Present-day species of piranha result from a marine incursion into the Amazon Basin

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Piranhas inhabit exclusively the fresh waters of South America. Their geographical distribution extends from the Orinoco River basin (Venezuela) to the North, down to that of the Paraná (Argentina) to the South. Over this whole area, which also embraces the entire Amazon Basin, biologists have recorded 28 carnivorous species of these fish. In spite of the evolutionary success of this subfamily of fish, the mechanisms that generated the species richness of this group are still insufficiently known.

A team from the IRD, working in partnership with Bolivian and Peruvian scientists, aimed to establish how these species were able to evolve over the past 15 million years. They consequently took samples from around their whole distribution range. Between September 2002 and June 2003, numerous specimens of piranhas were collected from the Bolivian part of the Amazon.

Complementary sampling was then conducted in the Brazilian and Peruvian sectors, from the Orinoco in Venezuela, and the São Francisco and the Paraná-Paraguay in Brazil. The team selected 57 specimens representative of 21 different species of piranhas, from 15 collection points distributed over the whole South-American hydrographic network,.

Mitochondrial DNA (mtDNA) of piranhas has a particularly high mutation rate and thus could be used as a molecular basis for reconstructing the evolution of the present-day species which are

different yet very close to one another. These techniques using mtDNA sequences led to the conclusion that the origin of the piranha species inhabiting the rivers of South America today dates back to some ancestor at only a few million years B.P. Yet dating from fossils, whose morphologies are strikingly similar to those of present-day piranhas, strongly suggests that this fish subfamily already existed in South America's hydrographic system 25 million years ago. The modern species must therefore stem from a recent diversification.

Further investigation involving the construction of a phylogenetic tree by categorizing the study's 21 species allowed phylogenetic relationships between each of them to be established in order to test alternative hypotheses for the diversification that occurred over time. Examination of these data alongside geological-scale changes that have affected aquatic ecosystems with time brought out evidence that marine incursions played a fundamental role in the appearance then the distribution of piranha species. Five million years ago, the Atlantic Ocean advanced, its waters finding their way far onto the Amazon flood plain. The saline water invaded the lowland expanse of the great river and penetrated its tributaries situated below 100 metres of altitude, provoking the disappearance of many species of freshwater fish. Some of these would nevertheless have succeeded in finding refuge at high altitude, in particular in rivers that flowed on the Guianan and Brazilian shields.

DNA analysis confirmed this hypothesis and showed that the piranha populations present in the Amazon flood plain but situated 100 metres above sea-level have been in existence for no more than 3 million years. Hitherto, certain specialists had suggested that the present-day piranha species had arisen in the lower sections of the great rivers of South America. The scientists thought that from centres of speciation, piranhas would subsequently have dispersed to colonize the more upstream reaches of the river system. However, the results of the study give

sustenance to another scenario.

According to that new hypothesis, during the marine incursion phase some piranha populations would have survived in the upstream parts of the network. Such populations would have differentiated into species–following the fragmentation of their zone of distribution, but probably also in response to ecological constraints specific to the basin where they were kept in isolation from each other. Once the ocean had regressed again, 3 million years ago, these piranhas could finally have dispersed downstream, finding their way back to the Amazon's lowland plain which would have served as a gathering ground for biodiversity. What now remains to be found are the ecological parameters that could have favoured the diversification of piranha populations so confined to the upper reaches of the river network.

One of the hypotheses advanced highlights water quality as a factor in stimulating ecological and morphological differentiation of species. The field survey observations indicated that some of the species were highly localized, in both geographical and ecological terms. For example, Serrasalmus hollandi is mostly found in turbid, sediment-laden waters flowing down from Andean mountain streams. In contrast, a new species the biologists discovered, lives in the same hydrographic basin but only in rivers with crystal-clear waters bearing very little sediment content.

However, water quality cannot be considered as the sole factor behind speciation, seeing that a third piranha species was found living in either of these two categories of river. The research results as a whole suggest that the superimposition of factors linked to geographical history and ecological conditions, intervening at different spatial and temporal scales, is responsible for the diversification of the piranhas. This is an evolutionary progression which should be transposable to other fish communities inhabiting South American waters.

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