Multi-trophic patterns in mammalian joint and bone morphology and their potential for palaeoenvironmental reconstruction

E.E. Sabourin[1], G. A. Macho[1,2]

1 - Archaeology, Environmental Changes & Geo-Chemistry Research Group, Vrije Universiteit Brussel, Brussels, Belgium.
2 - Department of Earth Sciences, University College London, London, United Kingdom

During the Plio-Pleistocene transition, marine sediment records indicate global cooling and aridification across Africa, associated with the expansion of grasslands [1]. This trend disrupted existing ecosystems and exposed biological communities to new selective pressures, particularly affecting locomotor adaptations. However, at regional scales, this pattern may have been more complex, as more covered environments could persist along perennial watercourses, allowing a higher diversity of habitats [2]. For South African hominins habitats, the uncertainties are even greater, bearing in mind that these sites are in the temperate zone and outside the rain shadow of the Intertropical Convergence Zone. Here we test whether studying articular joint morphology across several African mammalian taxa simultaneously may provide information about the regional environmental context in which early hominins evolved and diversified.

Ecomorphological studies are commonly conducted on single mammalian groups or using single morphological traits [3,4]. However, Short et al. [5] demonstrated that the ability to detect ecological relationships between joint morphology and vegetation cover is strengthened when animals from multiple trophic levels are considered simultaneously. In this pilot study, we test if further improvements can be made integrating multiple articular joints from multiple trophic levels

To capture community-wide responses, we combine articular joint measurements from the appendicular skeleton of primates, suids, and carnivorans, representing both primary and secondary consumers. Their morphology are analysed in relation to locomotor repertoires, habitat and climatic conditions, both past and present (using the PastClim package). The morphological material used for our pilot studyis housed at the Royal Museum for Central Africa, Tervuren, Belgium.

Uni and multivariate analyses were carried out and demonstrate that habitat conditions reconstruction can be enhance by multi-pronged approach. Besides, care should be taken when inferring current climate/habitat conditions for morphology and the potential for evolutionary lag to morphological evolution needs be considered when analysing fossil remains. Finally, we discuss how the results will inform our reconstruction of South African hominin habitats.

This study is funded by ERC_101141770_PLIODIS, We thank the Royal Museum for Central Africa, Tervuren and Emmanuel Gilissen and Mathys Rotonda for their support.

We acknowledge the historical extraction of resources from central Africa during European colonisation.

[1] Caley, T., Souron, A., Uno, K.T., Macho, G.A., 2025. Climate and Human Evolution: Insights from Marine Records. Annual Review of Marine Science 17, 23–53. https://doi.org/10.1146/annurev-marine-032223-031306

[2] Negash, E.W., Alemseged, Z., Bobe, R., Grine, F., Sponheimer, M., Wynn, J.G., 2020. Dietary trends in herbivores from the Shungura Formation, southwestern Ethiopia. Proc. Natl. Acad. Sci. U.S.A. 117, 21921–21927. https://doi.org/10.1073/pnas.2006982117

[3] Barr, W.A., 2015. Paleoenvironments of the Shungura Formation (Plio-Pleistocene: Ethiopia) based on ecomorphology of the bovid astragalus. Journal of Human Evolution 88, 97–107. https://doi.org/10.1016/j.jhevol.2015.05.002

[4] Pallas, L., Daver, G., Merceron, G., Boisserie, J.-R., 2023. Postcranial anatomy of the long bones of colobines (Mammalia, Primates) from the Plio-Pleistocene Omo Group deposits (Shungura Formation and Usno Formation, 1967-2018 field campaigns, Lower Omo Valley, Ethiopia). https://doi.org/10.31233/osf.io/bwegt

[5] Short, R.A., McGuire, J.L., Polly, P.D., Lawing, A.M., 2023. Trophically integrated ecometric models as tools for demonstrating spatial and temporal functional changes in mammal communities. Proc. Natl. Acad. Sci. U.S.A. 120, e2201947120. https://doi.org/10.1073/pnas.2201947120

Multi-trophic patterns in mammalian joint and bone morphology and their potential for palaeoenvironmental reconstruction

Eliott Sabourin[1], Gabriele Macho[1, 2]

1 - Archaeology, Environmental Changes & Geo-Chemistry Research Group, Vrije Universiteit Brussel, Brussels, Belgium.

