Exploring the relationship between mandible morphology and diet in ungulates: a geometric morphometrics approach

Soledad DE ESTEBAN-TRIVIGNO[1], Jesús MARUGÁN-LOBÓN[2], Manuel MENDOZA[3] & Miquel DE RENZI[2]

[1] *Area de Paleontología, ICBiBE, Apdo Oficial 22085, Valencia, 46071, Spain;* [2] *Unidad de Paleontología, Dpto de Biología, UAM, 28049, Cantoblanco, Madrid, Spain;* [3] *Unidad de Ecología y Geología, UM, Campus de Teatinos s/nº, Málaga, 29071, Spain*

Four factors rule the organic form: phylogenetic legacy, fabrication, function and effective environment (Seilacher, 1991). Function includes ecomorphology, which has produced a lot of research. These studies have commonly two goals: on the one hand, to understand how form and function link each other, and on the other hand, to predict from the form of fossil remains some ecological character of their extinct species.

In this way, the skull-mandible complex in mammals has been paid much attention to. There are many papers on ecomorphology dealing with the mandible from a functional or morphometric point of view. Morphometric analyses commonly correspond to traditional metrics (i.e. distances or angles), which are thereafter analysed with univariate or multivariate statistics (Mendoza et al., 2002). While certainly useful, traditional metrics are only capable to underscore certain aspects of form variation. The more recently developed techniques of landmark-based geometric morphometrics provide a different perspective. They allow capturing the geometry of the whole structure under study, and one can only discern resultant variation after analyses have been performed. These shape differences are captured mathematically with standard multivariate statistical analyses (Rohlf and Marcus, 1993).

Although geometric morphometric is becoming a customary methodology in morphological sciences, few attempts have been carried out in order to analyse the relationship between diet and shape in vertebrates (Adams and Rohlf, 2000). In this work we explore this relationship in the ungulate mandible using geometric morphometric methods, which we thereafter compare with traditional morphometric results.

We photographed 63 ungulate mandibles in lateral view (each representing an extant different species) and a series of 14 homologous landmarks were designed to homogeneously capture their geometry. The landmark configurations were processed using common Procustes analysis, and shape differences were visualised using the thin plate spline (for detailed description of the methods see also Zelditch et al., 2004). Ordination methods (relative warps, essentially a principal components analysis of the weight matrix including the uniform component; Bookstein, 1991; Rohlf, 1993) were used to explore directions of greater shape variance. A canonical variates analysis (CVA) was also performed to test the possible discrimination between trophic groups in association with their mandible shape.

The canonical variates analysis shows that diet discrimination can be solved with shape variables. However, traditional morphometrics could seem to be more adequate to make inferences in the fossil record due the straightforward way to apply it. Nevertheless, the results obtained from shape analysis of ungulates mandibles shows a higher explicative power. It allow us to understand the mandible changes as a whole, and to identify patterns of change. Anyway, it would be suggestive to combine their operability with other statistic-geometric techniques, such as Partial Least Squares, in order to gain further insights on ungulate ecomorphology, as well as to include more species in the analysis.

References

Adams, D.C. & Rohlf, F.J. 2000. PNAs, 97 (8), pp: 4106-4111.

Bookstein, F.L. 1991. "Morphometric Tools for Landmark Data: Geometry and Biology". Cambridge University Press.

Mendoza, M., Janis, C.J. & Palmqvist, P. 2002. Journal of Zoology, 258, pp: 223-246.

Rholf, F.J. 1993. In: "Contributions to morphometrics." Marcus et al. (eds.). Museo Nacional de Ciencias Naturales.

Rohlf, F.J. and Marcus, L.F. 1993. Trends in Ecology and Evolution, 8 (4), pp: 129-132.

Seilacher, A. 1991. In: "Constructional morphology and evolution". Shcmidt-Kittler, N. & Vogel, K. (eds.)

Zelditch, M.L., Swiderski, D.L., Sheets, H.D. & Fink, W.L. 2004. "Geometric morphometrics for biologists. A primer". Elsevier.