

# A hydrogen isoscape for tracing the migration of terrestrial herbivorous insects across the Afro-Palearctic range

Sana Ghouri<sup>1</sup>, Megan S. Reich<sup>1</sup>, Roger Lopez-Mañas<sup>2</sup>, Gerard Talavera<sup>2</sup>, Gabriel Bowen<sup>3</sup>, Roger Vila<sup>4</sup>, Valery N. K. Talla<sup>5</sup>, Steve C. Collins<sup>6</sup>, Dino J. Martins<sup>7</sup>, and Clement Bataille<sup>8</sup>

<sup>1</sup>University of Ottawa Department of Biology

<sup>2</sup>Institut Botanic de Barcelona

<sup>3</sup>The University of Utah Department of Geology and Geophysics

<sup>4</sup>Institut de Biologia Evolutiva

<sup>5</sup>Universite de Dschang

<sup>6</sup>Kenya Gatsby Charitable Trust Nairobi

<sup>7</sup>Kenya Agricultural and Livestock Research Organization Sugar Research Institute

<sup>8</sup>University of Ottawa Department of Earth Sciences

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## Abstract

**Rationale:** Many insect species undertake multi-generational migrations in the Afro-tropical and Palearctic ranges, and understanding their migratory connectivity remains challenging due to their small size, short life span and large population sizes. Hydrogen isotope ( $\delta^2\text{H}$ ) can be used to reconstruct the movement of dispersing or migrating insects, but applying  $\delta^2\text{H}$  for provenance requires a robust isotope baseline map (i.e., isoscape) for the Afro-Palearctic. **Methods:** We analysed the  $\delta^2\text{H}$  in the wings ( $\delta^2\text{H}_{\text{wing}}$ ) of 142 resident butterflies from 56 sites across the Afro-Palearctic. The  $\delta^2\text{H}_{\text{wing}}$  values were compared to the predicted local growing-season precipitation  $\delta^2\text{H}$  values ( $\delta^2\text{H}_{\text{GSP}}$ ) using a linear regression model to develop an insect wing  $\delta^2\text{H}$  isoscape. We used multivariate linear mixed models and high-resolution and time-specific remote sensing climate and environmental data to explore the controls of the residual  $\delta^2\text{H}_{\text{wing}}$  variability. **Results:** A strong linear relationship was found between  $\delta^2\text{H}_{\text{wing}}$  and  $\delta^2\text{H}_{\text{GSP}}$  values ( $r^2=0.53$ ). The resulting isoscape showed strong patterns across the Palearctic but limited variation and high uncertainty for the Afro-tropics. Positive residuals of this relationship were correlated with dry conditions for the month preceding sampling whereas negative residuals were correlated with more wet days for the month preceding sampling. High intra-site  $\delta^2\text{H}_{\text{wing}}$  variance was associated with lower relative humidity for the month preceding sampling and higher elevation. **Conclusion:** The  $\delta^2\text{H}_{\text{wing}}$  isoscape is applicable to trace butterflies, moths and other terrestrial herbivorous insects that migrate across the Afro-Palearctic range but has limited geolocation potential in the Afro-tropics. The spatial analysis of uncertainty using high-resolution climatic data demonstrated that many African regions with highly variable evaporation rates and relative humidity have  $\delta^2\text{H}_{\text{wing}}$  values that are less related to  $\delta^2\text{H}_{\text{GSP}}$  values. Increasing geolocation precision will require new modeling approaches using more time-specific environmental data and/or independent geolocation tools.

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A butterfly wing isoscape for the Afro\_Ghouri et al.docx available at <https://authorea.com/users/637469/articles/653780-a-hydrogen-isoscape-for-tracing-the-migration-of-terrestrial-herbivorous-insects-across-the-afro-palearctic-range>

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