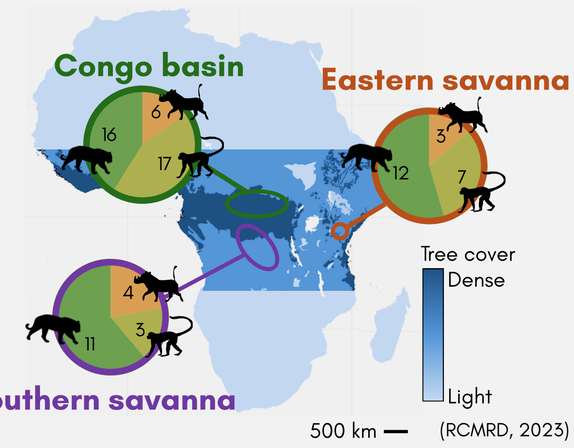
2 - Department of Earth Sciences, University College London, London, United Kingdom

Questions

- Is **ecomorphology** a **reliable tool** to reconstruct past environments?
- Do **clades** respond similarly to environmental/habitat changes?

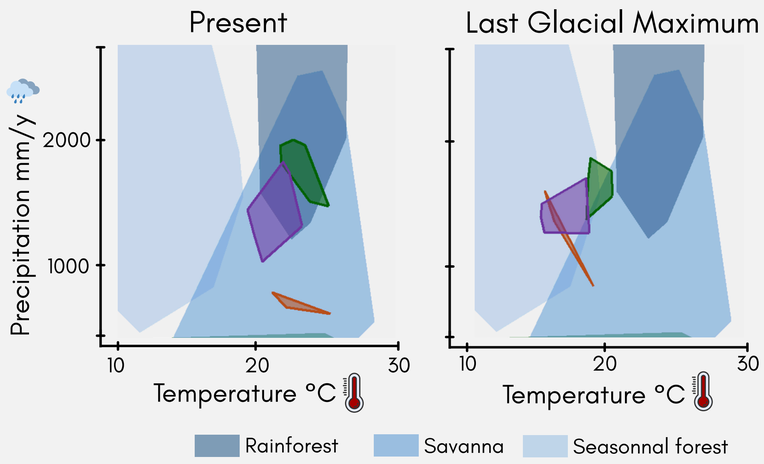
Material and context

Sample



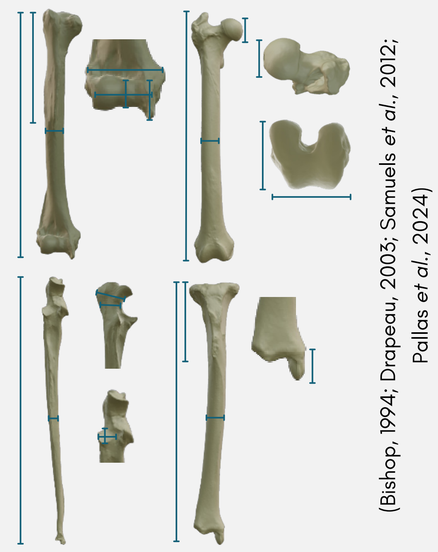
Environment

Modified Whittaker's (1975) biome diagram



- Rainforest expansion in the last 21 000 Ya

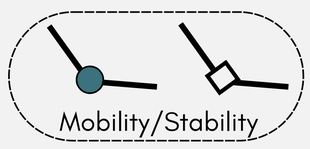
Measurements



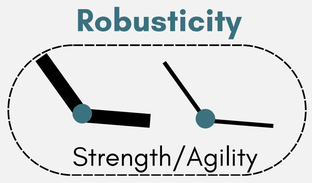
(Bishop, 1994; Drapeau, 2003; Samuels *et al.*, 2012; Pallas *et al.*, 2024)

