Archaeofauna 34(1) (2025): 167-173

The impact of data from early fusing and basipodial bones on adult body size estimate: methodological insights from Upper Palaeolithic sites in southern Italy

L'uso degli standard biometrici in archeozoologia: spunti metodologici da siti del Paleolitico superiore dell'Italia meridionale

CLARISSA DOMINICI[1,2] & FRANCESCO BOSCHIN[1]

[1]UR Preistoria e Antropologia, Dipartimento di Scienze Fisiche, della Terra e dell'Ambiente, Università degli Studi di Siena, Via Laterina 8, 53100 Siena, Italy
clarissa.dominici@unisi.it; francesco.boschin@unisi.it

[2]Department of Archaeology, Simon Fraser University, 8888 University Dr W, Burnaby, BC V5A 1S6, Canada

(Received *5 October 2022*; Revised *14 March 2023*; Accepted *15 May 2023*)

ABSTRACT: In this paper, we present a biometric dataset of four wild ungulate species from two Late Pleistocene sites of southern Italy to highlight potential issues in estimating population body size when bone remains are highly fragmented. The materials come from the Epigravettian archaeological layers of Grotta Paglicci (Rignano Garganico) and Grotta della Cala (Marina di Camerota) and are ascribed to *Bos primigenius*, *Capra ibex*, *Equus ferus* and *Cervus elaphus*. Width measurements of long bone epiphyses, as well as width measurements of carpal and tarsal bones, were compared to reference standards using logarithmic ratio. The analysis showed a systematic difference between the results obtained when considering bones without epiphyses (e.g., talus) and with early ossifying epiphyses, on the one hand, and those obtained when measuring later fusion epiphyses, on the other. In particular, the first group provided more variable and often more downwardly skewed values. This means that biometric analyses used to estimate adult body size in a population are affected by those anatomical elements that are more likely to belong to animals that still have a good margin for growth, despite the effort to discard bones that look juvenile. Our results underline the need for caution when choosing anatomical elements for biometric analysis.

KEYWORDS: BIOMETRY, LOG-RATIO, EPIGRAVETTIAN, GROTTA PAGLICCI, GROTTA DELLA CALA

RIEPILOGO: In questo contributo presentiamo i dati biometrici relativi a quattro specie di ungulati selvatici provenienti da due siti del Pleistocene finale dell'Italia meridionale per sottolineare potenziali criticità nella stima delle dimensioni corporee di una popolazione quando i resti ossei sono altamente frammentati. I materiali vengono dai livelli archeologici di Grotta Paglicci (Rignano Garganico, FG) e Grotta della Cala (Marina di Camerota, SA) e appartengono alle specie *Bos primigenius*, *Capra ibex*, *Equus ferus* e *Cervus elaphus*. Le misure di larghezza delle epifisi, così come quelle di ossa del carpo e del tarso, sono state confrontate con standard attraverso l'utilizzo del rapporto logaritmico. L'analisi ha mostrato una sistematica differenza tra i risultati ottenuti considerando ossa prive di epifisi (per esempio l'astragalo) o con epifisi ad ossificazione precoce, da un lato, e quelli ottenuti misurando epifisi a fusione più tarda, dall'altro.

http://www.doi.org/10.15366/archaeofauna2025.34.1.016

Il primo gruppo ha fornito valori molto più variabili e spesso più schiacciati verso il basso. Questo indica che, per quanto si cerchi di scartare le ossa che hanno un aspetto giovanile, le analisi biometriche volte a stimare la stazza degli individui adulti in una popolazione vengono influenzate dagli elementi anatomici che hanno maggiori probabilità di appartenere ad animali con ancora un buon margine di aumento della taglia corporea. I risultati ottenuti indicano la necessità di una certa cautela nella scelta degli elementi anatomici usati per le analisi biometriche.

