Unexpected pattern of fish species richness found in the Amazon Basin

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An international collaboration results in largest-ever inventory of Amazon fish fauna. Credit: Felipe Rocha

The Amazon Basin contains the largest number of scientifically described freshwater fish species in the world: 2,257 or 15% of the total

number of known freshwater species. According to a new study, however, this vast biodiversity is unevenly distributed and follows a completely unexpected pattern.

The study was conducted by researchers affiliated with Amazon Fish, an international collaboration that is supported by São Paulo Research Foundation—FAPESP and is building a high-quality database on the freshwater fish species in the Amazon Basin.

According to the distribution model developed by Amazon Fish researchers, species richness is higher upriver in the western part of the basin than downriver in the eastern portion, which includes the mouth of the Amazon River. This is the reverse of the diversity gradient usually observed in river basins.

The Amazon originates in the Andes not far from the Pacific Ocean in the west of South America and flows into the Atlantic in the east.

Led by scientists from France's Development Research Institute (IRD) and ERANet-LAC, a network of researchers from the European Union, Latin America and the Caribbean (LAC), the consortium involves collaborators in the Amazon Basin countries (Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru and Venezuela) as well as Belgium and the United States. The latest results are published in the journal *Science Advances*.

"According to the classic diversity distribution pattern, species richness is higher near the river estuary, where water flow is greater, therefore supporting a larger number of species. However, our data show a reverse gradient for the Amazon Basin, with the highest species richness in the western portion, west of the Purus Arch relatively near Manaus. We also show that fish species are not evenly distributed across the basin and that endemic species, for example, are concentrated in the upstream portion

of the major rivers, such as the [Amazon tributaries] Negro, Madeira, Xingu and Tapajós, where there are more rapids and waterfalls, and where large dams are a threat to biodiversity and habitat connectivity," said Gislene Torrente-Vilara, a professor in the Federal University of São Paulo's Marine Sciences Department (DCMAR-UNIFESP) in Brazil and principal investigator for the project supported by FAPESP.

Downstream

The unexpected distribution pattern suggests that the processes whereby new species evolved were more intense on one side of the basin than on the other side. To verify the possible hypotheses for this unusual diversity gradient, the researchers analyzed fish species richness in 97 subdrainage basins along the main stem of the Amazon and its tributaries, correlating the data with climate and other historical variables associated with the region's formation. They also analyzed the pattern of species richness increase for 15 families of species, of which 14 families, or 78% of the 2,257 known species, matched the model.

According to the article, one of the probable reasons for the unexpected species diversity gradient is historical (on the geological timescale): western Amazonia had a relatively stable climate over the last 250,000 years, whereas the eastern side of the region alternated drastically between wet and dry periods, especially during the Last Glacial Maximum (LGM) approximately 21,000 years ago.

Another finding of the study relates to water drainage. "More diversification in the western portion of the basin suggests water drainage can be considered recent enough for species not to have had time to colonize the entire downstream system," Torrente-Vilara told.

Rivers typically rise in mountains or hills and drain toward lower altitudes, eventually reaching the sea. In Amazonia, however, Torrente-

Vilara noted, blackwater and clearwater rivers flow from the Guyana and Central Brazilian Shields to the Solimões-Amazon channel. The Solimões-Amazon is a whitewater river that originates in the Andes.

The confluence of these different types of water should facilitate species accumulation and high levels of species richness downstream near the Atlantic. "That's not what we found in our study," she said. "The pattern we found for fish species in the Amazon seemed counterintuitive when compared with the gradients identified in other river basins around the world but made sense when we observed the effects of the historical variables in the models."

According to Torrente-Vilara, another historical factor that must be considered is the existence of Lake Pebas, which formed approximately 23 million years ago. "The Amazon River's original position [proto-Amazon] was completely different," she said. "It flowed toward the Maracaibo Basin in Venezuela, to the north of Amazonia. There is no consensus on when it reversed course. Estimates range from 9 million to 2.5 million years ago. The fish species diversity patterns we found suggest that the river's change of course is very recent by geological standards."

Massive database

In addition to contributing to the massive database and involving the collaboration of scientists from several countries, the project also provided surprising results from expeditions conducted to fill sampling gaps in areas about which there was little or no information on ichthyofauna (fish species). "In a single 18-day expedition on the Javari River, for example, we inventoried 430 species, 23 of which were previously unknown to science," Torrente-Vilara said.

Amazon Fish, she added, is not only the world's largest database on the

region's ichthyofauna but also a source of historical information on natural species distribution patterns, permitting comparisons, estimates of the impact of human activity on these patterns, and endemic species conservation planning.

"By recounting the history of the basin's formation from the standpoint of its fish fauna, the currently available data will help measure the impacts of deforestation, dams, waterways, mines and other human activities as well as the impact of climate change. To estimate the impacts of human activities, we need to know what the environment and its fauna were like before the event," she said.

More information: Thierry Oberdorff et al, Unexpected fish diversity gradients in the Amazon basin, *Science Advances* (2019). DOI: 10.1126/sciadv.aav8681

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