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Quantitative classification of metapodial bones of *Ursus spelaeus* and *Ursus arctos* from Northwestern Iberia using multivariate analysis

D. Estraviz-López[1, 2], A. García-Vázquez[3, 4] & A. Grandal-D'Anglade[4]

[1] Departamento de Ciências da Terra, FCT-NOVA, 2829-516, Caparica, Portugal.
[2] Museu da Lourinhã, Rúa João Luis de Moura, Nº 95, 2530-158, Lourinhã, Portugal.
[3] ArchaeoScience#RO Platform, Research Institute of the University of Bucharest (ICUB), 90-92 Sos. Panduri, 5th District, Bucharest, Romania.
[4] Instituto Universitario de Xeoloxía, Universidade da Coruña. ESCI, Campus de Elviña, 15071, A Coruña, Spain.

Corresponding author:
D. Estraviz-López
estravizlopez.dario@gmail.com

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Abstract

Cave and browns bears lived sympatrically during the Late Pleistocene in Northwestern Iberia. Their bones have been easily identified qualitatively, but new evidences regarding the hybridization of both species made a quantitative approach necessary, in order to detect hybrids with intermediate morphologies. In this work we use measurements of 273 metapodials of both species to classify them in one of the two with multivariate statistics. We found that it was indeed possible to differentiate them through their metapodials, as previous studies have shown, but we also found that metatarsals discriminate both species better than metacarpals, unlike previous studies with multivariate morphometrics. Only one specimen of the 273 analyzed, which was qualitatively classified as *U. spelaeus*, is consistently placed as *U. arctos*. Our results open the gates for finding putative hybrids in the future with this method and allow us to better classify previously known material.

Keywords: Ursus spelaeus, Ursus arctos, metapodial bones, multivariate statistics, Pleistocene.

1. Introduction

During the Late Pleistocene two different bear species occurred in the Northwestern Iberian Peninsula; one was the cave bear (*Ursus spelaeus* Rosenmüller, 1794) and the other was the still extant brown bear (*Ursus arctos* Linnaeus, 1758) (Estraviz -López & Grandal-d'Anglade, 2017). The differences between both are well established, because given the tendency of both species to hibernate in caves, they have left behind immense amounts of fossil bones that have been studied during decades with a great amount of techniques; from isotopic and DNA analysis (García Vazquez, 2015; Barlow *et al*., 2018) to morphometric ones (Kurtén, 1976; Figueirido & Van Heteren, 2019). Besides differences in the skull and dentition, in general the postcranial bones of the cave bear are more robust and with more marked muscular insertions than the ones in the brown bear, therefore it has been possible for researchers to qualitatively separate the remains of both species in the past (Kurtén, 1976).

But recent discoveries point towards a more complicated scenario; the possible presence of hybrids between *U. spelaeus* and *U. arctos* with intermediate morphologies needs to be addressed not only from a genetic point of view, but also a morphological one (Barlow *et al*., 2018). How well do the morphologies of the two species from Northwestern Iberia separate from each other using quantitative methods? Is it possible to detect hybrids with such intermediate morphologies?

2. Material and methodology

In order to solve these questions it was decided to use the bear metapodials, given that they were available in numbers and that they have been used in the past in similar studies about the taxonomy of cave bears (Baryshnikov & Puzachenko, 2017). The *U. spelaeus* material was recovered in three Galician caves: Eirós, with an age of about 35.000 YBP; Liñares with and age between 50.000 and 35.000 YBP and A Ceza with an age between 43.000 and 37.000 YBP (Fortes *et al*., 2016). The *U. arctos* material was of Holocene age, although some specimens used are Late Pleistocene in age (García Vázquez, 2015).

