Sardines take us to the sources of biodiversity in the Amazon River

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The Amazonian sardine. Credit: Queiroz et al. (2013). Peixes do Rio Madeira. Dialeto.

The Amazon River harbors the largest biodiversity of freshwater fish in the world. What is the origin of this abundance of species? Researchers at the University of Geneva (UNIGE), Switzerland, have integrated a range of potential factors into a single statistical model to study the genesis of genetic diversity within a typical species, the Amazonian sardine. Published in the journal *PLOS ONE*, their study describes the contribution of each factor and the synergies at work. This approach, which can easily be used for any species, could be integrated into the study of the impact of various planned projects, such as the creation of

new dams on the Amazon, as well as any human large-scale alteration in various ecosystems.

The immense network of tributaries and the diversity of the environments drained by the Amazon River may explain the frequent appearance of new species. Being able to identify the many factors of diversification involved, their respective contribution and their interactions is essential for our understanding of the origin of new species, the preservation of species and for anticipating the consequences of human activities. "We used a method of analysis that combines genetic and mathematical techniques, which compares the different factors in search of correlations," says Juan Montoya-Burgos, researcher at the Department of Genetics and Evolution of the UNIGE Faculty of Science.

The Amazon cut in two during glaciations

In collaboration with researchers from the Universities of São Paulo and Rondônia, in Brazil, the scientists have selected the Amazonian sardine as a representative species of the entire basin, which covers more than 7 million square kilometers, and collected samples from many tributaries of the Amazon. They discovered that this species contains three genetically very different populations, with variations within the same population. "Multiple factors, such as floodplain vegetation or the chemical composition of water, previously proposed as individual factors of divergence, have in fact acted together and often synergistically, to divide this species into three distinct lineages," adds Luiz Jardim de Queiroz, researcher at UNIGE and first author of the study.

One of these factors dates back to a recent geological time, the late Pleistocene (500'000 to 12'000 years ago). During the dry climatic periods of this epoch, the white waters of the Upper Amazon were temporarily disconnected from the dark waters of the Lower Amazon.

The isolation of sardines in both regions has led to an adaptive specialization to both types of water, whose chemical composition differs - particularly in acidity and amount of silt - to the extent that fish no longer mix when these waters join.

This is the first time that the contribution of each factor, either alone or combined, is revealed using a statistical model which makes it possible to identify, among all the factors proposed and measured, which ones explain the changes in the variable of interest, in this case the genetic diversity within a species. "In the case of sardines, the interaction of the impact of waterfalls and of the geographical distance between sardine populations is responsible for 38% of their genetic differentiation. The effect of the floodplain size alone accounts for 23% of this differentiation. This effect, much more important than previously thought, pushes back the role of the chemistry of the water, whose incidence has been much emphasized, to only 3%", says Luiz Jardim de Queiroz.

Develop appropriate conservation strategies

Human modifications of the Amazon landscape, such as the new dams planned in major Amazon tributaries, will also have an impact on the genetic differentiation processes of aquatic organisms and threaten their diversity: "To develop conservation strategies in these areas, assessments should be made to determine the diversity of species and the role played by landscape peculiarities, such as waterfalls, water composition, floodplain size and vegetation composition," explains Juan Montoya-Burgos.

The results obtained with this complex analysis of multiple correlations exemplify the power of the methodology applied, for the first time, in the study of Amazonian biodiversity. This approach, which may include as many factors as desired, leads to a more accurate estimate of the

impact of human intervention in various terrestrial or aquatic ecosystems, as it can be easily implemented for any species.

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