Reconstructing habitat type and mobility patterns of Rangifer tarandus during the Late Pleistocene in Southwestern France: an ecomorphological study

Ana Belén Galán López, Ariane Burke, Sandrine Costamagno

EMORPH PROJECT

Reconstructing habitat type and mobility patterns of *Rangifer tarandus* during the Late Pleistocene in Southwestern France: an ecomorphological study.

Ana Belén Galán López[1]; Ariane Burke[2];Sandrine Costamagno[3]

1. Centre National de la Recherche Scientifique (CNRS) & Université de Montréal 2. Université de Montréal 3. Centre National de la Recherche Scientifique (CNRS) & Université Toulouse Jean Jaurès

EMORPHPROJECT

INTRODUCTION

The link between seasonal game movements and the season of occupation of human territories during the Magdalenian period (18.000-14.000 cal BP) in South-Western France remains an open question. The EMORPH project proposes an actualistic approach to reconstructing migratory patterns of Palaeolithic reindeer as a means of studying how their migration patterns affected human hunting strategies and socio-economic decisions. This research will allow us to better understand the behaviour of Magdalenian people and identify the precise role of reindeer in their economy.

An animal´s habitat preferences and mobility patterns hypothetically affect their bone density and limb bone morphometry. The goals of this project are twofold: 1) test this ecomorphological hypothesis for a given taxon (*Rangifer tarandus*), establishing a reference sample that includes animals from different habitat types and mobility patterns, and; 2) apply the knowledge gained towards an analysis of archaeological populations. This project will quantify the link between habitat type and mobility and bone density and morphology using Computer Tomography (CT) and geometric morphometry (GMM). The study will focus on reindeer because it is a key prey species in many prehistoric contexts in both Europe and North America. Modern reference samples will be collected in North America, where *Rangifer tarandus* (caribou, aka reindeer) herds still exist in woodland (non-migratory) and tundra (migratory) habitats, making the creation of a referential framework possible.

Once the relationship between habitat, mobility and bone structure has been quantified, the information collected will be applied to faunal assemblages from Upper Palaeolithic archaeological sites in Southwestern France and used to reconstruct prey mobility. Prey mobility, in particular the migration of key species such as reindeer, is thought to influence the seasonal mobility of human predators and affect their hunting strategies. There is a long-standing debate as to the migratory behaviour of reindeer in Western Europe during the Late Pleistocene and its influence on Magdalenian populations. This project will enable us to test whether Magdalenian people were hunting animals which migrated over long or short distances. This information will be used to explore the impact of prey mobility on human mobility, hunting strategies and potentially technological choices.

Finally, the overarching goal of the project is to improve our knowledge about our past and the results are expected to have a significant impact on our understanding of the Magdalenian period.

SAMPLE AND METHODS

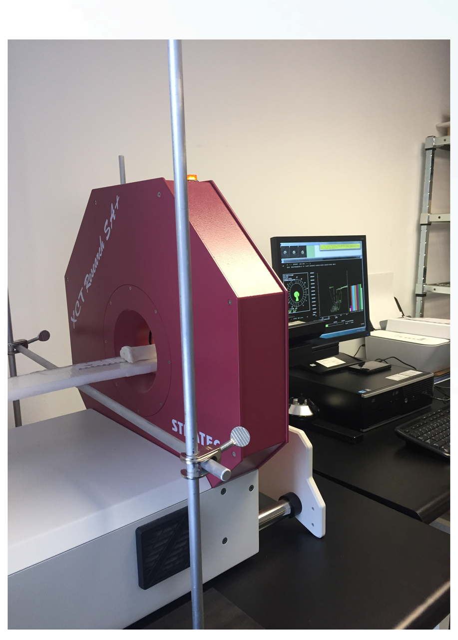
Rangifer tarandus metapodia and phalanges from woodland (non-migratory) and tundra (migratory) settings will be use to create a referential framework to study ecomorphological differences between animals from different biomes and with different mobility patterns. To date we have collected 15 metatarsals, 14 metacarpals and 35 phalanges from non migratory ecotypes, and 31 metatarsals, 37 metacarpals and 50 phalanges from migratory settings.

The impact of habitat type and mobility on bone density and morphology of reindeer living in different habitats will be studied using Computer Tomography (CT), a non-invasive technique. This technique will be used to obtain detailed images of the cross-sectional area (virtual cross-sections) and visualise the internal structure of the bone, assessing its robusticity at five locations along the diaphysis for metapodia (20%, 35%, 50%, 65% and 80%) and one (50%) for phalanges.

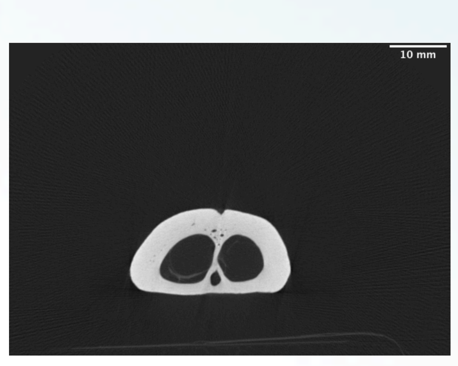
Once cross-sectional images are obtained, they will be analysed using Geometric morphometrics (GMM) and Cross-Sectional Geometry (CSG).

