearly, the sample sizes are so small that the tests are only likely to provide significant differences when the differences between the means are very substantial.

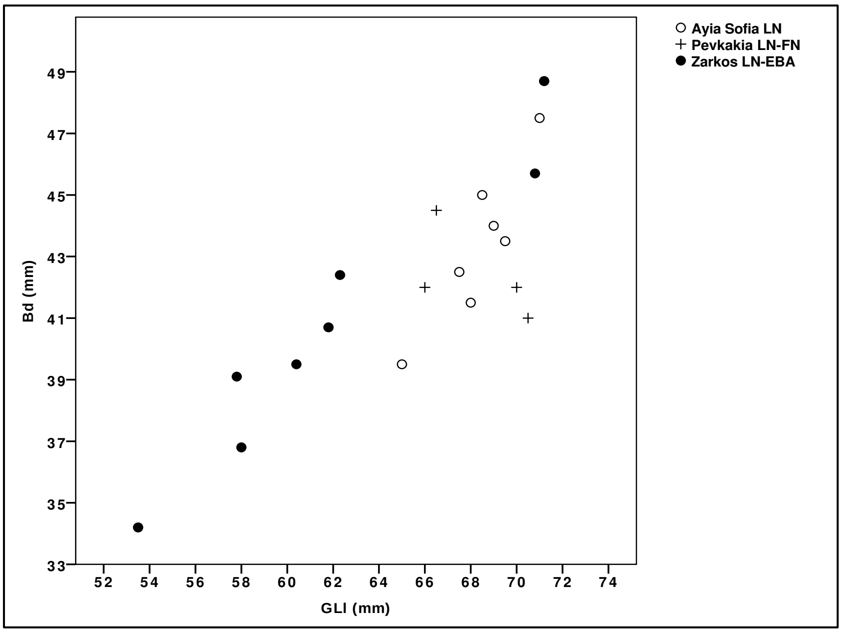

Figure 4: Cattle astragalus. Comparison between Ayia Sofia (N = 7), Pevkakia (N = 4) and Zarkos (N = 8).

3.1.3. Macedonia-Thessaly

We compare the size of the cattle astragalus between Macedonian and Thessalian sites (**Figure 5**). As previously noted, although the aurochs appears to be documented in Thessaly, no astragali were attributed to this species. What can be inferred from the scatterplot is that the astragali from Macedonia tend to be larger than those from Thessaly, despite the substantial overlap. This makes the large astragali from Ayia Sofia and Zarkos unlikely to come from aurochsen. In terms of shape, the astragali from Thessaly clearly plot more in the Promachon than Sitagroi area, which means that they are similarly slender to those from Promachon and less robust than those from Sitagroi.

An ANOVA t-test indicates that there is no significant difference in the greatest length of the lateral half (GLl) of the astragalus between Macedonia and Thessaly, but there is a highly significant difference in the distal breadth (Bd) between the two groups (**Table 2**), with the astragali from Macedonia having a greater distal breadth (μ= 44.9 mm) than those from Thessaly (μ= 42.3 mm).

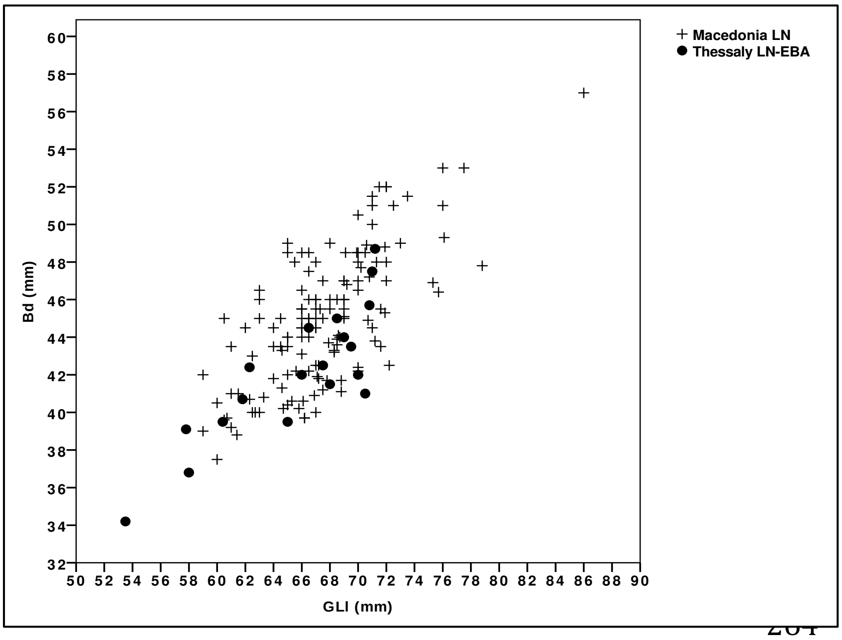

Figure 5: Cattle astragalus. Comparison between Macedonia (N = 140) and Thessaly (N = 19).

3.2. *Ovis aries*

3.2.1. Macedonia

Figure 6 compares the size of sheep astragalus between Promachon and Sitagroi. It indicates that astragali from Promachon are, on average, much smaller than those from Sitagroi. This is reflected in both length and width, which means that, unlike cattle, there is no perceivable variation in shape between the two sites. The few larger Promachon astragali tend, however, to have relatively smaller widths than those from Sitagroi, an indication of slenderness.

An ANOVA t-test indicates that there are highly significant differences in both the greatest length of the lateral half (GLl) and the distal breadth (Bd) of the astragalus, with Sitagroi astragali having a much greater length (μ= 28.7 mm) and distal breadth (μ= 20.2 mm) than Promachon astragali (GLl μ= 25.5 mm; Bd μ= 16.4 mm) (**Table 2**).

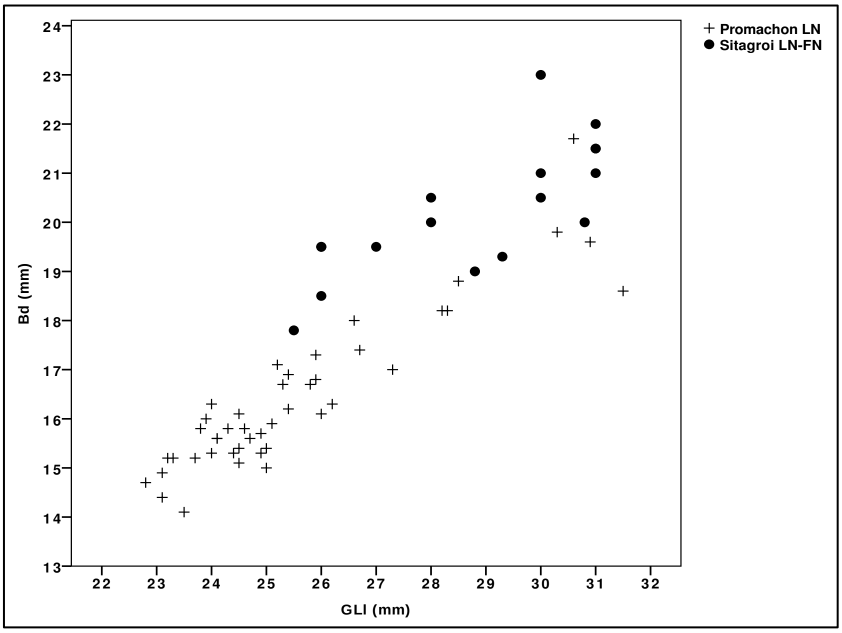

Figure 6: Sheep astragalus. Comparison between Promachon (N = 44) and Sitagroi (N = 17).

Figure 7 plots Promachon (top diagrams) and Sitagroi (bottom diagrams) length and width measurements in order to see how these are distributed according to the standard. The standard that we use for the calculation of the log ratio is - as for cattle - the mean of the length and the width measurements of sheep postcranial elements from Promachon. Log ratios from depth measurements were not calculated, since the depths of sheep postcranial elements were not measured at Sitagroi.

The log ratio diagrams show that the means of both length and width measurements from Sitagroi plot on the right side of the standard (Promachon mean) indicating that, in terms of absolute size, Sitagroi sheep bones have greater lengths and widths than those from Promachon. Therefore, the log ratio diagrams are consistent with the astragalus scatterplot (and the statistical test), which indicated that sheep from Sitagroi are taller and wider than their counterparts from Promachon. The difference in lengths appears to be greater, but the difference between lengths and widths is not substantial. Nonetheless, the greater relative length of the Sitagroi animals may be due to a greater occurrence of castrates (i.e. wethers), known to keep their epiphyses unfused for longer, therefore allowing greater length of their bones (Davis 1996; Hatting 1974).

