Peer Community In Archaeology

Exploring eastern Mediterranean Iron Age coastal connections through sheep astragali using geometric morphometrics

Louise Le Meillour *based on peer reviews by 4 anonymous reviewers*

Sierra A. Harding, Angelos Hadjikoumis, Shyama Vermeersch, Nimrod Marom (2024) The contribution of Mediterranean connectivity to morphological variability in Iron Age sheep of the Eastern Mediterranean. bioRxiv, ver. 6, peer-reviewed and recommended by Peer Community in Archaeology. https://doi.org/10.1101/2022.12.24.521859

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It currently seems obvious that the Mediterranean basin is a place of great exchanges of cultures, populations and goods. Although studies have focused quite extensively on the archaeology of maritime exchanges [1–3], it is challenging to assess archaeologically to what extent these networks had an influence on the biology of domesticated animals in the past, or even if animals were part of the trip. The question of past populations establishing extensive connections in the Mediterranean basin during the Iron Age and Persian period and especially, if these population exchange livestock and how these connections contributed to the animals phenotype or morphotype diversity is still difficult to document in the (zoo)archaeological record. These are amongst the questions Harding et al. [4] are making an attempt at documenting. Focusing on archaeological deposits from Cyprus and Israel in the eastern part of the Mediterranean basin, they use sheep astragali as a proxy to explore the potential connections that might have existed between evolution of the animals' morphology and exchanges through sea travel. Postulating that animals from inland sites should have variant morphology from those of coastal sites due to more intensive exchanges for the latter, mainly because of the incorporation of non-native animals, they conducted geometric morphometrics analyses to make an attempt at documenting the phenomenon. Observing changes in size and shape, but also an increased morphological variability within the assemblages from coastal sites, they nicely discuss and put their results in perspectives with the archaeological record and literature [5,6]. Although, as they acknowledge, their sample size is rather limited to draw any general conclusion, this paper sheds new lights on the influence of maritime transport and its influence over domesticated sheep diversity between Cyprus and the southern Levant, paving the way for future studies.

References

1. Leidwanger, J. and Knappett, C. (2018). Maritime Networks in the Ancient Mediterranean World. (Cambridge University Press). https://doi.org/10.1017/9781108555685
2. Leidwanger, J. (2020). Roman Seas: A Maritime Archaeology of Eastern Mediterranean Economies. (Oxford University Press). https://doi.org/10.1093/oso/9780190083656.001.0001
3. Bernard Knapp, A., Russell, A. and van Dommelen, P. (2022). Cyprus, Sardinia and Sicily: A Maritime Perspective on Interaction, Connectivity and Imagination in Mediterranean Prehistory. Cambridge Archaeological Journal 32, 79–97. https://doi.org/10.1017/S0959774321000330
4. Harding, S. A., Hadjikoumis, A., Vermeersch, S., Shafir, R. and Marom, N. (2024) The contribution of Mediterranean connectivity to morphological variability in Iron Age sheep of the Eastern Mediterranean. bioRxiv2022.12.24.521859 https://doi.org/10.1101/2022.12.24.521859.
5. Price, M. D., Perry-Gal, L. and Reshef, H. (2023). The Southern Levantine pig from domestication to Romanization: A biometrical approach. J. Archaeol. Sci. 157, 105828. https://doi.org/10.1016/j.jas.2023.105828
6. Vigne, J., Zazzo, A., Cucchi, T., Briois, F. and Guilaine, J. (2014). The transportation of mammals to Cyprus shed light on early voyaging and boats in the mediterranean sea. Eurasian Prehistory 10, 157–176.

Reviews

Evaluation round #3

Reviewed by anonymous reviewer 1, 07 May 2024

The paper has been significantly improved, particularly in its structure. Most of my comments have been addressed, except for the two remarks below, which I believe are important for this article. Apart from these, I think the article is ready for publication. Congratulations to the authors for this preliminary work.

Discussion:
L400-401: ”Our results demonstrate a significant pairwise difference between ABM and LTD (p=0.001), but not between Dor and Keisan.” This result is not presented in the Results section, and I believe it should be before it is discussed and compared with other literature.

Supplementary data:
Regarding the duplicate points, I understand what you have done. However, have you tried something like this: tps_op_total <- readland.tps(XXXXX, specID = ”imageID”, readcurves = TRUE) tps_op_total <- tps_op_total[-c(8, 17, 18, 27, 28, 37, 38, 47, 48, 57, 58, 67)„] # Delete landmarks number 8, 17, 18, 27, 28, 37 XXXX because they are duplicates, like your number 12 and 25.