GMM will be used to quantify the size and overall shape of the sections. With quantified geometric information about shape differences we can examine ecomorphological patterns and test morphological differences between populations in a highly effective, reproducible, accurate and statistically powerful way (Viscosi and Cardini, 2011).

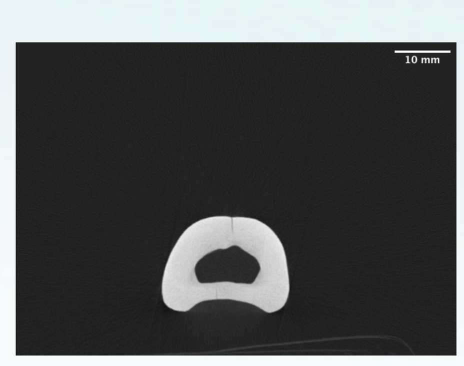
The calculation of Cross-Sectional Geometry (CSG) properties will allow us to interpret skeletal morphology within the context of the mechanical environment (Ruff, 2008) and identify how these properties might reflect mobility patterns (Demes and Jungers, 1993).



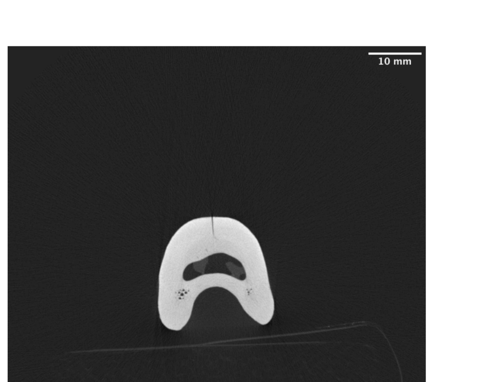
CT scanner



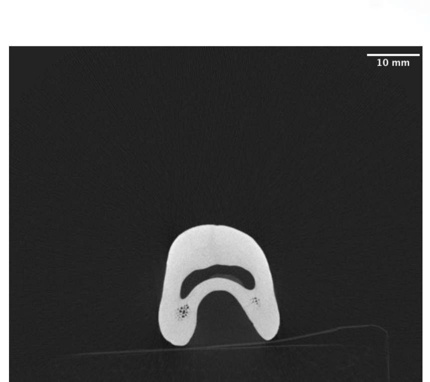
20%



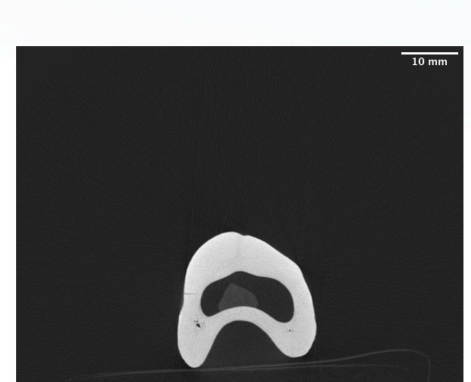
35%



50%



65%



80%

Furthermore, being aware that it is not always is possible to have access to a CT scanner, linear measurements are also included in this project.

GMM analysis of the resulting images will be obtained using ImageJ (Schindelin, et al. 2012), to set landmarks and obtain geometric coordinates. Then, the data collected will be transported, rotated and scaled through a Generalised Procrustes Analysis (GPA) in MorphoJ (Klingenberg, 2011). Next, a PCA analysis of landmark coordinates will be conducted to examine changes in shape and morphological differences and a Multivariate Analysis of Covariance (MANCOVA) will be used to statistically test for differences in mean shape as a function of ecological predictors such as vegetation type, substrate and mobility patterns.

Cross-Sectional Analysis will be carried out in ImageJ (Schindelin, et al. 2012) using the plugin BoneJ to obtain cross sectional properties (standardized prior to analysis). Then, in order to quantify and test differences between groups, t-tests will be applied in R (R Development Core Team, 2008).

Finally, linear measurements will be scaled prior to analysis and a Principal Component Analysis (PCA) will be carried out in R. Once the most effective variables are identified, a logistic regression (LR) will be performed to determine which variables discriminate between migratory and non-migratory settings.

The referential framework created from contemporary reindeer will be put into practice during the second phase of the project, using archaeological material from Southwestern France, allowing us to address on-going debates about prey mobility and its impact on human mobility patterns during the Upper Palaeolithic.