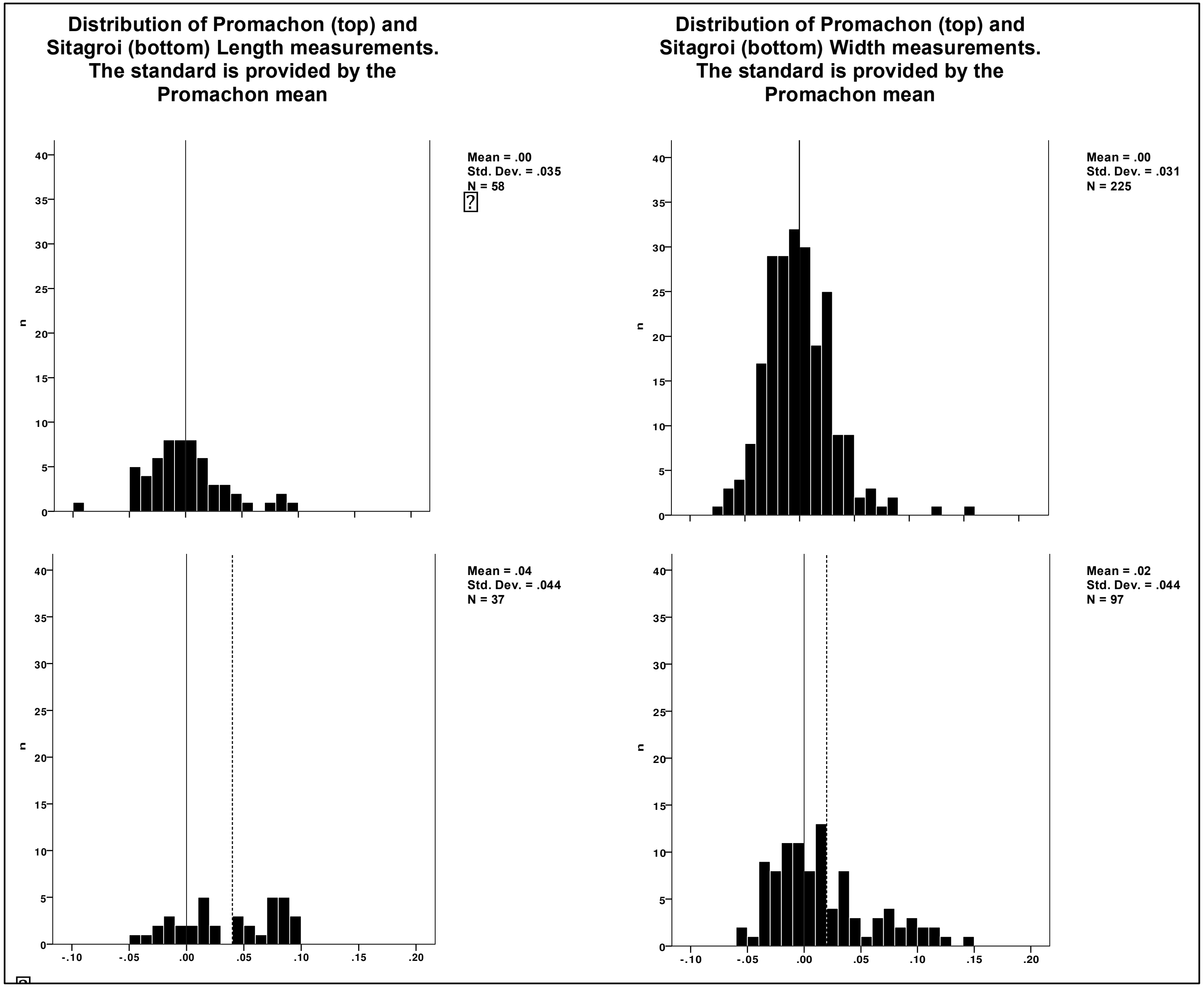

Figure 7: Distribution of Promachon (top diagrams) and Sitagroi (bottom diagrams) sheep postcranial length and width measurements using the log ratio technique (Simpson et al. 1960). The standard is provided by the Promachon mean. Only fully fused postcranial bones from Promachon were considered. The mean of Sitagroi length and width measurements is marked by a black dashed vertical line, and the standard measurement by a black vertical line at .00. The scale of the vertical axis is fixed to emphasize differences in sample sizes.

3.2.2. Thessaly

Figure 8 compares the size of the sheep astragalus between Ayia Sofia, Pevkakia and Zarkos. Sheep astragali from Zarkos are on average substantially larger than those from Pevkakia and Ayia Sofia, though we must consider that the sample size from the latter site is small. The large size of the sheep from Zarkos is noteworthy, particularly in view of the completely opposite trend showed by cattle. Two astragali from Zarkos are also different in shape from those from other sites as their widths are relatively smaller in comparison to their lengths; this makes them more slender in comparison to sheep astragali from Ayia Sofia and Pevkakia.

ANOVA T-tests were also undertaken to test the significance of the differences in the size of the sheep astragalus between the three Thessalian sites. The only significant difference that could be found concerned the distal breadth (Bd), which is substantially larger at Zarkos (μ= 18.4 mm) than the other two sites (Pevkakia μ= 16.3 mm; Ayia Sofia astragali μ= 16.2 mm) (**Table 2**).

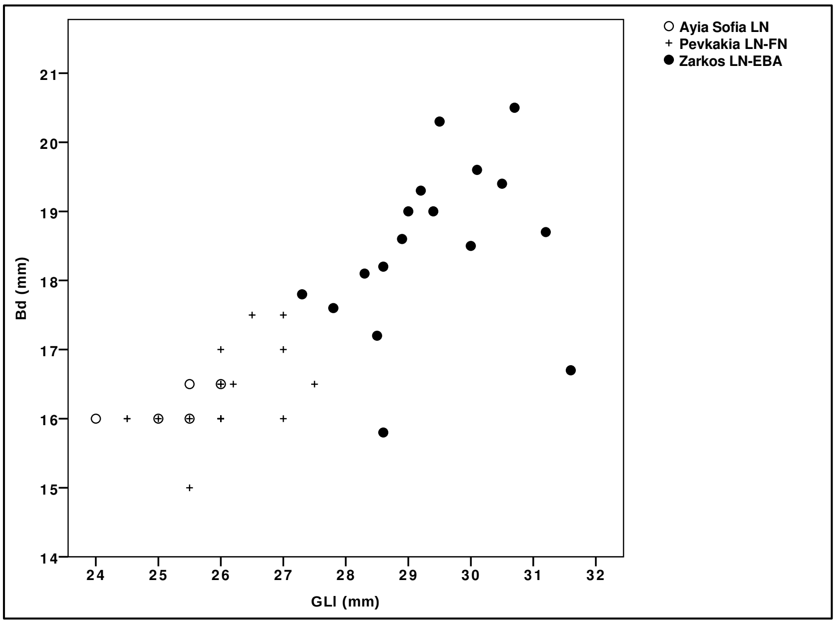

Figure 8: Sheep astragalus. Comparison between Ayia Sofia (N = 5), Pevkakia (N = 18) and Zarkos (N = 17).

3.2.3. Macedonia-Thessaly

Figure 9 compares the size of sheep astragalus between Macedonian and Thessalian sites. The scatterplot indicates that the average size of the sheep astragali between the two regions is roughly the same, but there are other substantial differences. In Thessaly there is less variability, with the top and bottom ends of the distribution almost exclusively occupied by Macedonian specimens (Promachon at one end and Sitagroi at the other). There are a number of sheep astragali from

Thessaly that have a relatively smaller width in comparison to their length, and therefore are more slender than those from Macedonia.

In order to statistically test the significance of the difference in the size of the sheep astragalus between Macedonia and Thessaly, an ANOVA t-test was conducted. This indicates that there are no significant differences in the greatest length of the lateral half (GLl) and the distal breadth (Bd) of the sheep astragalus between Macedonia and Thessaly (**Table 2**). This does not mean that the two groups are similar, but simply that they cannot merely be characterized as one being larger than the other.

The results likely reflect the great variation existing between the two Macedonian sites.

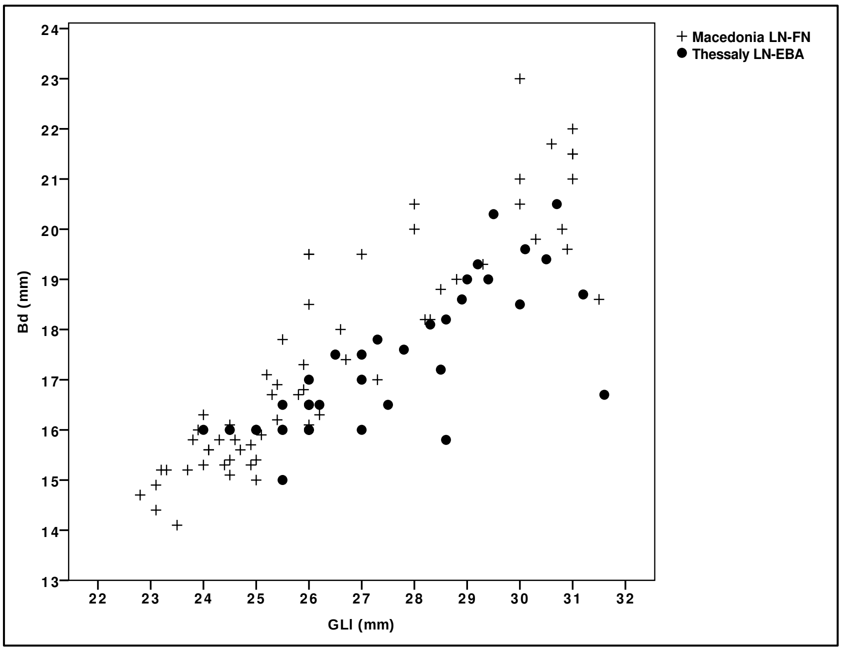

Figure 9: Sheep astragalus. Comparison between Macedonia (N = 61) and Thessaly (N = 40).