Evaluation round #2

DOI or URL of the preprint: https://doi.org/10.1101/2022.12.24.521859
Version of the preprint: 4

Authors' reply, 02 May 2024

Dear Dr. Le Meillour,

Please see attached our point-by-point replies to the comments submitted by Reviewer #1.

We thank you and the Reviewer for your careful and thorough editing and critiques, which have so significantly improved the manuscript.

Nimrod (on behalf of the authors)

Download author's reply

Download tracked changes file

Decision by Louise Le Meillour, posted 16 April 2024, validated 16 April 2024

Decision on preprint #457

Dear authors,

I have reached a decision concerning your preprint #457, entitled "**The contribution of Mediterranean connectivity to morphological variability in Iron Age sheep of the Eastern Mediterranean**" after receiving reviewer #1 new comments.

Firstly, I would like to apologise for the processing time. I was waiting for reviewer #2 to send back their comments and unfortunately I still have not received anything.

Although reviewer #1 was content with the changes you made in the manuscript, they still raise few points that need to be addressed before acceptance (especially concerning figures clarity). I suggest you carefully address these and resubmit a modified version of the manuscript. Once you address these last comments, I would be happy to recommend your preprint that is of interest to the community.

You should find reviewers' comments attached to the present email.

Looking forward receiving your modified version,

Kind regards,

Louise Le Meillour for PCI Archaeology

Reviewed by anonymous reviewer 1, 19 March 2024

The article's format has significantly improved, which is commendable. The discussion now presents stronger arguments compared to the previous version, offering a critical analysis of both the data and results, which is highly insightful. I'm pleased to see that most of my previous comments have been taken into account, and I extend my gratitude to the authors. Despite being preliminary, this work has the potential to pave the way for further research.

- **Specific Comments**:
  - Line 27: Could you elaborate more on the conclusions?
  - Line 49: Consider using "Antiquity" instead of "antiquity."
  - Line 128: It would be helpful to include a legend explaining the zone referred to in the table.
  - Lines 140-141: The mention of "IA1/IA2" appears for the first time without explanation. It would be beneficial to standardize this throughout the text.
  - Lines 205, 201, 301: Please ensure consistent spacing with double spaces.
  - Digitization Error & GPA: I suggest rearranging the order of the paragraphs discussing digitization error and GPA. Since analyses Procrustes are already being discussed for error testing, this rearrangement would avoid repetition.
  - Lines 276-278: Bibliographic references should be reserved for the discussion section. However, it's worth noting that the percentage of error is similar to other studies.

- Line 411: This result seems new (unless I missed it previously). If so, it should be presented earlier. The paragraph discussing variability due to topography is particularly intriguing!
- Supplementary Data: Regarding geometric morphometrics analysis, it's crucial to address duplicate points. For instance, in the sliding procedure, landmarks 1 & 3 are duplicated. I suggest removing slidings 12 & 25 to prevent double-counting points, which could introduce bias.

Further, it's worth noting that placing the end of one curve, the beginning of the next, and a fixed landmark in the same position results in the point being counted thrice, potentially leading to bias. Additionally, after digitization, consider removing two of these points before analysis,(given that the 3 landmarks are supposed to be in the same place, and therefore with 3 times more weight for this point than for another)

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Evaluation round #1

DOI or URL of the preprint: https://doi.org/10.1101/2022.12.24.521859
Version of the preprint: 2

Authors' reply, 28 February 2024

Dear Dr. Le Meillour,

We thank you and the reviewers, whose comments greatly improved the manuscript. Please find attached our replies and the manuscript with TC.

Regards,

Nimrod (on behalf of the authors)

Download author's reply

Download tracked changes file

Decision by Louise Le Meillour, posted 06 February 2024, validated 06 February 2024

Decision on preprint #457

Dear authors,

I have reached a decision concerning your preprint number 457, entitled "The contribution of Mediterranean connectivity to morphological variability in Iron Age sheep of the Eastern Mediterranean" after receiving the reviewers comments.

Although all reviewers agreed on the interest and quality of the work presented in your manuscript, they feel the need to ask for specific points to be addressed before acceptance. I suggest you carefully address these and resubmit a modified version of the manuscript.

You should find reviewers' comments attached to the present email.