PAROLE CHIAVE: BIOMETRIA, CONFRONTO LOGARITMICO, EPIGRAVETTIANO, GROTTA PAGLICCI, GROTTA DELLA CALA

RESUMEN: En este artículo presentamos una base de datos biométricos de cuatro especies de ungulados silvestres en dos yacimientos del Pleistoceno tardío del sur de Italia para resaltar problemas potenciales en la estimación de talla de una población cuando las osamentas se encuentran muy fragmentadas. Los materiales incorporan restos de *Bos primigenius*, *Capra ibex*, *Equus ferus* y *Cervus elaphus* de los niveles epigravettienses de la Grotta Paglicci (Rignano Garganico) y la Grotta della Cala (Marina di Camerota). Las anchuras de las epífisis de huesos carpales y tarsales, se compararon con los estándares de referencia utilizando relaciones logarítmicas. El análisis mostró diferencias sistemáticas entre los resultados obtenidos al considerar huesos carentes de epífisis (como, por ejemplo, el astrágalo) con huesos con epífisis de osificación temprana frente a los de epífisis de fusión tardía. Así, los valores de las epífisis de osificación temprana fueron más variables y, con frecuencia, más sesgados a la baja que los valores de las epífisis de osificación tardía. Esto significa que los análisis biométricos dirigidos a estimar el tamaño corporal adulto en una población se verán afectados por aquellos elementos anatómicos que tienen mayores probabilidades de pertenecer a animales que todavía presentan un amplio margen de crecimiento, con independencia del esfuerzo que se haga por descartar huesos que remitan a individuos juveniles. Nuestros resultados subrayan la precaución que resulta necesaria a la hora de elegir elementos anatómicos para análisis biométricos de estas características.

PALABRAS CLAVE: BIOMETRÍA, LOG-RATIOS, EPIGRAVETIENSE; GRUTA PAGLICCI, GRUTA DE LA CALA

INTRODUCTION

Biometry is a valuable tool for zooarchaeologists, insofar as it can provide useful data for interpreting various phenomena, such as the effect of climate on faunas (Wright & Viner-Daniels, 2015), the effect of hunting on wild populations (Davis & Mataloto, 2012), or the domestication process (Boschin *et al*., 2020). Although the use of new digital technologies begins to spread in zooarchaeological biometric studies (Harbers *et al*., 2020; Pelletier *et al*., 2022), the 'traditional' collection of linear measurements of skeletal elements continues to provide fundamental information for a better interpretation of human management of animals (e.g., Albarella, 2002; Salvagno & Albarella, 2017; Trentacoste *et al*., 2018, 2021). Yet, biometry is challenged by the high degree of fragmentation of skeletal elements when considering zooarchaeological material from prehistoric sites, especially those related to Mesolithic and Palaeolithic. In these contexts, the systematic recovery of within-bone fats by both humans and large carnivores is indeed a critical factor for bone integrity. As a result, skeletal elements are often reduced to fragments of a few centimetres (see for instance Boscato & Crezzini, 2012; Crezzini *et al*., 2016; Boschin, 2020; Spagnolo *et al*., 2020 for Italy). This implies the presence of a large number of isolated teeth, and a sharp reduction in the amount of postcranial elements available for measurement (e.g. epiphyses). The biometric significance of isolated teeth then faces a number of problems. Firstly, the sample of measurable teeth is always smaller than the total, as some of them are fragmented or not completely identifiable from an anatomical point of view. In fact, in many cases it is not possible to distinguish between certain molars, while in equids it is often not even possible to distinguish certain molars from certain premolars. In addition, in bovids the accurate measurement of tooth size may be prevented by the deposition of cementum. Moreover, some standard measurements are taken at the occlusal surface (Driesch, 1976), the size of which may vary with age. These latter problems can make data collected by different scholars scarcely comparable when, for instance,