3.3. *Sus* sp.

3.3.1. Macedonia

Figures 10 and **11** compare pig tibia and astragalus between Sitagroi and Promachon. We also include the astragali and tibiae from Sitagroi, which were identified by Bökönyi (1986) as belonging to the wild form (*Sus scrofa*). At both sites, there are two distinct metric groups, presumably domestic and wild. The Sitagroi evidence supports the suggestion that the larger astragali and tibiae from Promachon belong to the wild form.

For tibiae, both domestic and wild populations appear to be metrically consistent at the two sites. In addition, ANOVA t-tests indicate that there are no significant differences in the distal breadth (Bd) and the distal depth (Dd) of the domestic pig tibiae between the two sites (**Table 2**).

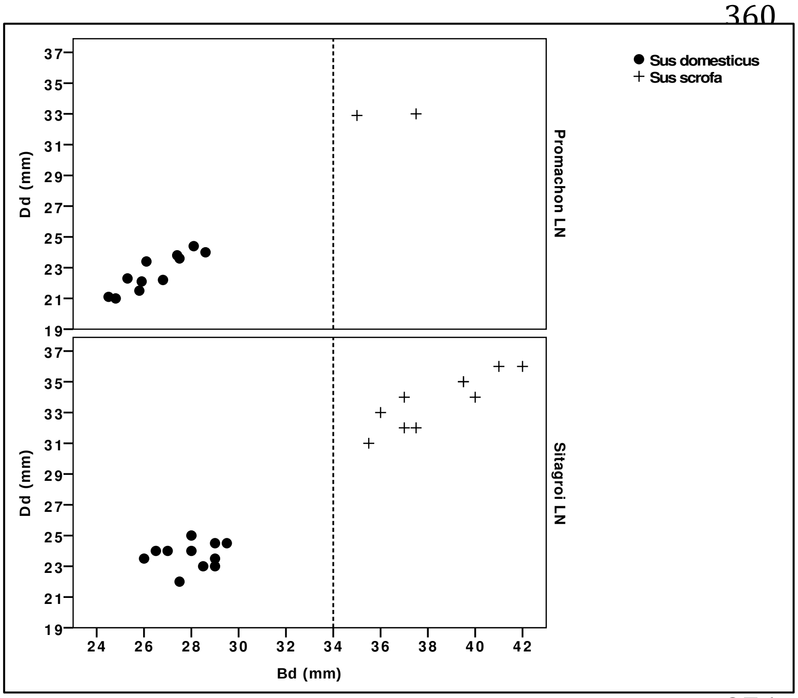

Figure 20: Pig tibia. Comparison between Promachon (N = 14) and Sitagroi (N = 21).

Domestic pig astragali from Sitagroi seem to be larger than those from Promachon, but the sample is small and the significance of the difference is not confirmed by ANOVA t-tests (**Table 2**).

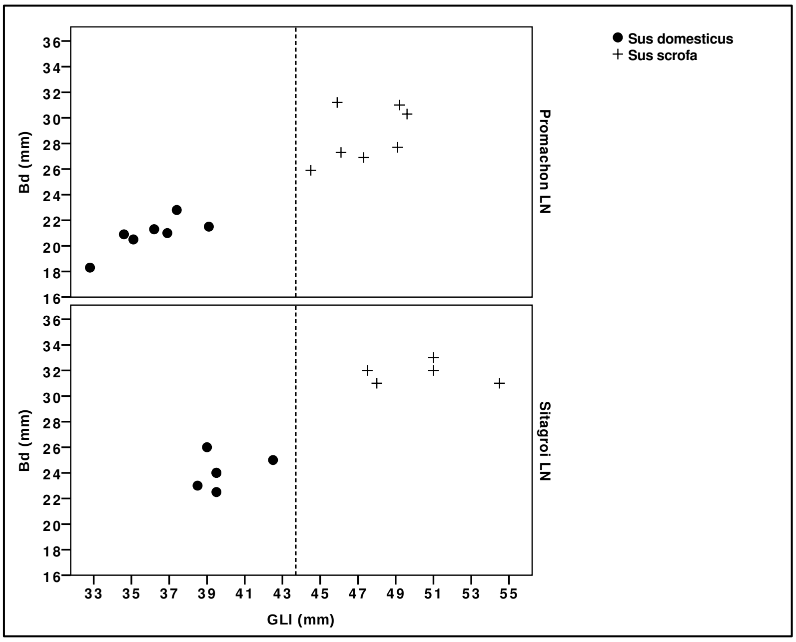

Figure 11: Pig astragalus. Comparison between Promachon (N = 14) and Sitagroi (N = 11).

Figure 12 plots the width (BT) against the smallest diameter (HTC) of the trochlea of the distal humerus of pig between Promachon and Makriyalos. The diagram shows that most measurements plot at the smaller end of the distribution, but there are a number of large outliers from both sites. In general, pig forelimb bones tend to be fairly age dependent as they are subject to greater post-fusion growth than hind limb bones (Albarella and Payne 2005; Albarella *et al.* 2006; Rowley-Conwy et al. 2012), but they are also much affected by sex variation (Payne and Bull 1988). Despite such variation, and considering that BT and HTC are much less affected by post-fusion growth than the commonly taken distal breadth (Bd) (Payne and Bull 1988; Albarella and Payne 2005), the two main groups are best interpreted as representing domestic (the majority) and wild forms. Both domestic pigs and wild boar are similar in size at the two sites. The few points plotting in-between the two main clusters could equally represent large domestic males or small wild females. Nonetheless, the distinction between the domestic and wild forms is fairly pronounced.

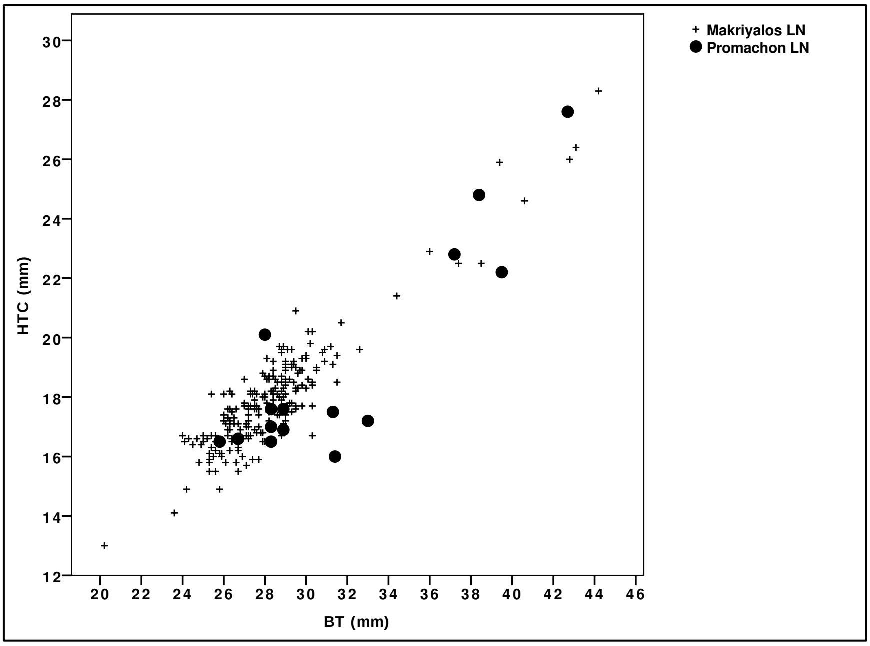

Figure 12: Pig humerus. Comparison between Promachon (N = 15) and Makriyalos (N = 215).

3.3.2. Thessaly

Figure 13 presents a comparison of pig astragali between Ayia Sofia, Pevkakia and Zarkos. Since the distal breadth (Bd) of the pig astragalus was not measured at Pevkakia (Jordan 1975) and Ayia Sofia (Driesch and Enderle 1976), we plot the greatest length of the lateral half of the astragalus (GLl) against the greatest length of the medial half of the astragalus (GLm). As in the case of Sitagroi, we also include the astragali that were originally identified as belonging to wild individuals, though there are only a few of them. However, we should once again note that - unlike Promachon - the attribution of pig specimens to either the domestic or the wild form at Thessalian sites was made on the basis of the general impression of the size of pig bones at the time of the recording (rather than biometrically).