Looking forward receiving your modified version,

Kind regards,

Louise Le Meillour for PCI Archaeology

Reviewed by anonymous reviewer 1, 23 January 2024

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Reviewed by anonymous reviewer 3, 25 January 2024

The paper submitted by Harding et al. "The contribution of Mediterranean connectivity to morphological variability in Iron Age sheep of the Eastern Mediterranean", addresses the question of the movement of flocks by sea around the Mediterranean during the Iron Age. It examines this question by analyzing the morphology of sheep talus from two coastal sites and two inland sites in Israel and Cyprus. The authors hypothesize that the intra-site morphological variability of this bone must be more significant on the coastal sites than the inland sites due to the greater genetic diversity of sheep populations on the coast exposed to commercial networks. To highlight this variability, the authors use a geometric morphometric approach, which should better analyze the phylogenetic signal by isolating the variables of shape and size. Their results support the initial hypothesis, as the data show more significant variability at coastal sites.

The authors present the issues related to the studied assemblages and remain cautious in the interpretation of the results. Except for one site (ABM), the number of sites and bones per site is minimal, and the chronology is very broad, covering several centuries with the pooling of phases.

The study supports the idea that maritime connectivity is related to morphological variability in the Iron Age. Later studies should verify these results by analyzing more Iron Age II assemblages.

Despite the limited number of sheep talus and archaeological sites, this study merits attention. It explores a new approach using GMM to investigate the role of domestic animals in trade and commerce in the Mediterranean during the Iron Age, providing promising results.

Please, note that the following references cited in the text are missing from the bibliography:

Aubet, 2014

Bartosiewicz and Lisk, 2018

Briend and Humbert, 1980

Gambash, 2015

Gilboa, 2015

Gilboa et al., 2015

Gilboa and Sharon, 2017

Lehmann, 2001; 2021

Lehmann and Peilstocker, 2012

Nitschke et al., 2011

Panitz-Cohen et al., 2013;

Panitz-Cohen and Yahalom-Mack, 2019

Raban, 1981

Raban and Galili, 1985

Raban-Gerstel et al., 2008

Raveh and Kingsley, 1991

J. F. Rohlf, 2017

Sapir-Hen et al., 2014

Stern et al., 1993a

Stern et al., 1993b

Wachsmann and Raveh, 1984

Yahalom-Mack et al., 2018

Yasur-Landau et al., 2018

Reviewed by anonymous reviewer 4, 04 January 2024

This paper discuses the morphological variability of sheep astralali bones from Levantine sites to test the hypothesis that coastal sites will have a higher varibility of livestock introduced by trade. The authors use GMM to undertake detailed analysis of shape of the bones and, despite the small sample sizes and equifinality of

the underlying causes of variation, this paper discusses is a novel application of the method. The paper is primilinary as noted by the authors but will be a useful starting point for more detailed analyses with larger samples sizes, better dated material and a comparison with aDNA data in the future will make results more meaningful. However, the paper is a very useful publication as a starting point for more detailed analysis.

Reviewed by anonymous reviewer 2, 22 January 2024

Preprint strengths:• The issue of the impact of maritime trade on the spread of livestock and the evolution of domestic sheep breeds is very interesting and innovative from the point of view of geometric morphometrics methods.
• Chronological period poorly documented for these lines of research
• Fluid writing, easy to readPreprint weaknesses:• Problems with the structure of the article
• Insufficient justification for statistical tests
• Socio-cultural heterogeneity of the sites selected and, in fact, of astragali corpus
• The discussion section lacks important data, such as the impact of the taxonomic identification of the astragali, or the links between the heterogeneity of the socio-cultural contexts of the corpus and the results obtained in GMM, even though an effort has been made to highlight this. GENERAL COMMENTS:TitleNo comments.AbstractNo comments.
Introduction, Materials & Methods:The article presents a structural problem in the ”study sites”, ”material” and ”methods” sections. Many sentences describing the corpus and the method are in the introductive part. You could move the methodological sections written in paragraphs 5 and 6 of the introductions to the method section to present GMM and justify its use. Similarly, the sites presentation should be moved to the material section, where table 1 referring to sampling should be referred to in the text (data currently missing).
I suggest the following structure:

1. Present the corpus, adding information on the temporal resolution of the data + the origin of the assemblages (paragraph 2 of the material and method section).