the level of abrasion of each measured tooth is not given. As for the postcranial elements, their scarcity makes it often necessary to merge data from different anatomical districts, thus implying the use of biometric standards and logarithmic ratios, as proposed by various authors (see Albarella, 2002 for a synthesis). In the selection of measurable bones within the appendicular skeleton, the above-mentioned problems affecting Palaeolithic assemblages are compounded by the presence of elements lacking ossification centres (carpals and tarsals), as well as elements whereby the epiphyses fuse early (e.g., proximal metapodials). It is hence difficult to determine whether some of these elements belong to adult individuals who are already fully developed or rather individuals who still have some room to increase their body size. From this point of view, it must be emphasised that fragmentation does not allow the analysis of length measurements on a large scale, thus bringing the focus to width measurements. However, while length growth appears to cease with the fusion of the epiphyses, width growth may continue (Payne & Bull, 1988). Taking these issues into account, the aim of this work is to evaluate width measurements of ungulate postcranial bones from two Late Pleistocene sites of southern Italy, to identify reliable datasets for inferring changes in large mammal body size during the last glacial cycle and discuss their validity from a methodological perspective.

MATERIALS AND METHODS

The specimens analysed in this work come from Grotta Paglicci (Apulia), and Grotta della Cala (Campania) (Figure 1). At Grotta Paglicci, apart from evidence dating back to the Middle Palaeolithic, the Upper Palaeolithic sequence ranges from the Aurignacian to the Final Epigravettian (Palma di Cesnola, 2004; Ronchitelli *et al*., 2015; Borgia *et al*., 2016). The sample from this site consists of remains of wild horse (*Equus ferus*), aurochs (*Bos primigenius*) and ibex (*Capra ibex*). The remains come from the early Epigravettian Stratigraphic Units 16 and 10, dated to about 20 and 18 ka BP, respectively. The faunal remains were accumulated in the cave by humans (Boschin *et al*., 2018; Boschin, 2019).

Grotta della Cala is another reference site for the Italian Upper Palaeolitic: its sequence, starting from the Mousterian, covers Uluzzian, Protoaurignacian, Gravettian, Epigravettian, Mesolithic and other Holocene phases (Palma di Cesnola, 2001; Moroni *et al*., 2016; Martini *et al*., 2018; Rossini *et al*., 2025). The sample from this site consists of remains of red deer (*Cervus elaphus*) from layer M (evolved Epigravettian, 19-16 ka cal BP).

Artiodactyl carpal and tarsal bones (except for talus, calcaneum and os centrotarsale) were measured following Boessneck *et al*. (1963). All other bones were measured following Driesch (1976). Horse bones were measured following Eisenmann *et al*. (1988). To make the comparison more reliable, only width measurements were considered, even where length and thickness measurements were available. The high degree of fragmentation at both sites led to few complete bones (usually basipodium and some phalanges). This resulted in many isolated epiphyses being found. Bone measurements were then divided into two groups:

- Group 1: measurements of bones that could still have increased in size. It includes the elements without ossification centres (for instance almost all carpals and tarsals) and those epiphyses that fuse early (distal scapula, distal humerus, proximal radius, proximal metacarpus and metatarsus, distal phalanges 1 and 2).
- Group 2: measurements of bones that should belong to individuals with little room for growth available. It includes the other measures (proximal humerus, distal radius, femur, tibia, calcaneum, distal metacarpal and metatarsal, proximal epiphysis of phalanx 1 and 2).

In some cases, measurements from the first group were included in the second one: an example is provided by the measurement of the proximal epiphysis of a radius with the distal epiphysis well ossified but not measurable due to fragmentation. In this case, the element we are dealing with does not have large margins for growth. The logarithmic ratio was used to assess the variability of the measurements within the two groups with respect to reference standards (Payne & Bull, 1988). To evaluate the dimensional variability of the aurochs, the measurements of the skeleton of a domestic cow from the osteological reference collection of the Research Unit of Prehistory and Anthropology at the DSFTA of the University of Siena were used as a standard. The specimen is a Maremmana hybrid that has lived in the wild. For the first and the second phalanges, the aver-

FIGURE 1
Sites' location.

age of the measurements of all 8 phalanges of the complete skeleton was used. As a standard for the horse, the averages of bone measurements of 20 individuals (males and females in equal proportion) of *Equus przewalskii* made available by Vera Eisenmann were considered (data from: http://www.vera-eisenmann.com). For the red deer, the standard used consisted of the averages of measurements of individuals from the Neolithic site of Ölkam, Austria (Schmitzberger, 2001). The standard used for the ibex comprised the measurements of current male individuals published by Fernández & Monchot (2007). Data processing and Mann-Whitney test for statistical significance were performed using PAST software (Hammer *et al*., 2001). Datasets are available in the Supplementary Materials.