WHAT WE EXPECT TO FIND

Modern ethological data indicate that reindeer herds adopt different mobility strategies that correlate with habitat type and topography. Long-distance migrations tend to take place in tundra and steppe habitats, while animals living in or near woodlands tend to migrate over much smaller distances (Schaefer *et al*. 2000; Weinstock, 2000; Thomas and Gray, 2002; Courtois *et al*. 2003; Goddard, 2009). The mobility patterns of prehistoric reindeer, therefore, should be predictable if palaeoenvironmental reconstructions allow us to identify whether or not they lived in more open or more wooded environments. Palaeolithic environment does not offer a current analogue and in consequence it is not possible to infer reindeer mobility patterns from palaeoenvironmental reconstructions. On the other hand, it has been proven that an animal´s environment influences its' mobility patterns which, in turn, affect bone density and limb bone morphometry as has been demonstrated in several species, e.g., African bovids, cervids or wild horses (Plummer and Bishop, 1994, DeGusta and Vrba, 2003; Bignon et *al*. 2005; Van Asperen, 2010; Curran, 2012) including humans (Stock and Pfeiffer 2004).

Thus, we expect that the postcranial morphology of tundra dwelling and forest dwelling reindeer will reflect differences in adaptation, specifically their migratory behaviour.

The analysis of the ecological preferences of extinct fauna can contribute to reconstructing the paleobiology of Magdalenian hominids in South-Western France. Through the analysis of habitat preferences, we have the potential to advance in our understanding of the ecological context of hominid adaptation and evolution (Bishop, 1999).

ACKNOWLEGMENTS

This project has received funding from the European Union´s Horizon 2020 research and innovation programme under the Grant Agreement 794925.

BIBLIOGRAPHY

Bignon, O., Baylac, M., Vigne, J.D., Eisenmann, V. 2005. Geometric morphometrics and the population diversity of Late Glacial horses in Western Europe (*Equus caballus arcelini*): phylogeographic and anthropological implications. *Journal of Archaeological Science* 32: 375-391.

Bishop LC. 1999. Suid paleoecology and habitat preferences at African Pliocene and Pleistocene hominid localities. In: Schrenk TGBaF, editor. *African Biogeography, Climate Change, & Human Evolution*. New York: Oxford University Press. 496 pp.

Courtois, R., Bernatchez, L., Ouellet, J.P., Breton, L. 2003. Significante of caribou (*Rangifer tarandus*) ecotypes from a molecular genetics viewpoint. *Conservation Genetics* 4: 393-404.

Curran, S. 2012. Expanding ecomorphological methods: geometric morphometric analysis of Cervidae post-crania *Journal of Archaeological Science*, 39: 1172-1182.

DeGusta D, and Vrba E. 2003. A method for inferring paleohabitats from the functional morphology of bovid astragali. *Journal of Archaeological Science* 30(8):1009-1022.

Demes, B., Jungers. 1993. Long bone cross-sectional dimensions, locomotor adaptations and body size in prosimian primates. *Journal of Human Evolution* 25: 57-74.

Goddard, A.D. 2009. Boreal caribou in Northeastern British Columbia. *Peace Region Technical Report:* 1-27.

Hammer, Ø., Harper, D, Ryan, P.D.2001.PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica* 4: 9pp.

Klingenberg, C. P. 2011. MorphoJ: an integrated software package for geometric morphometrics. *Molecular Ecology Resources* 11: 353-357

Plummer, T.W. Bishop, L. C. 1994. Hominid paleoecology at Olduvai Gorge, Tanzania, as indicated by antelope remains. *Journal of Human Evolution* 27: 47-75.

R Development Core Team.2008.R:A language and environment for statistical computing. R Foundation for Statistical Computing,Vienna, Austria. http://www.R-project.org.

Shaefer, J.A., Bergman, C.M., Luttich, S.N. 2000. Site fidelity of female caribou at multiple spatial scales. *Landscape Ecology* 15: 731-739.

Schindelin, J.; Arganda-Carreras, I. & Frise, E. et al. 2012. "Fiji: an open-source platform for biological-image analysis", *Nature methods* 9(7): 676-682

Stock, J. T. and S. K. Pfeiffer .2004. Long bone robusticity and subsistence behaviour among Later Stone Age foragers of the forest and fynbos biomes of South Africa. *Journal Of Archaeological Science* 31(7): 999-1013.

Thomas, D.C., and D.R. Gray. 2002. COSEWIC assessment and update status report on the Woodland Caribou Rangifer tarandus caribou in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa.98 pp.

Van Asperen EN. 2010. Ecomorphological adaptations to climate and substrate in late Middle Pleistocene caballoid horses. *Palaeogeography, palaeoclimatology, palaeoecology* 297:584-596.

Viscosi V, Cardini A .2011. Leaf Morphology, Taxonomy and Geometric Morphometrics: A Simplified Protocol for Beginners. *PLoS ONE* 6(10): e25630.

Weinstock J.2000. Late Pleistocene reindeer populations in Middle and Western Europe, an osteometrical study of Rangifer tarandus. *BioArchaeologica*,3.