Our analysis included 273 metapodial bones, 198 classified as *U. spelaeus* and 75 of *U. arctos* (see

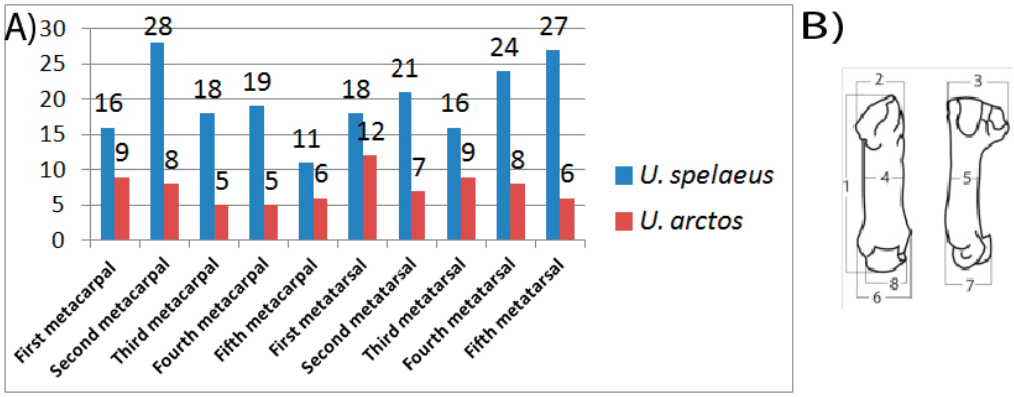

Fig. 1. -A-Distribution of the 273 measured specimens by metapodial bone and species ; B-Measurements for the metapodial bones according to the system of Tsoukala & Grandal-d'Anglade (2002) in dorsal (left) and lateral (right) views.

Fig. 1A for the number of specimens for each bone and species), the disparity in the numbers of the two species is caused by the rarity of the second species relative to the first one (García Vázquez, 2015). They have been measured following the system of measurements for ursids by Tsoukala & Grandal-d'Anglade (2002), and are stored and the University Institute of Geology of the University of A Coruña (Spain). All of the used bones are complete, so all of the measurements from the system (Fig. 1B) could be recorded, although the transversal diameter of distal articular surface was not recorded in the most abundant *U. spelaeus* sample of Eirós cave (because the after mentioned system was not published when they were measured) and therefore the measurement was not took into account in the entire sample. The measurements of the *U. spelaeus* from Eirós cave and Liñares were recovered from Grandal-d'Anglade