The evidence shows that the wild boar is rarer than in Macedonia. Domestic pig measurements overlap between the three sites, but, on average, those from Ayia Sofia are larger. At this site there is no clear size difference between the smaller, domestic group, and the larger, wild one. The separation that was proposed for this site (Driesch and Enderle 1976), between domestic and wild pigs is therefore, arbitrary. It is possible that the pigs from Ayia Sofia appear as large because of interbreeding with wild boar or the occurrence of some wild females within the 'domestic' group. Considering the large difference between the two large specimens from Pevkakia and Zarkos and the rest of the specimens, a stronger case can be made for the occurrence of the wild boar at these two sites.

Due to the small sample size, measurements from Zarkos were excluded from statistical analysis. An ANOVA t-test was undertaken in order to test the significance of the difference in the size of the pig astragalus between Ayia Sofia and Pevkakia. The test indicates that there is significant difference in the greatest length of the lateral half (GLl) between the two sites, with Ayia Sofia astragali having a much greater length (μ= 41.8 mm) than Pevkakia astragali (μ= 38.9 mm). However, no significant difference was found in the greatest length of the medial half of the astragalus between Ayia Sofia and Pevkakia (**Table 2**).

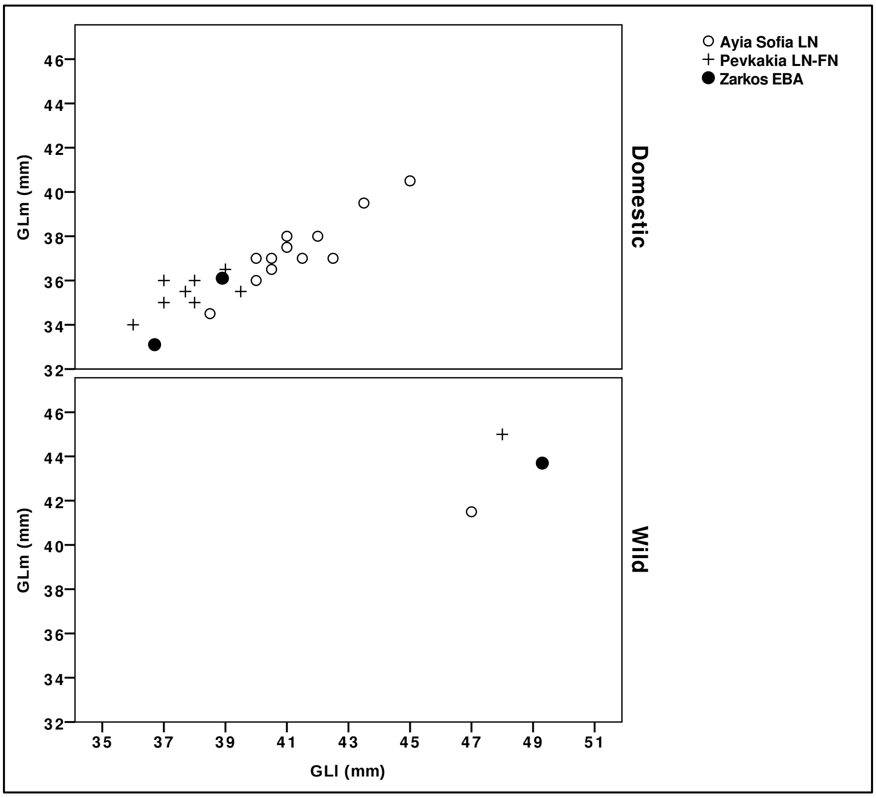

Figure 13: Pig astragalus. Comparison between Ayia Sofia (N = 14), Pevkakia (N = 9) and Zarkos (N = 3).

3.3.3. Macedonia-Thessaly

In order to obtain large enough samples of measurements to make further comparisons between Macedonian and Thessalian sites, we use the log ratio technique (**Figure 14**). The standard that we use for the calculation of the log ratio is represented by the mean of a group of modern wild boar from Kizilcahaman in Turkey (Payne and Bull 1988). Both postcranial bones and teeth are used, as they can provide different types of information. In particular, cheek teeth do not grow further once fully formed and are only slightly - if at all - sex dependent (Albarella and Payne 2005; Payne and Bull 1988; Rowley-Conwy et al. 2012). They can therefore be useful indicators of the occurrence of distinct populations (e.g. domestic *vs.* wild). With regard to postcranial measurements, since the collum of the scapula is heavily subject to post-fusion growth (Rowley-Conwy et al. 2012), the scapula SLC is excluded from the calculation of the log ratios for postcranial measurements. The figure shows log ratio diagrams for teeth (length and width measurements combined) and postcranial bones (length, width and depth measurements combined). This combination is not ideal (Albarella 2002; Meadow 1999), but it was necessary in order to obtain a sufficient sample size. By taking the Kizilcahaman wild pigs as a reference point, we can see how teeth and postcranial measurements of pigs from Macedonian and Thessalian sites compare to those of wild pigs from Kizilcahaman and, most importantly, with each other.

We can see that the log ratio diagrams for tooth and postcranial measurements from Promachon have a broadly unimodal distribution (with tails on the right hand side). The mean of each log ratio diagram from Promachon plots on the left side of the standard, thus indicating that teeth and postcranial measurements from Promachon are smaller than those from Kizilcahaman. This, in turn, suggests that the bulk of the pig population at Promachon belongs to the domesticated form, a pattern that corroborates the results of the scatterplots. There are, however, a number of larger specimens that plot on the right side of the standard, thus confirming the presence of wild pigs at Promachon. The evidence from Makriyalos is also consistent with the results of the scatterplot: log ratios of postcranial and tooth measurements from Makriyalos indicate clear 'peak and tail' distributions (on the right hand side), thus suggesting many domestic and a few wild pigs. On the other hand, the Sitagroi postcranial bones plot bimodally far more than teeth, indicating that wild pigs at Sitagroi are better represented by the main body than the head. Notable also is the fact that the mean of the Sitagroi postcranial bones is slightly higher than the mean of postcranial bones from other sites; this is probably due to a larger proportion of wild boar at Sitagroi. This is also consistent with the results of both the tibia and astragalus scatterplots.

Tooth measurements from Thessaly plot on the left side of the standard, thus indicating that they are smaller than the average tooth measurements from Kizilcahaman. There are no tooth measurements from Thessaly close to the Turkish standard, and therefore it can be suggested that they derive from domestic pigs. Postcranial measurements from Ayia Sofia, Pevkakia and Zarkos have broadly unimodal distributions; the means of postcranial measurements plot on the left side of the standard, indicating that these are smaller than those of Kizilcahaman. This suggests that the bulk of postcranial measurements belong to domestic pigs, a pattern that is also consistent with the result of the astragalus scatterplot. There are, however, a number of postcranial measurements from Zarkos and Pevkakia that pull away slightly on the right side of the distribution and also represent the only specimens that are larger than the standard. Overall, tooth and postcranial measurements from Thessaly suggest that - as in the case of Sitagroi - wild pigs are better represented by bones of the body rather than the head. It is possible, therefore, that wild pig crania from Thessaly were disposed off-site, due to their heavy weight and limited meat content.

There are a number of interesting points to be made on the inter-site level. First of all, Zarkos' postcranial measurements bear more resemblance to Macedonian, rather than Thessalian sites, in the sense that they have a broadly unimodal distribution with a tail on the right hand side (as in the cases of Promachon and Makriyalos). This suggests that the bulk of the pig population from this site belongs to the domestic form; however, wild pigs might have also been present. On the other hand, there are a small number of measurements from Pevkakia that plot on the right side of the standard and there is also a considerable distance between these measurements and the main distribution. These large measurements could almost certainly be attributed to wild pigs. However, it seems that the mean of postcranial measurements from Pevkakia plots far more to the left than the means of postcranial measurements from the other two Thessalian sites, indicating that domestic pigs from this site are smaller than their counterparts from Ayia Sofia and Zarkos. It is also interesting to note that the evidence from Ayia Sofia is consistent with the results of the astragalus scatterplot: this showed that there is no clear size difference between the smaller, domestic group, and the larger, wild one. This observation is also confirmed by the log ratio, which indicates that all postcranial measurements from this site plot on the left side of the standard, but there are also some measurements that are fairly close to the standard and may belong to the wild form. As in the case of astragalus scatterplots, the log ratios cannot suggest a clear separation between domestic and wild populations at Ayia Sofia.

All in all, it can be argued that log ratios of postcranial and tooth measurements for pigs from Sitagroi indicate a clear size difference between the smaller (domestic) pigs, and their larger (wild) counterparts. The evidence from Makriyalos and Promachon also confirm the results of the astragalus scatterplot, indicating that the bulk of the pigs from these sites belong to the domestic form, but there are also a number of wild pigs. In Thessaly, however, there is less clear bimodality. The identification of wild animals appears to be more difficult here, apart from the very obvious large outlier from Pevkakia. Either wild pigs are more sparsely represented in Thessaly, or the wild pig population from Macedonia was larger-sized in comparison to that from Thessaly.