Capturing functionaly important aspects

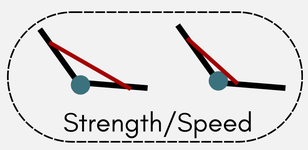
Joint constraint



Robusticity



Muscle lever arm



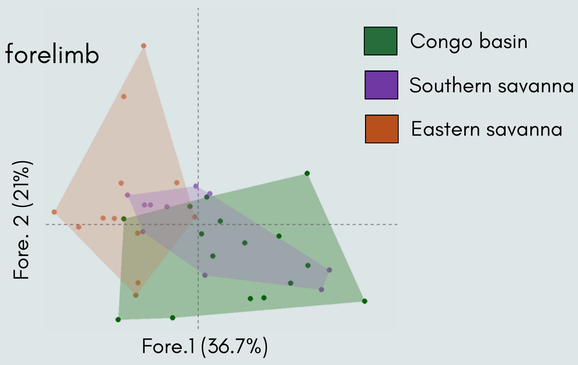
Method

Workflow

1) **PCA** for each of the **limbs**, by **Taxa**

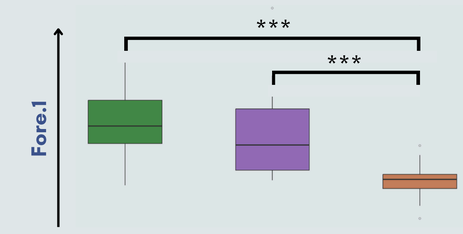
- Summary and description of the morphologies with PC dimensions

Example:
Carnivore's forelimb



2) **Comparison** of the PC dimensions between **habitats**

- Wilcoxon Tests



3) Testing the **relationship** between PC dimensions and **climate**

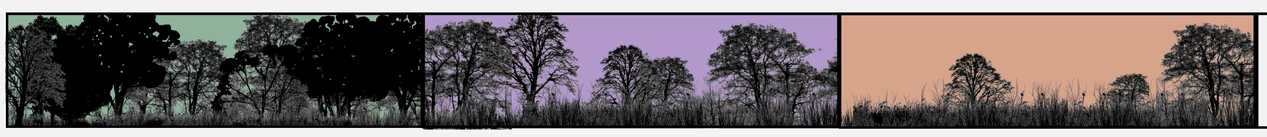
- Linear regressions between PC dimensions and present and LGM climatic variables

Temperature
Temperature seasonality
Precipitation
Precipitation seasonality

(Beyer *et al.* 2020)