RESULTS

Of the five datasets analysed, the horse and ibex samples from layer 10 of Grotta Paglicci are low in number (17+15 and 11+16 specimens respectively). Figure 2 shows the comparison of the biometric data for each species with the respective standard. In the case of the aurochs, the horse (layer 10) and the red deer, Group 1 presents the lowest extremes in value distribution. This is not the case for the ibex, but this result may be due to the low number of finds. In two cases (aurochs and horse - layer 10) the variability is much higher, and Group 1 also contains the highest values. This last finding is not surprising, as some of the elements included in Group 1 are certainly bones of adult individuals that have reached their maximum body size. In three cases, using a Mann-Whitney test,

the difference between the medians is significant, although sometimes borderline (aurochs: p=0.03; horse: p=0.05; red deer: p=0.05). Although the datasets of the ibex look different, the variation between their medians is not significant (p=0.15). Once again, this could be due to the low number of observations. The most interesting case emerging from Figure 2 is that of the horse from layer 16 of Grotta Paglicci: in this case the distribution of values between Group 1 and Group 2 is very similar and the medians do not differ significantly (p=0.8). The results obtained for the horse population of layer 16 are consistent with the distribution of individuals by age classes, since in this layer deciduous or non-abraded permanent teeth represent 45.6% of the total, whereas in layer 10 only 23.4% belong to this category (Boschin, 2013). This suggests that the higher incidence of young individuals in layer 16 may lead to an overrepresentation of crossover cases and thus a harder separation between the groups, in contrast to layer 10 where the distinction is clearer.

DISCUSSION AND CONCLUSIONS

The aim of this work is to resume, through the discussion of new data, the problem of finding reliable post-cranial anatomical elements to be used in biometric analyses when bone remains are extremely fragmented. As other authors have pointed out (e.g., Payne & Bull, 1988), it is clear that certain anatomical parts have greater margins for growth during life and may therefore give an inaccurate estimate of adult body size within a population. The importance of the choice of anatomical elements to be relied upon becomes clear when our data are used to test the shift in horse size at Grotta Paglicci between layer 10 and layer 16. Indeed, the two datasets have different distributions, and a significant variation in the median values would result from merging Group 1 and Group 2 (p=0.002). Using only the data from Group 2, which can be considered more reliable based on our results, there is no difference in the distribution of values, and the medians do not differ (p=0.16). Another interesting aspect lies in the combination of age-at-death data with the biometric ones: as observed for the horse in layer 10 of Grotta Paglicci, the lower the number of young individuals, the less significant the difference between Group 1 and Group 2, and thus the greater the reliability of Group 1 values.

As a general assessment of the results obtained, all analysed populations refer to extremely late phases of the Last Glacial Maximum (Paglicci - layer 16) or to phases of the early Late Glacial (Paglicci - layer 10 and Cala - layer M). The horses tend to be larger than the average size of the reference population (*E. przewalski*), the latter consisting of both male and female individuals. As far as the aurochs are concerned, we are faced with individuals tending to be larger than the standard (although not all of them). The aurochs appear to be comparable in size to the individuals from MIS 9 published by Wright