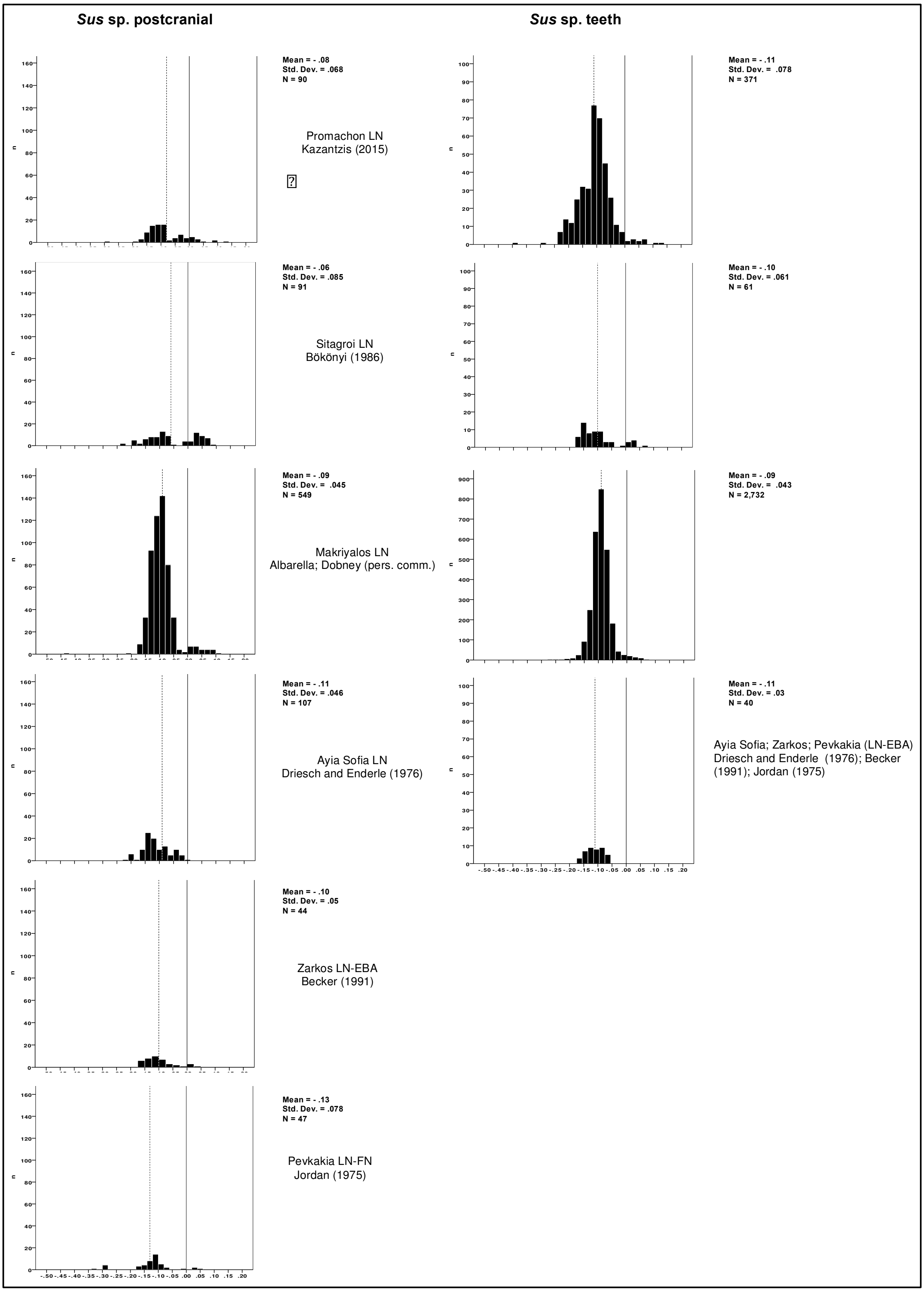

Figure 14: Comparison of pig postcranial and tooth measurements from Macedonia and Thessaly with a standard *Sus scrofa* sample from Kizilcahaman, Turkey (Payne and Bull 1988), using the log ratio technique (Simpson et al. 1960). Tooth measurements from Promachon, Sitagroi and Makriyalos were combined. Tooth measurements from all three Thessalian sites were combined in order to increase sample size. The mean of postcranial and tooth measurements is marked by a black dashed vertical line, and the standard measurement by a black vertical line at .00. The scales of the vertical axes are fixed to emphasize differences in sample sizes.

4. Discussion

Our evidence indicates that:

- Concerning Macedonia, cattle were more robust at Sitagroi than Promachon. In Thessaly there is variation in size between sites, but at all sites cattle were as gracile as those from Promachon.
- At Sitagroi sheep were clearly larger than at Promachon. In Thessaly, Zarkos has the largest animals, of similar size to Sitagroi.
- Domestic pigs are possibly slightly larger at Sitagroi than Promachon and Makriyalos and, again, there are differences between the Thessalian sites, with Ayia Sofia having the largest animals.
- The aurochs is present at Sitagroi, but in small numbers. Its occurrence does not seem obvious at Promachon and Ayia Sofia. However, the species was originally reported for Pevkakia and Zarkos.
- Overall the wild boar is better represented than the aurochs. At Sitagroi is almost as common as the domestic pig, while at Promachon and Makryialos is clearly present but in smaller numbers. In Thessaly it is sporadic and Ayia Sofia is the only analysed site where domestic and wild pigs cannot easily be distinguished, raising the possibility of interbreeding.

Bökönyi (1986) argues that the large size of cattle from Sitagroi is the result of the presence of a "transitional" form of cattle, represented by the crossbreeding of aurochs and domesticated cattle, as well as by "newly domesticated cattle" (Bökönyi 1986; 72). Bökönyi's argument was based on a group of cattle metapodials, plotting between the smaller bones, assumed to derive from domestic cattle, and the larger bones, assumed to derive from aurochs (Bökönyi 1986: Figures 5.2-5.4). However, Bökönyi did not take into account the effects of sexual dimorphism, which is highly pronounced in cattle metapodials (Albarella 1997; Bartosiewicz et al. 1993; 1997; Rowley-Conwy 2003; Wright and Viner-Daniels 2015). Thus, it is possible that the intermediate-sized cattle metapodials, which Bökönyi had identified in his assemblage, could have been female aurochsen or male domesticated cattle.

The question of whether crossbreeding between aurochs and domestic cattle occurred in Europe, has been the subject of much debate (Bollongino et al. 2008; Edwards et al. 2007; Götherström et al. 2005; Troy et al. 2001). Its proponents have argued that crossbreeding might have been unavoidable - or even encouraged - by Neolithic pastoralists, in order to improve the breeding stock and increase the numbers of their domestic livestock (Bollongino et al. 2008). Studies of ancient cattle DNA initially resulted in the identification of repeated hybridization between domesticated cattle and aurochs (Götherström et al. 2005), though this has more recently been questioned (Bollongino et al. 2008). The crossbreeding of domestic cattle with aurochs should not be discounted but it is not required to explain the pattern identified in this paper.

In addition to crossbreeding, Bökönyi also argued in favour of “newly domesticated” cattle in Sitagroi. In general, Bökönyi has been a proponent of the domestication of cattle in Europe. Local domestication of cattle has also been suggested by Boessneck (1962) in his study of the faunal material from Argissa in Thessaly (Early Neolithic), as well as Becker in her study of the faunal material from Zarkos (1991; 1999). However, in the Aegean area domestication was introduced much earlier (*c.* 9,000 to 8,000 Cal. BP) (Zeder 2008) than the period of occupation at Sitagroi. The Late Neolithic cannot be considered as a time-period during which cattle was still in the process of domestication and therefore Bökönyi’s hypothesis should be discounted.

As concerns sheep, Bökönyi (1986) does not elaborate on the large size of the domestic sheep population at Sitagroi during the Late Neolithic[2], yet this is the pattern that emerges clearly from our analysis. Overall, Sitagroi appears unusual for its large sheep and robust cattle, in comparison to other Macedonian and Thessalian sites (except the sheep from Zarkos).

The settlement pattern in the plain of Drama (where Sitagroi is located) may provide some explanation. In the Late Neolithic, there was a considerable expansion in the number of settlements in the plain of Drama with the use of a greater variety of locations. This could have resulted in intensification in the production of food resources, which allowed population numbers to increase (Blouet 1968). It is possible that settlements in the plain of Drama progressed from small habitation sites to fully functional villages, which provided a greater and more diversified number of services (Blouet 1968).