Focus on the **R2**

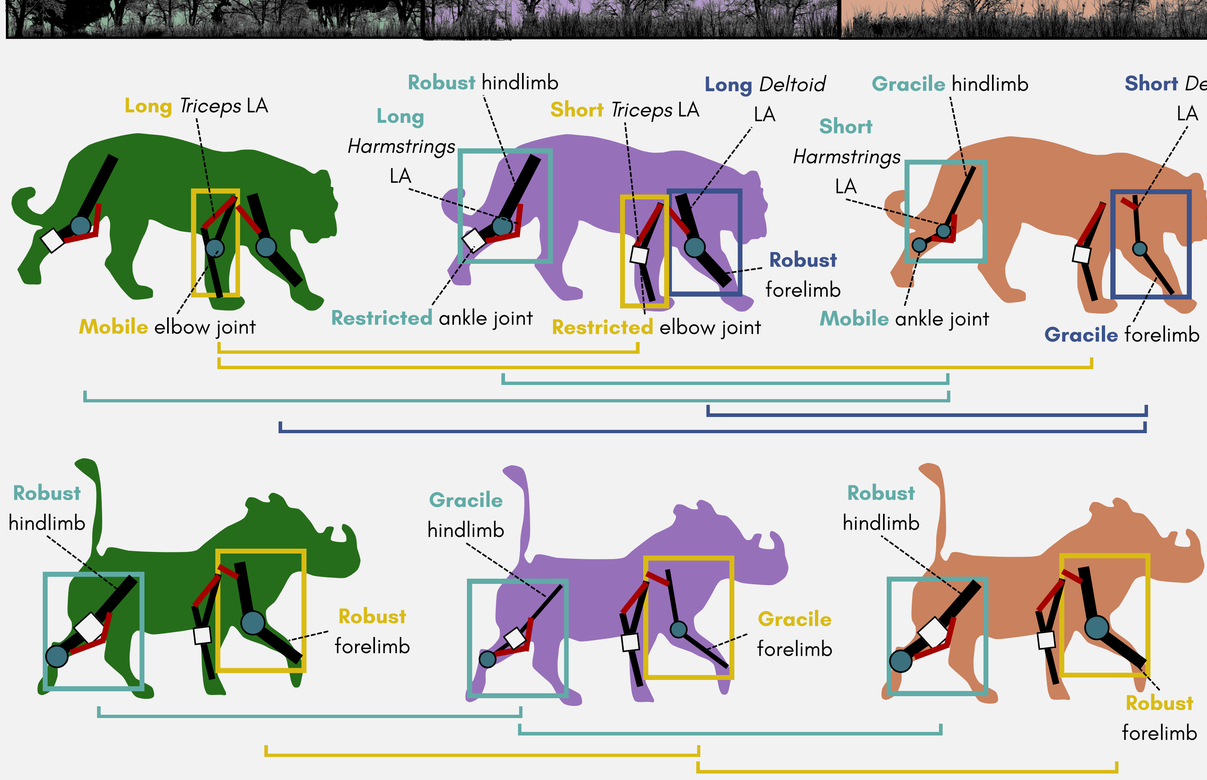
Results

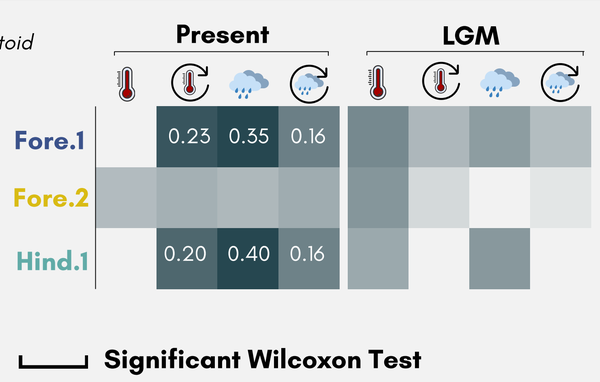


Variance explained by climate
only significant relations

R2 0.25 — 0

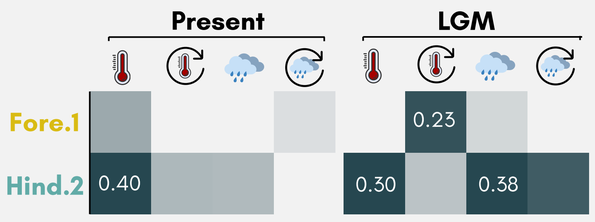
Biological interpretation



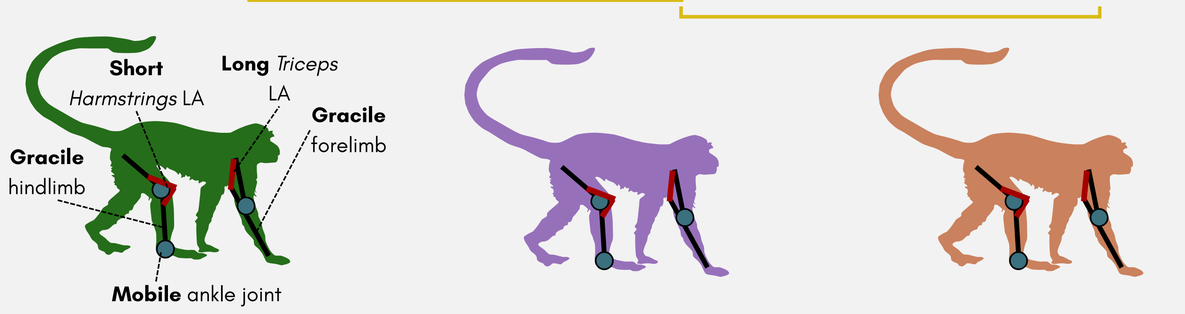


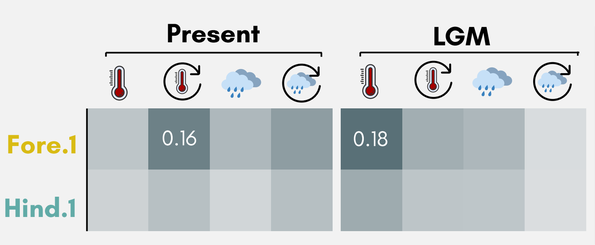
Significant Wilcoxon Test

- **Current closed habitat** carnivores display lengthened muscle lever arm and robust limbs that together with elbow mobility may indicate **climbing abilities**
- **Current open habitat** carnivores display shortened muscle lever arm and gracile limbs that may indicate **cursorial abilities**
- Overall, limb morphology displays a strong relation to **modern climate**



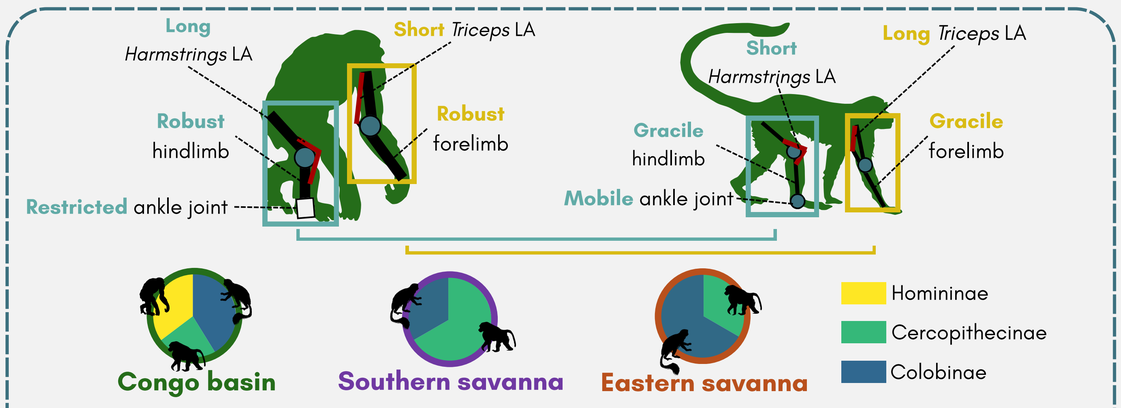
- Suid limbs **do not** display correlations with **current habitats**
- Limb robusticity displays a strong relation to **LGM climate**
- Both the functional significance and why it has been selected **is unclear**





- Primate limbs **do not** display direct correlations with **current habitats**
- Primate limbs **do not** display direct correlations with either present or LGM **climate**

Focus on Congo Basin primates



- High **morphological diversity** and **faunal composition** may indicate a **diversity of substrates**, including large trees