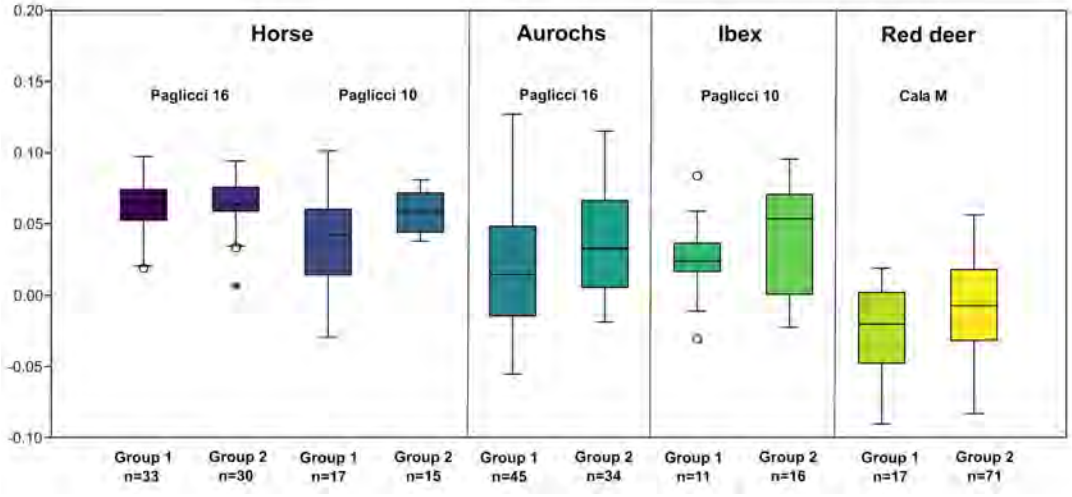

FIGURE 2

Distribution of values from the log-ratio analysis in the considered populations.

& Viner-Daniels (2015), although they do not reach the larger sizes. On the contrary, they seem to tend to be larger in size than Holocene individuals from northern Europe published by the same authors, even though some overlap is visible. The data on the ibex show a tendentially higher distribution with respect to the standard. This is striking to note, as the reference population averages are based on males only. Paglicci individuals would therefore be more robust than the current alpine individuals. Finally, the red deer show dimensions comparable to those of the reference standard, which has a Holocene chronology. Despite being thus faunas referable to a cold climatic phase, the red deer in Grotta della Cala do not show the same trend observed, for example, among the ibexes in Paglicci.

The data discussed here represent preliminary results. As stated earlier, the purpose of this work is to keep the debate on the choice of biometric data alive. This contribution can therefore serve as a basis for the collection of further biometric data from other layers of Grotta della Cala and Grotta Paglicci, to observe possible diachronic trends in size variations of individuals and to compare the Tyrrhenian and Adriatic areas of Italy during the last glacial period.

ACKNOWLEDGEMENTS

The authors are grateful to the Soprintendenza ABAP per le Province di Barletta-Andria-Trani e Foggia and to the Soprintendenza ABAP per le Province di Salerno e Avellino for supporting research at sites. The authors also thank prof. A. Ronchitelli and prof. A. Moroni (University of Siena) for making the specimens analysed in this study available.

SUPPLEMENTARY MATERIAL

See supplementary material at https://revistas.uam.es/archaeofauna/article/view/archaeofauna34.1_016

REFERENCES

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 honour of Don Brothwell*: 51-62. Oxbow Books, Oxford.

Boessneck, J.; Jequier, I.P. & Stampfli, H.R. 1963: Seeberg Burgäschisee-Sud, Teil 3, Die Tierreste. *Acta Berniensa 2*, Verlag Stämpfli & Cie, Bern.

Borgia, V.; Boschin, F. & Ronchitelli, A. 2016: Bone and antler working at Grotta Paglicci (Rignano Garganico, Foggia, southern Italy). *Quaternary International* 403: 23–39. DOI:10.1016/j.quaint.2015.11.116.

Boscato, P. & Crezzini, J. 2012: Middle-Upper Palaeolithic transition in Southern Italy: Uluzzian macromammals from Grotta del Cavallo (Apulia). *Quaternary International* 252: 90-98. DOI: 10.1016/j.quaint.2011.03.028.

Boschin, F. 2013: *I macromammiferi epigravettiani di Grotta Paglicci: dati paleoecologici, tafonomici e paleoeconomici inseriti nel contesto Tardoglaciale dell'Italia Meridionale*. Università degli Studi di Siena, Siena.