It is likely that Sitagroi was linked to a group of settlements in the plain of Drama, where opportunities for better responses to environmental constraints and/or food limitations (possibly through a system of exchange) could have taken place. We have clear evidence of such dynamic society in the plain of Drama from the site of Dikili Tash (Darcque et al. 2007; Koukouli-Chrysanthaki 2006), where there was persistence and density of occupation, abundance of finds, variety and quality of artefacts and a number of innovations in food-consuming procedures (such as wine-pressing) (Valamoti et al. 2007). The greater size and robustness of the Sitagroi livestock can be interpreted as part of this dynamic economic regime, which may have led to better feeding and husbandry care. The age-at-death data of the domestic livestock from Late Neolithic Sitagroi indicate a marked increase in the frequency of adult deaths through time (Sitagroi III-I) (Bökönyi 1986). According to Bökönyi, this indicates that these animals were not merely used for their meat, but also for secondary uses (milk, wool and traction). However unlikely the use of wool

[2] On the contrary, he argues for a large size of sheep during the Bronze Age at Sitagroi.

and traction during the late stages of the Neolithic may have been (cf. Bartosiewicz et al. 1997; Halstead 1995; Helmer et al. 2005; 2007; Johanssen 2005; Perlès 2001; Ryder 1969; 1982; 1993), milk production remains a distinct possibility (Evershed et al. 2006; Legge and Moore 2011). The greater size and robustness of the Sitagroi livestock may therefore be the result of a feeding regime, which provided ample and/or better quality fodder in order to meet the demands of a growing population. On the other hand, the difference in the size of domestic pigs is much less substantial, perhaps indicating that less importance was placed on the rearing of these animals; this could go hand in hand with the still heavy reliance on wild boar hunting at Sitagroi.

Different emphasis on the importance of different livestock may also explain variation in livestock size that we have seen between sites in Macedonia and Thessaly. In general, the large size of the animals may be associated with care in their husbandry regimes (e.g. a good feeding regime), which seems to have varied according to the site and livestock type. For instance at Zarkos, great emphasis was placed on sheep breeding. At Ayia Sofia, however, the large pig size may also be linked with regular interbreeding with wild boar, therefore indicating a free-range herding system, rather than intensive husbandry.

Probably the most remarkable phenomenon that our evidence highlights is the great variation in livestock size between sites and regions – and how this may vary according to animal species. This evidence suggests that the sites operated rather independently from each other, and husbandry regimes needed to be adapted to local conditions, in terms of environment, organization of the society and cultural preferences. Sitagroi probably benefitted from the support of a network of local sites in the plain of Drama, in contrast with Promachon, which seems to have been rather isolated in the plain of Serres. The settlement pattern in the plain of Serres indicates a number of prehistoric settlements (i.e. Toumba BA, Dimitra LN, Kryoneri LN, Pentapoli BA), which are located in the southern part of the plain. Promachon on the other hand, is the only known site located in the northern part of the plain. However, it is possible that Promachon's 'isolation' may be due to 'gaps' in the archaeological research, rather than a 'genuine' pattern (Kazantzis 2015). It is likely that other contemporary sites will eventually emerge, thus adding to the information currently available (Koukouli-Chrysanthaki 2006).

Promachon and Makriyalos appear to be substantially different also. Metrical analyses showed that cattle from Promachon were larger and more robust in comparison to Makriyalos, whereas sheep were of roughly similar size (Kazantzis 2015). It is worth pointing out that the environmental conditions between the two sites are substantially different. Promachon is located on the northernmost part of Macedonia, close to the mountainous and forested regions of the Balkans, with low winter temperatures and high precipitation levels, which may have been ideal for cattle pasture (Kazantzis 2015). Makriyalos is located on the southernmost part of Macedonia near the Thessalian plain; the site is fairly close to the sea with warmer and drier climatic conditions in comparison to Promachon, even during the winter.

Thessalian sites on the other hand, are really different from each other, which means that, despite a lack of substantial geographic barriers in the region, those sites still seem to be operating rather independently. This isolation, however, is not reflected on the evidence from the material culture: the evidence from the Late Neolithic indicates that ware types had very widespread distributions (Perlès and Vitelli 1999). The movement of fine decorated pottery and the similarities with regard to the stylistic *répertoire* in locally produced wares suggest a high level of direct social contact and interaction between sites and settlements (cf. Halstead 1999; Perlès 1990; 1992; 2001; Theocharis 1993). It is therefore clear that different sites maintained distinctive husbandry strategies not because of a lack of opportunity but rather as a choice.

5. Conclusions

Our analyses show that most sites differ from each other in terms of livestock size and, in some cases, even shape. This suggests the existence of multiple areas of cultural influence as well as distinctive environmental conditions that would have encouraged different husbandry regimes. Macedonia and Thessaly are different from each other, but there seems to be variation in livestock size also within each of the two main regions. The level of nourishment and the placement of care vary according to animal species across sites and regions. Sitagroi stands out because of its large livestock size and heavier than average reliance of wild boar hunting. It seems that the site invested substantially in cattle and sheep husbandry, perhaps supported in this by the high degree of interaction with other contemporary settlements in the plain of Drama. Environmental conditions may be the cause of differences in livestock size between Promachon and Makriyalos, but the Thessalian area indicates that different sites, even when not separated by clear geographic or environmental barriers, had different husbandry priorities, perhaps dictated by cultural choices. It is for this reason that we should consider these different local traditions as representing *cultures*, rather than just *economies*. The overall impression that one gains is that, in the Late Neolithic, Greece was a mosaic of many different cultures, interacting with each other but at the same time maintaining their distinctiveness.

Acknowledgements

Part of this paper is based on the results of George Kazantzis' PhD thesis at the University of Sheffield, UK. George Kazantzis would like to thank, Chaido Koukouli-Chrysanthaki for making the zooarchaeological material from Promachon available for study, and Katerina Peristeri for allowing him to study this material at the labs of the Ephoria of Antiquities of Serres, Greece. Umberto Albarella carried out most of his work on this paper while on research leave funded by the British Academy, to which he is extremely grateful. The pig data from Makriyalos discussed in this paper are previously unpublished and were collected by Keith Dobney and Umberto Albarella on material made available by Paul Halstead.

References

Albarella U., 1997. Shape variation of cattle metapodials: age, sex or breed? Some examples from Medieval and Postmedieval sites. Anthropozoologica 25, 37-47.

Albarella, U., 2002. 'Size matters': how and why biometry is still important in zooarchaeology. In: Dobney, K., O'Connor, T., (Eds.) Bones and the Man: Studies in honor of Don Brothwell. Oxford, Oxbow, 51-62.

Albarella, U., Payne, S., 2005. Neolithic pigs from Durrington Walls, Wiltshire, England: a biometrical database. Journal of Archaeological Science 32, 589-99.

Albarella U., Dobney K., Rowley-Conwy, P., 2006. The domestication of the pig (*Sus scrofa*): new challenges and approaches. In: Zeder, M., Bradley, D., Emshwiller, E., Smith, B., (Eds.) Documenting Domestication: new genetic and archaeological paradigms. Berkeley, University of California Press, 209-227.

Albarella, U., Johnstone, C., Vickers, K., 2007. The development of animal husbandry from the Late Iron Age to the end of the Roman period: a case study from South- East Britain. Journal of Archaeological Science 20, 1-21.

Albarella U., Dobney K., Rowley-Conwy, P., 2009. Size and shape of the Eurasian wild boar (*Sus scrofa*), with a view to the reconstruction of its Holocene history. Environmental Archaeology 14, 103-136.

Amberger, K.P., 1979. Neue Tierknochenfunde aus der Magula Pevkakia in Thessalien II: Die Wiederkäuer. Inaugural Dissertation, Ludwig-Maximilians Universität, München.

Andreou, S., Fotiadis, M., Kotsakis, K., 1996. Review of Aegean prehistory V: the Neolithic and Bronze Age of northern Greece. American Journal of Archaeology 100 (3), 537-597.

Bailey, W.D., 2000. Balkan prehistory: Exclusion, Incorporation and Identity. London, Routledge.

Bartosiewicz, L., Van Neer, W., Lentacker, A., 1993. Metapodial asymmetry in draft cattle. International Journal of Osteoarchaeology 3, 69-75.

Bartosiewicz, L., Van Neer, W., Lentacker, A., 1997. Draught Cattle: Their Osteological Identification and History. Musee Royal de L'Afrique Centrale Tervuren, Belgique, Annales Sciences Zoologiques, Vol. 281.

Becker, C., 1991. Die tierknochenfunde von der Platia Magoula Zarkou: neue untersuchungen zu haustierhaltung, jagd und rohstoffverwendung im Neolithisch-Bronzezeitlichen Thessalien. *PZ* 66, 14-78.

Becker, C., 1999. The Middle Neolithic and the Platia Magoula Zarkou: A review of current archaeozoological research in Thessaly (Greece). Anthropozoologica 30, 3-22.

Blouet, B., 1968. Development of the settlement pattern. In: Renfrew, C., Gimbutas, M., Elster, S., (Eds.) Excavations at Sitagroi: a prehistoric village in northeastern Greece Volume 1 (Monumenta Archaeologica 13). Los Angeles, California, Institute of Archaeology, University of California,133-143.

Boessneck, J., 1962. Die Tierreste aus der Argissa Magula vom präkeramischen Neolithikum bis zur Mitteleren Bronzezeit. In: Milojcic, V., Böessneck, J., Hopf M., (Eds.) Argissa-Magula 1, Bonn, Rudolf Habelt, pp. 27-99.

