Juliano Morimoto, DPhil

Zoology

Universität Aberdeen

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Born in 1991 in São Paulo, Brazil

Studied Biological Sciences at the Federal University of Parana and Zoology at the University of Oxford

FELLOWSHIP
College for Life Sciences

Individuals as Particles and Species as Shapes in Infinite Spaces

Can we better predict how species will interact and respond to climate change?

From micro to macro, nature repeats itself across spatial scales: planets are like particles if we consider the vastness of space. This means that, in some cases, it is possible to adapt theories designed from one scale to another or to use knowledge from one theory to predict results across scales. One example is the quantum gravity theory in physics, which aims to integrate Einstein's theory of relativity (macro) with quantum mechanics (micro) in a unified theory. This led to the prediction of a new particle: the "graviton."

In biology, a similar approach could be taken. Imagine the distribution of a species (say, humans) on the planet. Each individual could be considered as a particle, while the entire human population could be represented as a geometrical shape within which all individuals (particles) live. The limits (or "walls") of this geometrical shape are determined by climate conditions (e.g., temperature) and by interactions with other species. For example, there are no (natural) human populations living in Antarctica due to its overly harsh climate and lack of other species for food. This concept could be imagined as analogous to a balloon full of gas, where the balloon walls are the limits of the species' survivability and the gas particles inside are individuals interacting within those limits. What happens when the climate changes? Environments that were inhospitable can become mild and vice versa. Species that did not interact now might do so. This means that, as the climate changes, the limits of species' distribution also change.

In this project, I will model species as shapes and individuals as particles, to integrate species-species interaction in changing climates into a thermodynamic model of species distribution. In particular, I will first borrow the concepts and equations from statistical thermodynamics and fluid dynamics to model the interaction between two species in changing environments. The species will be considered as immiscible fluids (i.e. not forming a homogeneous mixture with one another) with different densities and viscosities, and their interaction will be modelled using a partial differential equation. One can imagine the approach here as if we were modelling how water (species A) and oil (species B) interact in a flask and how this interaction changes as we increase the temperature of the solution.

Overall, this project will develop a new framework to investigate how species respond to climate change. This new framework combines for the first time concepts from physics (fluid and thermodynamic) and mathematics (differential geometry) and biology into an integrative model.

Recommended Reading

Morimoto, Juliano, and Mathieu Lihoreau (2019). "Quantifying Nutritional Trade-Offs across Multidimensional Performance Landscapes." The American Naturalist 193 (6): E168–E181. https://doi.org/10.1086/701898.

Morimoto, Juliano, Pedro Conceição, and Knut Smoczyk (2022). "Nutrigonometry III: Curvature, Area and Differences between Performance Landscapes." Royal Society Open Science 9 (11): 221326. https://doi.org/10.1098/rsos.221326.

Morimoto, Juliano, Pedro Conceição, Christen Mirth, and Mathieu Lihoreau (2023). "Nutrigonometry I: Using Right-Angle Triangles to Quantify Nutritional Trade-Offs in Performance Landscapes." The American Naturalist 201 (5). https://doi.org/10.1086/723599.

KOLLOQUIUM, 02.07.2024

Die Ökologie des Unsichtbaren: Von Molekülen bis zu Gemeinschaften

Unsichtbare Muster sind überall, doch im Vollzug unseres Lebens konzentrieren wir uns hauptsächlich auf das, was wir sehen oder bemerken, ohne uns ganz auf das zu konzentrieren, was abwesend, unbemerkt und ungesehen ist. Dennoch kann das Unsichtbare tiefgreifende Auswirkungen darauf haben, wie wir die Welt um uns herum sehen und mit ihr interagieren, und leider auch darauf, wie wir unseren Planeten vor dem Klimawandel schützen können. In meinem Vortrag möchte ich drei laufende Projekte vorstellen, die hier am Wissenschaftskolleg entstanden sind und die eng mit dem Konzept des „Unsichtbaren“ bzw. „Ungesehenen“ verknüpft sind. Wir sprechen zunächst darüber, dass Arten als Partikel betrachtet werden können und wie wir sie dadurch vielleicht besser vor dem Klimawandel schützen können. Anschließend sprechen wir über zwei Projekte, in denen ich mich mit unsichtbaren Katastrophen befasse, die Natur und Mensch aktuell widerfahren, und über die Maßnahmen, die wir ergreifen, um diese sozio-ökologischen Probleme mit Hilfe der Wissenschaft anzugehen. Dieser Vortrag ist wirklich interdisziplinär und ich hoffe, dass Sie – das Publikum – etwas Neues lernen und das „Unsichtbare“ sehen. Die Mathematik wird auf ein Minimum von einer Folie beschränkt, da dies das Verständnis der wesentlichen Begriffe und Ziele nicht behindert. Trigger-Warnung: Ich zeige Ihnen Bilder, die Sie verstören könnten, also achten Sie bitte darauf, wie es Ihnen während des Vortrags geht.

PUBLIKATIONEN AUS DER FELLOWBIBLIOTHEK

Morimoto, Juliano (Lawrence, KS,2025)

Permeability selection of biologically relevant membranes matches the stereochemistry of life on earth

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=1926407679

Morimoto, Juliano (Chicago, Ill.,2023)

Nutrigonometry I : using right-angle triangles to quantify nutritional trade-offs in performance landscapes

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=1850915709

Morimoto, Juliano (London,2022)

Nutrigonometry III : curvature, area and differences between performance landscapes

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=185091432X

Morimoto, Juliano (Chicago, Ill.,2019)

Quantifying nutritional trade-offs across multidimensional performance landscapes

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=185090717X