2. Present the GMM method + statistical tests and justify it.

Regarding the methodological presentation, in my mind it lacks many justifications for the choice of statistical tests used and bibliographical references. I didn’t find any references on GMM. These need to be added.
A methodological presentation of the various statistical tests that are used in the results section to discuss the data are missing: centroid size, ANOVA, permutation tests, allometry tests, visualisation of unrooted morphological proximity trees.
Similarly, the method used to produce the average conformation patterns per site and their visualisations is not explained.
The sites are not presented in the same terms. In introduction view, I recommend that you provide additional information describing the topographical characteristics of the environment in order to justify your choice of your samples when you write « we chose samples that derive from sites in a similar topographic setting ».
I would also advise you to add information on the main findings of the archaeozoological studies to give an overview of animal economy identified.
Furthermore, if it is possible, I advise you to add as co-authors of the publication your colleagues who participated in the acquisition of the morphometric data on which your results are based.
Discussion:
Overall, interpretations need to be nuanced due to corpus heterogeneity (bones from totally different contexts). Even though these arguments are set out in the third paragraph, I suggest that you detail your hypotheses on morphotypical ovine diversity, taking these limitations into account.

I would also advise you to write some details of the interpretative problems associated with taxonomic identification that might suggest the variability of the data within sites. Although it is doubtful that the outliers from the LTD site were wild animals, this hypothesis cannot be refuted due to the anatomical identifications.
Figure 5: explain in the text.
DETAILS COMMENTS:Introduction
« to minimize possible functional morphological differences » = justify

« Our results, which represent the first study of animal mobility in the southern Levant using geometric morphometric methods, should be somewhat liberally interpreted due to the primacy of this study »: I think the term 'liberally interpreted' is completely inappropriate. On the contrary, as the data set is heterogeneous and limited, and as no comparative study has yet been carried out on the influence of maritime mobility on the introduction of new sheep varieties thanks to GMM, we need to be extremely cautious about the results.Methods
« osteologically mature at time of death » = to be justified due to the age identification problems based on talus ossification.
« Ovis sp. » = explain why the identification remained at the gender level and why this may be problematic in relation to the hypotheses formulated in the article.
Better justify the use of CVA.
Can you include the results of the PCA in the additional data?
Results
Overall, in this section, you should remove the comparisons with other studies and describe the results objectively.
Digitization error
Can you also indicate the result obtained on landmarks alone (without taking sliding into account).

Centroid size
« The smaller size of the Dor specimens also resonates well with the results from other Levantine coastal sites in the Iron Age (Chahoud et al., 2023). The specimens from Cyprus are especially small. We do not know how universal this pattern may be on the island during the Iron Age, and this observation requires further investigation » = for discussion
« The effect of the interaction between group and size on shape is not significant » = indicate the pvalue. You should make the results of the allometric tests more obvious. I recommend adding this information to the subtitle « centroid size » and "allometric pattern".

Ordination:
In view of the CVA results, I doubt the need to add the tree calculated from the Mahalanobis distances from the CVA. I advise you to add this graph and this information to the "supplementary" section.
« The group-based CVA ordination of the first ten principal components explains almost all the variability in that dataset » pay attention to the formula. The first two axes of the CVA performed on the first 10 dimensions of the PCA explain 98% of the variability.
Disparity:
Be careful with the formulation: here the data are calculated on the basis of Procrustes distances using which method (PCA)?
« The similarity between the results of two different analyses—direct measurements of disparity on landmark data and on eigen-ordinated coordinates—support the statistical results »: add the raw data.

Figure 3: I advise you to divide up this figure for greater clarity and visibility. You could, for example, present the boxplots and then present the conformation data in a second figure. In addition, I would suggest that you remove the individual numbers from the CVA biplot and, if possible, use colour plates to bring the groups together.

Figure 4B is not explained in the text: either explain it and therefore add the method that enabled it to be carried out in the method section, or remove it. In my own view, this description is very important in order to show the differences in shape that exist between the 'average' sheep astragalus at each of the sites.

REFERENCES

All the references mentioned are appropriate and accurate.

However, GMM references are missing. You have to add some references concerning the origin of the method like (Rohlf and Marcus, 1993, Bookstein, 1991...)

If you want, you can add too the PhD thesis of Manon Vuillien next to the reference of Colominas et al., 2019 and Haruda et al., 2019 : https://www.theses.fr/2020COAZ2020

She works on the morphological variability of Late Neolithic and Iron Age sheep in Provence combining GMM and more traditional approaches in archaeozoology.

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