Bökönyi, S., 1986. Faunal remains. In: Renfrew, C., Gimbutas, M., Elster, S., (Eds.) Excavations at Sitagroi: a prehistoric village in northeastern Greece Volume 1 (Monumenta Archaeologica 13). Los Angeles, California, Institute of Archaeology, University of California, 63-132.

Bökönyi, S., 1989. Animal remains. In: Gimbutas, M., Winn, S., Shimabuku, D., (Eds.) Achilleion, a Neolithic Settlement in Thessaly, Greece, 6400-6500 BC. Los Angeles, UCLA Institute of Archaeology, 315-332.

Bollongino, R., Elsner, J., Vigne, J.D., Burger, J., 2008. Y-SNPs do not indicate hybridization between European aurochs and domestic cattle. PLoS ONE 3.

Darcque, P., Koukouli-Chrysanthaki, Ch., Malamidou, D., Treuil, R., Tsirtsoni, Z., 2007. Recent researches at the Neolithic settlement of Dikili-Tash, Eastern Macedonia, Greece: an overview. In: Todorova, H., Stefanovic, M., Ivanov, G., (Eds.) The Struma/Strymon river valley in prehistory: Proceedings of the International Symposium 'Strymon Praehistoricus' Kjustendil-Blagoevgrad (Bulgaria) and Serres-Amphipolis (Greece). Sofia, Gerda Henkel Stiftung, 247-256.

Davis, S.J.M., 1992. A rapid method for recording information about mammal bones from archaeological sites. AML Report 19/92.

Davis, S.J.M., 1996. Measurements of a group of adult female Shetland sheep skeletons from a single flock: a baseline for zooarchaeologists. Journal of Archaeological Science 23, 593-612.

Davis, S.J.M., 2000. The effect of castration and age on the development of the Shetland sheep skeleton and a metric comparison between bones of males, females and castrates. Journal of Archaeological Science 27, 373-390.

Driesch von den, A., 1976. A guide to the measurement of animal bones from archaeological sites, Harvard Peabody Museum, Bulettin 1.

Driesch von den, A., 1987. Haus - und Jagdtiere im Vorgeschichtlichen Thessalien. Prähistorische Zeitschrift 62, 1-21.

Driesch von den, A., Enderle, K., 1976. Die Tierreste aus der Agia Sofi a-Magoula in Thessalien. In: Milojcic, V., Driesch von den, A., Enderle, K., Milojcic von Zumbusch J., Kilian K., (Eds.) Die deutschen Ausgrabungen auf Magulen um Larisa im Thessalien, 1966: Agia Sofi a-Magula, Karagyos-Magula, Bunar Baschi. Bonn, Rudolf Habelt,15-54.

Edwards, C.J., Bollongino, R., Scheu, A., Chamberlain, A., Tresset, A., et al. 2007. Mitochondrial history of the aurochs (*Bos primigenius primigenius*) in Europe. Proceedings of the Royal Society B 274, 1377-1385.

Evershed, R.P., Payne, S., Sherratt, A., Copley, M.S., Coolidge, J., Urem-Kotsu, D., Kotsakis, K., Özdoğan, M., Özdoğan, A.E., Nieuwenhuyse, O., Akkermans, P., Bailey, M.M.G., Andeescu, D., Campbell, R.R., Farid, S., Hodder, I., Yalman, N., Özbasaran, M., BIçakcI, E., Garfinkel, Y., Levy T., Burton, M.M., 2008. Earliest date for milk use in the Near East and southeastern Europe linked to cattle herding. Nature 455, 528-531.

Fotiadis, M., 2001. Imagining Macedonia in prehistory, *ca.* 1900-1930. Journal of Mediterranean Archaeology 14, 115-135.

Gejvall, N.G., 1969. Lerna, a Pre-classical site in the Argolid: Results of excavations conducted by the American School of Classical Studies at Athens. Vol. I: The Fauna. American School of Classical Studies, Princeton N.J.

Götherström A., Anderung C., Hellborg L., Elburg R., Smith, C., 2005. Cattle domestication in the Near East was followed by hybridization with aurochs bulls in Europe. Proceedings of the Royal Society B 272, 2345-2350.

Halstead, P., 1989a. Like raising damp? An ecological approach to the spread of farming in southeast and central Europe. In: Milles, A., Williams, D., Gardner, N., (Eds.) The beginnings of Agriculture, Symposia of the Association for Environmental Archaeology No. 8. British Archaeological Reports Series 496, 23-53.

Halstead, P., 1989b. The economy has a normal surplus: economic stability and social change among early farming communities of Thessaly, Greece. In: Halstead, P., O'Shea, J., (Eds.) Bad year economics. Cambridge, Cambridge University Press, 68-80.

Halstead, P., 1992. Dimini and the 'DMP': faunal remains and animal exploitation in Late Neolithic Thessaly. Annual of the British School of Athens 87, 29-59.

Halstead, P., 1995. Plough and power: the economic and social significance of cultivation with the ox-drawn ard in the Mediterranean. Bulletin of Sumerian Agriculture 8, 11-22.

Halstead, P., 1999. Neighbours from hell? The household in Neolithic Greece. In: Halstead, P., (Ed.) Neolithic society in Greece. Sheffield, Sheffield Academic Press, 77-95.

Hatting, T., 1974. The influence of castration on sheep horns. In: Clason, A., (Ed.) Archaeozoological Studies. Amsterdam, Elsevier, 345-351.

Helmer, D., Gourichon, L., Maamar, H.S., Vigne, J.D., 2005. L'élevage des caprinés Néolithiques dans le sudest de la France: saisonnalité, des abattages, relations entre grottes-bergeries et sites de plein air. Anthropozoologica 40, 167-189.

Helmer, D., Gourichon, L., Vila, E., 2007. The development of the exploitation of products from *Capra* and *Ovis* (meat, milk and fleece) from the PPNB to the Early Bronze in the northern Near East (8700-2000 BC Cal), Anthropozoologica 42, 41-69.

Hinz, G., 1979. Neue Tierknochenfunde aus der Magula Pevkakia in Thessalien I: Die Nichtwiederkäuer. Inaugural Dissertation, Ludwig-Maximilians Universität, München.

Johanssen, N.N., 2005. Paleopathology and Neolithic cattle traction: methodological issues and archaeological perspectives. In: Davis, J., Fabiš, M., Mainland, I., Richards, M., Thomas, R., (Eds.) Diet and health in past animal populations: current research and future directions (Proceedings of the 9th Conference of the International Council of Archaeozoology, Durham August 2002). Oxford, Oxbow, 39-51.

Johnstone, C., Albarella, U., 2015, The Late Iron Age and Romano-British mammal and bird bone assemblage from Elms Farm, Heybridge, Essex. In: Atkinson, M., Preston, S.J., Heybridge: A Late Iron Age and Roman Settlement, Excavations at Elms Farm 1993-5, Internet Archaeology 40, http://dx.doi.org/10.11141/ia.40.1.albarella.

Jordan, B., 1975. Die Tierknochenfunde aus der Magula Pevkakia in Thessalien. Inaugural Dissertation, Ludwig-Maximilians Universität, München.

Kazantzis, G., 2015. The Zooarchaeology of the Late Neolithic Strymon (Struma) river valley: the case of the Greek sector of Promachon-Topolnica. Unpublished PhD Thesis, University of Sheffield, Sheffield, UK.

Kotsakis, K., 1999. What Tells can tell: social space and settlement in the Greek Neolithic. In: Halstead, P., (Ed.) Neolithic society in Greece. Sheffield, Sheffield Academic Press, 67-76.

Koukouli-Chrysanthaki Ch., 2006. The Neolithic and Bronze Age of Eastern Macedonia: A review of the recent archaeological research. In: Tasić N., Grozdanov C., (Eds.) Homage to Milutin Garašanin, Belgrade, Serbian Academy for Science and Arts, 469-487.

Koukouli-Chrysanthaki, Ch., Todorova, H., Aslanis, I., Vajsov, I., Valla, M., 2007. Promachon-Topolnica: a Greek-Bulgarian archaeological project. In: Todorova, H., Stefanovic, M., Ivanov, G., (Eds.) The Struma/Strymon river valley in prehistory: Proceedings of the International Symposium 'Strymon Praehistoricus' Kjustendil-Blagoevgrad (Bulgaria) and Serres-Amphipolis (Greece). Sofia, Gerda Henkel Stiftung, 43-78.

Koukouli-Chrysanthaki, Ch., Todorova, H., Aslanis, I., Vajsov, I., Valla, M., 2014. Γεωφυσική Έρευνα και Αρχαιολογική Πραγματικότητα στο Νεολιθικό Οικισμό Προμαχών-Topolnica. In: Stefani, E., Merousis, N., Dimoula, A., (Eds.) A century of research in prehistoric Macedonia: Proceedings of the International Conference, Archaeological Museum of Thessaloniki, 251-260.