— 2019: Exploitation of carnivores, lagomorphs and rodents at Grotta Paglicci during the Epigravettian: The dawn of a new subsistence strategy? *Journal of Archaeological Science: Reports* 26: 101871. DOI: 10.1016/j.jasrep.2019.101871.

— 2020: Holocene macromammal remains from Grotta dell'Edera/Stenašca, Trieste Karst (excavations in 1990–2001). *Arheološki vestnik* 71: 321–357; DOI: 10.3986/AV.71.11 321.

Boschin, F.; Boscato, P.; Berto, C.; Crezzini, J. & Ronchitelli, A. 2018: The palaeoecological meaning of macromammal remains from archaeological sites exemplified by the case study of Grotta Paglicci (Upper Palaeolithic, southern Italy). *Quaternary Research* 90: 470-482. DOI:10.1017/qua.2018.59.

Boschin, F.; Bernardini, F.; Pilli, E.; Vai, S.; Zanolli, C.; Tagliacozzo, A.; Fico, R.; Fedi, M.; Corny, J.; Dreossi, D.; Lari, M.; Modi, A.; Vergata, C.; Tuniz, C.; Moroni, A.; Boscato, P.; Caramelli, D. & Ronchitelli, A. 2020: The first evidence for Late Pleistocene dogs in Italy. *Scientific Reports* 10: 13313. DOI: 10.1038/s41598-020-69940-w.

Crezzini, J.; Boscato, P.; Ricci, S.; Ronchitelli, A.; Spagnolo, V. & Boschin, F. 2016: A spotted hyaena den in the Middle Palaeolithic of Grotta Paglicci (Gargano promontory, Apulia, Southern Italy). *Archaeological and Anthropological Sciences* 8: 227–240. DOI: 10.1007/s12520-015-0273-0

Davis, S.J.M. & Mataloto, R. 2012: Animal remains from Chalcolithic São Pedro (Redondo, Alentejo): evidence for a crisis in the Mesolithic. *Revista Portuguesa de Arqueologia* 15: 47-85.

Driesch, A. von den 1976: *A guide to the measurement of animal bones from Archaeological Sites*. Peabody Museum, Harvard University, Cambridge.

Eisenmann, V.; Alberdi, M.T.; De Giuli, C. & Staesche U. 1988: Volume I: Methodology. In: Woodburne, M. & Sondaar, P. (eds.): *Studiyng Fossil Horses, Collected Papers after the "New York International Hipparion Conference, 1981"*. E.J. Brill, Leiden.

Fernández, H. & Monchot, H. 2007: Sexual Dimorphism in Limb Bones of Ibex (*Capra ibex* L.): Mixture Analysis Applied to Modern and Fossil Data. *International Journal of Osteoarchaeology 17*: 479–491. DOI: 10.1002/oa.876.

Hammer, Ø.; Harper, D.a.t. & Ryan, D.P. 2001: Past: Paleontological Statistics Software Pakage for education and data analysis. *Paleontologia Electronica* 4(1): 1-9.

Harbers, H.; Neaux, D.; Ortiz, K.; Blanc, B.; Laurens, F.; Baly, I.; Callou, C.; Schafberg, R.; Haruda, A.; Lecompte, F.; Casabianca, F.; Studer, J.; Renaud, S.; Cornette, R.; Locatelli, Y.; Vigne, J-D.; Herrel, A. & Cucchi, T. 2020: The mark of captivity: plastic responses in the ankle bone of a wild ungulate (Sus scrofa). *Royal Society Open Science* 7: 192039. DOI: 10.1098/rsos.192039.

Martini, I.; Ronchitelli, A.; Arrighi, S.; Capecchi, G.; Ricci, S.; Scaramucci, S.; Spagnolo, V.; Gambassini, P. & Moroni, A. 2018: Cave clastic sediments as a tool for refining the study of human occupation of prehistoric sites: insights from the cave site of La Cala (Cilento, southern Italy). *Journal of Quaternary Science* 33: 586-596. DOI: 10.1002/jqs.3038.