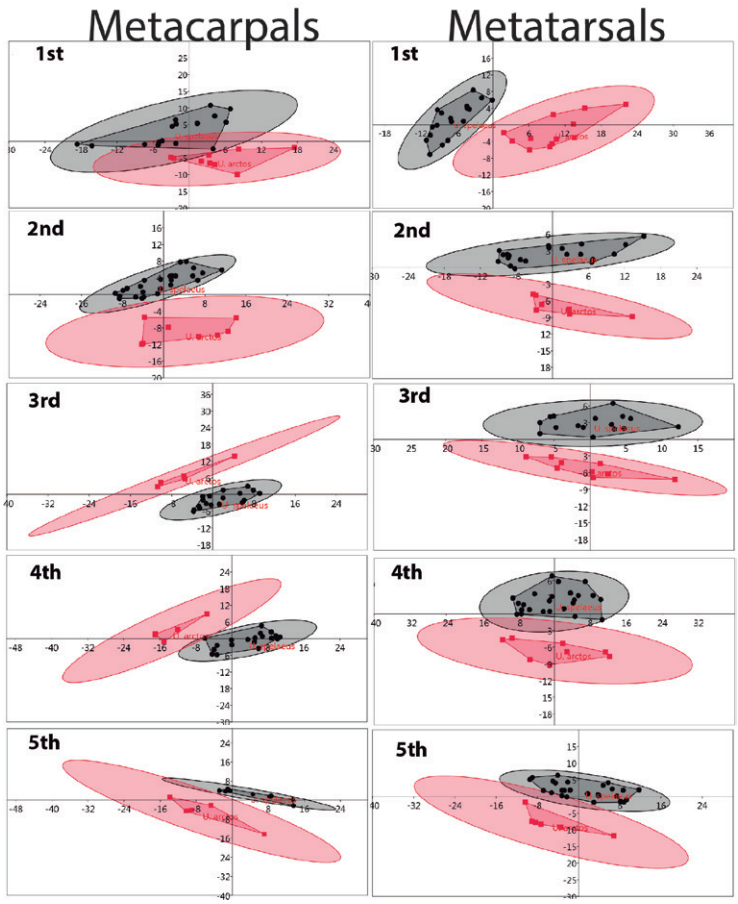

Fig. 2. -Scatter plot of the principal component analysis for metapodials of Northwestern Iberia Late Pleistocene bears. *Ursus spelaeus* is marked in black and *Ursus arctos* in red. The first principal component is always the vertical axis and the second is the horizontal one. 95% ellipses are drawn, as well as convex hulls around the morphospace for each species.

	First metacarpal	Second metacarpal	Third metacarpal	Fifth metacarpal
From *U. spelaeus* to *U. arctos*	**EI-1087**		EI-1055	
From *U. arctos* to *U. spelaeus*	TA-201	Modern 2		SH5-96-008

Fig. 3. -Specimens of *U. spelaeus* and *U. arctos* that were classified by the discriminant analysis in different groups than the given ones. The specimen marked in bold is the only one that appears consistently in other group other than the given one.

(1993) and López-González (2003) respectively; the specimens of cave bear from A Ceza cave were measured for this work. All the measurements for *Ursus arctos* were recovered from García Vázquez (2015). Our database comprised a total of 1911 individual measurements coming from 3 caves of NW Iberia for *U. spelaeus* and 17 caves of the same area for U. arctos, which were analyzed separately for each bone using the software PAST v. 3.14. First, a Principal Component Analysis (PCA) was carried out for each bone in order to obtain a visual representation of the groups, with 95% ellipses drawn around them. Then a discriminant analysis was performed using the same program in order to find out how well the software could classify the specimens into the given groups and identify the specimens that were classified by the program in different groups than by the authors in base of qualitative characters.

3. Results

After running the PCA, the first two principal components together explain between 87% (third metacarpal) and 96% (fifth metacarpal and second metatarsal) of the variability of the sample, with an average of 91.2% for the metacarpals and 93% for the metatarsals (Fig. 2). The first component is correlated in most of the metapodials with the general dimensions of the bone, and the second component is in most cases inversely correlated with the length and positively with the other parameters, reflecting the relative robustness of bone. As we can see in Fig. 3, the best-separated bones are the third metacarpal and the first and third metatarsals. The first metacarpal is the less selected element, with the morphospaces almost overlapping.

The discriminant analysis classified 100% of the metatarsals in the given groups. The metacarpals were classified in the same given groups 97% of the times. In figure 3 we have the specimens that changed groups, only one of them (EI-1087, a first metacarpal classified as *U. spelaeus* from Eirós cave) changed groups both with normal and jackknife methods, the others only in the later.

4. Discussion and conclusions

As the graphics and discriminant analysis show, it is possible to differentiate quantitatively with multivariate statistics between the metapodials of the two ursid species, especially with the metatarsals. The first observation agrees with the work by Baryshnikov & Puzachenko, (2017) but the second contradicts their findings, as they found the metacarpals to be more characteristic at specific level.

The appearance of one modern specimen of brown bear between the specimens that changed groups with the use of the jackknife method should make us consider with caution the nature of the other three specimens that were classified in different groups than the original by it. Even if the modern specimen is pathological or an atavism; we should consider that the specimens that change groups only with this method might not be genuine cases or misidentification or hybrids.

EI-1087 is a different case, because it appears consistently classified by the discriminant analysis as *U. arctos* instead of *U. spelaeus*; as it was classified by qualitative characters like overall robustness. It might be interesting to perform a DNA analysis on this specimen in the future.

This work also provide a database that will allow the classification of new specimens, which might be useful for the study of the bears of Portugal, a part of Iberia where only the *U. arctos* has been cited in the Late Pleistocene (Estraviz-López & Mateus, 2019).

More of these studies should be carried with different parts of the skeleton of the bears in order to better understand the differences between *U. arctos* and *U. spelaeus* and detect possible hybrids.

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