Legge, A., Moore, A., 2011. Clutching at straw: the Early Neolithic of Croatia and the dispersal of agriculture. In: Hadjikoumis, A., Robinson, E., Viner, S., (Eds.) Dynamics of Neolithisation in Europe: studies in honor of Andrew Sherratt. Oxford and Oakville, Oxbow, 176-195.

Meadow, R., 1999. The use of size index scaling techniques for research on archaeozoological collections from the Middle East. In: Becker, C., Manhart, H., Peters, J., Schibler, J., (Eds.) Historia Animalium ex Ossibus: Festschrift fur Angela von den Driesch. Rahden/Westf. L. Verlag Marie Leidorf GmbH, 285-300.

Pappa, M., 2008. Οργάνωση του χώρου και οικιστικά στοιχεία στους Νεολιθικούς οικισμούς της κεντρικής Μακεδονίας ΔΕΘ-Θέρμη-Μακρύγιαλος. Unpublished PhD Dissertation, Aristotle University of Thessaloniki.

Pappa, M., Besios, M., 1999. The Neolithic settlement at Makriyalos, northern Greece: preliminary report on the 1993-1995 excavations, Journal of field archaeology 26 (2), 177-195.

Payne, S., Bull, G., 1988. Components of variation in measurements of pig bones and teeth and the use of measurements to distinguish wild from domestic pig remains. Archaeozoologia, 2, 27-66.

Perlès, C., 1990. L'outillage de pierre taillée néolithique en Grèce: approvisionnement et exploitation des matières premières. Bulletin de Correspondance Hellénique 114(1), 1-42.

Perlès, C., 1992. Systems of exchange and organization of production in Neolithic Greece. Journal of Mediterranean Archaeology 5(2), 115-164.

Perlés, C., 2001. The Early Neolithic in Greece: The first farming communities in Europe. Cambridge, Cambridge University Press.

Perlès, C., Vitelli, D.,1999. Craft Specialization in the Neolithic of Greece. in Halstead, P. (Ed.) Neolithic society in Greece, Sheffield, Sheffield Academic Press, 96-107.

Renfrew, C., 1972. The Emergence of Civilization: Cyclades and the Aegean in the Third Millennium BC. London, Methuen.

Rowley-Conwy, P., 1999. East is east and west is west but pigs go on forever: domestication from the Baltic to the Sea of Japan. In: Anderson, S., (Ed.) Current Research in Osteoarchaeology 2. Oxbow Books, Oxford, 35-40.

Rowley-Conwy, P., 2003. Early domestic animals in Europe: imported or locally domesticated? In: Ammerman, A., Biagi, P., (Eds.) The Widening Harvest. The Neolithic Transition in Europe: Looking Forward, Looking Back. Boston, Archaeological Institute of America, 99-117.

Rowley-Conwy, P., Albarella, U., Dobney, K., 2012. Distinguishing wild boar from domestic pigs in prehistory: a review of approaches and recent results. Journal of World Prehistory 25, 1-44.

Ryder, M., 1969. Changes in the fleece of sheep following domestication (with a note on the coat of cattle). In: Ucko, P.J., Dimbleby G.W., (Eds.) The domestication and exploitation of plants and animals. London, Duckworth, 495-521.

Ryder, M., 1982. Sheep and Man. London, Duckworth.

Ryder, M., 1993. Sheep and goat husbandry with particular reference to textile fibre and milk production. Bulletin on Sumerian agriculture 7, 9-32.

Simpson, G., Roe, A., Lewontin, R., 1960. Quantitative Zoology. New York, Harcourt, Brace and World.

Theocharis, D.R., 1993. Neolithic Greece. National Bank of Greece, Athens.

Trantalidou, K., 2001. Archaeozoology in Greece: a brief historiography of the science. Archaeofauna 10, 183-199.

Troy, C.S., MacHugh, D.E., Bailey, J.F., Magee, D.A., Loftus, R.T., 2001. Genetic evidence for Near-Eastern origins of European cattle. Nature 410, 1088-1091.

Valamoti, S.M., Mangafa, M., Koukouli-Chrysanthaki, Ch., Malamidou, D., 2007. Grape-pressings from northern Greece: the earliest wine in the Aegean? Antiquity 81, 54-61.

Wright, E., Viner-Daniels, S., 2015. Geographical variation in the size and shape of the European aurochs (*Bos primigenius*). Journal of Archaeological Science 54, 8-22.

Zeder, M., 2008. Domestication and early agriculture in the Mediterranean Basin: origins, diffusion and impact. PNAS 11, 597-604.

Supplementary Online Material 1:
Differences are mainly noticed between German zooarchaeologists, who primarily worked on Thessalian faunal assemblages, and those who worked in Macedonia. For instance, most German zooarchaeologists did not measure the distal breadth (Bd) and the lateral depth (Dl) of the pig astragalus, both of which were commonly measured for Macedonian sites. Tooth measurements were also largely neglected by almost all German zooarchaeologists (only the lengths of the third mandibular molars were measured). Bökönyi, on the other hand, did not measure the depth of various postcranial elements (e.g. tibia Dd, astragalus Dl) of small ruminants (sheep/goats). There are also cases in which some of von den Driesch's measurements were reported with a different designation. For instance, the astragalus BC (Breite des Caput) measurement, which is commonly used by German zooarchaeologists in Thessaly, is actually equivalent to von den Driesch's Bd, which is a common measurement taken by the rest of the zooarchaeologists working in Macedonia. In this paper, the astragalus BC, as denominated by German zooarchaeologists, is considered equivalent to the astragalus Bd.

Supplementary Online Information 2

Click here to download Supplementary Online Information: SOM 2.docx

Supplementary Online Material 2: Postcranial and tooth measurements used in this paper. With asterisk, the measurements used by German zooarchaeologists in Thessalian sites and considered in this paper for the calculation of the log ratios for pigs.

Measurements	*Bos* sp.	*Ovis aries*	*Sus* sp.	Sources
dP^4 L, WP			✓	*Payne and Bull (1988)*
dP_4 L, WP			✓	*Payne and Bull (1988)*
M^1, M^2 L, WA, WP			✓	*Payne and Bull (1988)*
M_1, M_2 L, WA, WP			✓	*Payne and Bull (1988)*
M^3 L, WA			✓	*Payne and Bull (1988)*
M_3 L, WA			✓	*Payne and Bull (1988)*
Atlas GL	✓		✓	*Driesch, von den (1976)*
Scapula GLP*			✓	*Payne and Bull (1988)*
Humerus Bd*			✓	*Driesch, von den (1976)*
Humerus BT	✓	✓	✓	*Payne and Bull (1988)*
Humerus HTC	✓		✓	*Payne and Bull (1988)*
Radius Bp*			✓	*Driesch, von den (1976)*
Radius Bd*			✓	*Driesch, von den (1976)*
Ulna DPA*			✓	*Driesch, von den (1976)*
Metacarpal GL	✓			*Driesch, von den (1976)*
Metacarpal Bd	✓			*Driesch, von den (1976)*
Metacarpal BatF	✓			*Davis (1992)*
Metacarpal a	✓			*Davis (1992)*
Metacarpal b	✓			*Davis (1992)*
Metacarpal 3	✓			*Davis (1992)*
Metacarpal 6	✓			*Davis (1992)*
Pelvis LAR	✓		✓	*Payne and Bull (1988)*
Femur DC	✓			*Payne and Bull (1988)*
Tibia Bd	✓			*Driesch, von den (1976)*
Tibia Dd	✓			*Driesch, von den (1976)*
Metatarsal GL	✓			*Driesch, von den (1976)*
Metatarsal Bd	✓			*Driesch, von den (1976)*
Metatarsal BatF	✓			*Davis (1992)*
Metatarsal a	✓			*Davis (1992)*
Metatarsal b	✓			*Davis (1992)*
Metatarsal 3	✓			*Davis (1992)*
Metatarsal 6	✓			*Davis (1992)*
Astragalus GLl	✓			*Driesch, von den (1976)*
Astragalus GLm				*Driesch, von den (1976)*
Astragalus Bd	✓			*Driesch, von den (1976)*
Astragalus Dl				*Driesch, von den (1976)*
Calcaneum GL	✓			*Driesch, von den (1976)*
Calcaneum GD	✓			*Albarella and Payne (2005)*

Supplementary Online Information 3

Click here to download Supplementary Online Information: SOM 3.xlsx

Anatomical element	Measurement code
Teeth (maxillary and mandibular)	dP4L
	dP4WP
	M1L
	M1WA
	M1WP
	M2L
	M2WA
	M2WP
	M3L
	M3WA
Atlas	GL
Scapula	GLP
Humerus	Bd
	BT
	HTC
Radius	Bp
	Bd
Ulna	DPA
Metacarpal & Metatarsal	Bd
	3
	6
	BatF
	a
	b
Pelvis	LAR
Femur	DC
Tibia	Bd
	Dd
Astragalus	GLl
	GLm
	Bd
	Dl
Calcaneum	GL
	GD