Moroni, A.; Boscato, P.; Allevato, E.; Benocci, A.; Di Bella, F.; Di Pasquale, G.; Favilli, L.; Manganelli, G. & Gambassini, P. 2016: The Mesolithic occupation at Grotta della Cala (Marina di Camerota - Salerno - Italy). A preliminary assessment. *Preistoria Alpina* 48: 171–182.

Palma Di Cesnola, A. 2001: *Le Paléolithique supérieur en Italie*, Série 'Préhistoire d'Europe', 9. Jérôme Millon, Grenoble.

— 2004: La sequenza stratigrafica della Grotta. In: Palma di Cesnola, A. (ed.): *Paglicci. L'Aurignaziano e Il Gravettiano Antico*: 21-25. Claudio Grenzi Editore, Foggia.

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* II (1-2): 27-66.

Pelletier, M.; Kotiaho, A.; Niinimäki, S. & Salmi, A-K. 2022: Impact of selection and domestication on hindlimb bones of modern reindeer populations: Archaeological implications for early reindeer management by Sámi in Fennoscandia. *Historical Biology* 34: 805-820. DOI: 10.1080/08912963.2021.1947268.

Ronchitelli, A.; Mugnaini, S.; Arrighi, S.; Atrei, A.; Capecchi, G.; Giamello, M.; Longo, L.; Marchettini, N.; Viti, C. & Moroni, A. 2015: When technology joins symbolic behaviour: the Gravettian burials at Grotta Paglicci (Rignano Garganico - Foggia -Southern Italy). *Quaternary International* 359: 423–441. DOI:10.1016/j.quaint.2014.08.038.

Rossini, M.; Tomasso, A; Boschin, F.; Martini, I.; Crezzini, J.; Dominici, C.; Moroni, A. 2025: Early Epigravettian backed pieces from layer O of Grotta della Cala (Southern Italy). A techno-typological and use-wear integrated approach. Journal of Archaeological Science: Reports 62: 105046. DOI: 10.1016/j.jasrep.2025.105046

Salvagno, L. & Albarella, U. 2017: A morphometric system to distinguish sheep and goat postcranial bones. *PLoSONE* 12(6): e0178543. DOI: 10.1371/journal.pone.0178543.

Schmitzberger, M. 2001: Die Tierknochen aus der mittelneolithischen Kreisgrabenanlage Ölkam (Oberösterreich). *Jahrbuch des Oberösterreichischen Musealvereins* 146/I: 43-86 + Ergänzungsheft.

Spagnolo, V.; Marciani, G.; Aureli, D.; Martini, I.; Boscato, P.; Boschin, F. & Ronchitelli, A. 2020: Climbing the time to see Neanderthal behaviour's continuity and discontinuity: SU 11 of the Oscurusciuto Rockshelter (Ginosa, Southern Italy). *Archaeological and Anthropological Sciences* 12:54. DOI: 10.1007/s12520-019-00971-9.

Trentacoste, A.; Nieto-Espinet, A. & Valenzuela-Lamas, S. 2018: Pre-Roman improvements to agricultural production: Evidence from livestock husbandry in late prehistoric Italy. *PLoSONE* 13(12): e0208109. DOI: 10.1371/journal.pone.0208109.

Trentacoste, A.; Nieto-Espinet, A.; Guimarães, S.; Wilkens, B.; Petrucci, G. & Valenzuela-Lamas, S. 2021: New trajectories or accelerating change? Zooarchaeological evidence for Roman transformation of animal husbandry in Northern Italy. *Archaeological and Anthropological Sciences* 13: 25. DOI: 10.1007/s12520-020-01251-7.

Wright, E. & Viner-Daniels, S. 2015: Geographical variation in the size and shape of the Europeanaurochs (*Bos primigenius*). *Journal of Archaeological Science* 54: 8-22. DOI: 10.1016/j.jas.2014.11.021.