Take home message & future work

- Carnivores display specific adaptations to **current habitats**, thus, making them useful clades for reconstructing palaeoenvironments
- Suids and primates **do not** display specific morphological adaptations to current habitats or relation with present climate
- Primate **morphological diversity** is a useful model to reconstruct substrate diversity, which relates to **current** composition of the **tree coverage**
- Multi-trophic analyses considering **prey and predator dynamics** could bring further palaeoenvironmental reconstructions by cross validating **environmental filtering** signals

Acknowledgements

This study is funded by ERC_101141770_PLIODIS, We thank the Royal Museum for Central Africa, Tervuren and Emmanuel Gilissen and Mathys Rotonda for their support.
We acknowledge the historical extraction of resources from central Africa during European colonisation.

References

- Beyer, R.M. *et al.* (2020). Sci Data., 7:236.
- Bishop, L.C. (1994). Yale University.
- Drapeau, M.S.M. (2003). Am. J. Phys. Anthropol., 124:297-314.
- Pallas, L. *et al.* (2024). PCI Paleontology.
- RCMRD Online. (2023). [Africa Biomes Dataset].
- Samuels, J.X. *et al.* (2012). J. Morphol., 274:121-46.
- Venter, J.A. *et al.* (2014). Phacochoerus africanus. CC BY 3.0.
- Whittaker, R.H. (1975). New York: Macmillan.