Fossil study shows frogs were Florida's first-known vertebrates from the Caribbean

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Researchers found that frogs from the genus Eleutherodactylus are geologically the oldest Caribbean vertebrates to be found in Florida. Credit: Florida Museum of Natural History/Kristen Grace

Deep in the forests of Haiti lives the blue-eyed La Hotte glanded frog (Eleutherodactylus glandulifer), which once went 20 years without being

observed by scientists. It belongs to a diverse genus from the Caribbean that also includes the much more common coquí frog (Eleutherodactylus coquí), a cultural icon in Puerto Rico.

Now, a new fossil study shows that frogs from the genus Eleutherodactylus are geologically the oldest Caribbean vertebrates to be found in Florida. They also arrived in North America much earlier than previously thought.

Although scientists knew some North American frogs had origins in the Caribbean, they lacked fossil evidence showing when and how this movement had occurred. But María Vallejo-Pareja, a graduate student at the University of Florida, used understudied fossil collections to connect the dots.

"There was a gap in knowledge, but the answer was under our noses the whole time," said Vallejo-Pareja, first author of the paper. "We already had the fossils, which were collected from the 1970s through the 1990s. We just hadn't worked on them."

Scientists have an incomplete record of the evolutionary history of frogs. Data analyses show that frog families underwent rapid diversification after the Cretaceous-Paleogene mass extinction that famously killed off the dinosaurs 66 million years ago.

Frogs continued to diversify for the next several million years. They first show up in Florida's fossil record during the Oligocene Epoch, which lasted from around 34 to 23 million years ago. However, records from these eras are patchy.

This is because frogs are understudied in comparison with other vertebrate groups, with frog paleontology being an especially small field.

This posed a challenge when researchers at the Florida Museum uncovered an abundance of frog fossils at paleontological sites in Florida dating back to the Oligocene, including the Brooksville 2 and Live Oak SB-1A locations. Since frogs weren't a research priority when many of the fossils were collected from the 1970s through the 1990s, they were put in storage, where they sat, unstudied, until Vallejo-Pareja's project.

Vallejo-Pareja compared fossils found at the sites in Florida with existing collections containing specimens from both extinct and living frogs, including the Florida Museum's samples of the La Hotte glanded frog. She found that most of the collected fossils belong to the genus Eleutherodactylus, commonly referred to as rain frogs or robber frogs.

Rain frogs have a history of moving around. They originated in the Caribbean from an ancestor that dispersed from South America as early as 47 million years ago during the Eocene Epoch. Once on the islands, the ancestral population rapidly diversified into several species through a process called adaptive radiation. The finches that Charles Darwin documented in the Galapagos Islands, where one migrant species quickly evolved into at least 13 different species as it filled new feeding niches, are a classic example of this.

Many of the fossils used in this study were initially collected from the 1970s through the 1990s. They sat unstudied for decades because frogs weren't a research priority at collection time. Credit: Florida Museum of Natural History/Kristen Grace

Today, rain frogs are found in the Caribbean and parts of Central and North America. The oldest known fossil from the genus belongs to the coquí frog, which has been in Caribbean forests for at least 29 million years.

In the 1970s and '80s, it was unintentionally imported to Florida and Hawaii on nursery plants and is now considered an invasive species in both states.

DNA analysis led scientists to believe that Caribbean frogs in the genus Eleutherodactylus first arrived in Central America during the middle Miocene Epoch, 16 to 11 million years ago, before dispersing to North America. The fossils from this study, however, show rain frogs were in Florida during the late Oligocene, several million years before their recorded dispersal into Central America.

Rain frogs are evidently good at getting around, but it's not clear how they made it to Florida. Overwater dispersal on flotsam or other buoyant debris seems the likeliest scenario, but most of the Florida peninsula was still underwater when the frogs are estimated to have arrived. The increased distance between land would have made their journey even longer and more perilous than it would be today.

It is possible there were different dispersal events, but Vallejo-Pareja says that hypothesis would need to be tested by finding more fossils in Central America. Because frogs are small and highly mobile, however, it is easy to underestimate the presence of frogs in an area and hard to track their dispersal.

"These fossils are millimeters big," Vallejo-Pareja said. The smallest fossil frog was estimated to measure only 16 millimeters from snout to rear end, smaller than a U.S. penny. "So getting to work with them, without breaking or losing them, was a breathtaking moment. And I mean that literally, because if I'm sitting at the microscope with my fossil and I sneeze or breathe too hard, it's gone."

While rain frogs are widespread throughout North and Central America now, these findings suggest Florida was a first home, where they had interesting company. Other extinct animals from Live Oak SB-1A and Brooksville 2, the sites where rain frog fossils were found in abundance, included bear-dogs, bone-crushing dogs, a weasel-like carnivore, squirrels, beavers and rabbits.

Eleutherodactylus is by far the earliest known account of a Caribbean vertebrate spreading to Florida. Fossil evidence indicates there were rodents and salamanders that made the reverse trip, moving from North America to the Caribbean during the Oligocene and Miocene, but evidence for movement from the islands to Florida is scarce. Caribbean toads, snakes and lizards crossed over during the following epoch, the Miocene, but these records are inconclusive and require further study.

Vallejo-Pareja hopes the methodology and data created by her paper will help bolster frog paleontology research and expressed admiration for the good work that has already been done. We just need more of it, she said. She created digital 3D models of the fossil bones used in the study, generating more information for people interested in the field. Paleontologists might find a frog bone and not realize what it is, she said. Now, they have an additional reference point.

In the future, Vallejo-Pareja wants to use some of the methods she developed in this study to understand how frogs adapt to environmental changes. Although frogs have managed to survive a number of major extinction events, they are very responsive to changes in variables like temperature and precipitation.

"What happened to the frogs during a glacial maximum?" she asked. "Were they smaller or bigger? Did they decrease or increase in diversity? Did they survive? It would be very nice to take a look into the past and see how frogs responded."

The findings are published in the *Zoological Journal of the Linnean Society*.

More information: Maria Camila Vallejo-Pareja et al, Fossil frogs (Eleutherodactylidae: Eleutherodactylus) from Florida suggest overwater dispersal from the Caribbean by the Late Oligocene, *Zoological Journal*

of the Linnean Society (2023). DOI: 10.1093/zoolinnean/zlad130