Warning coloration paved the way for louder, more complex calls in certain species of poisonous frogs

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Brightly colored species such as the *Ameerega bilinguis* are likely to make loud elaborate calls because they are already established as unsavory prey. Credit: Juan C. Santos

Frogs are well-known for being among the loudest amphibians, but new research indicates that the development of this trait followed another: bright coloration. Scientists have found that the telltale colors of some poisonous frog species established them as an unappetizing option for would-be predators before the frogs evolved their elaborate songs. As a result, these initial warning signals allowed different species to diversify their calls over time.

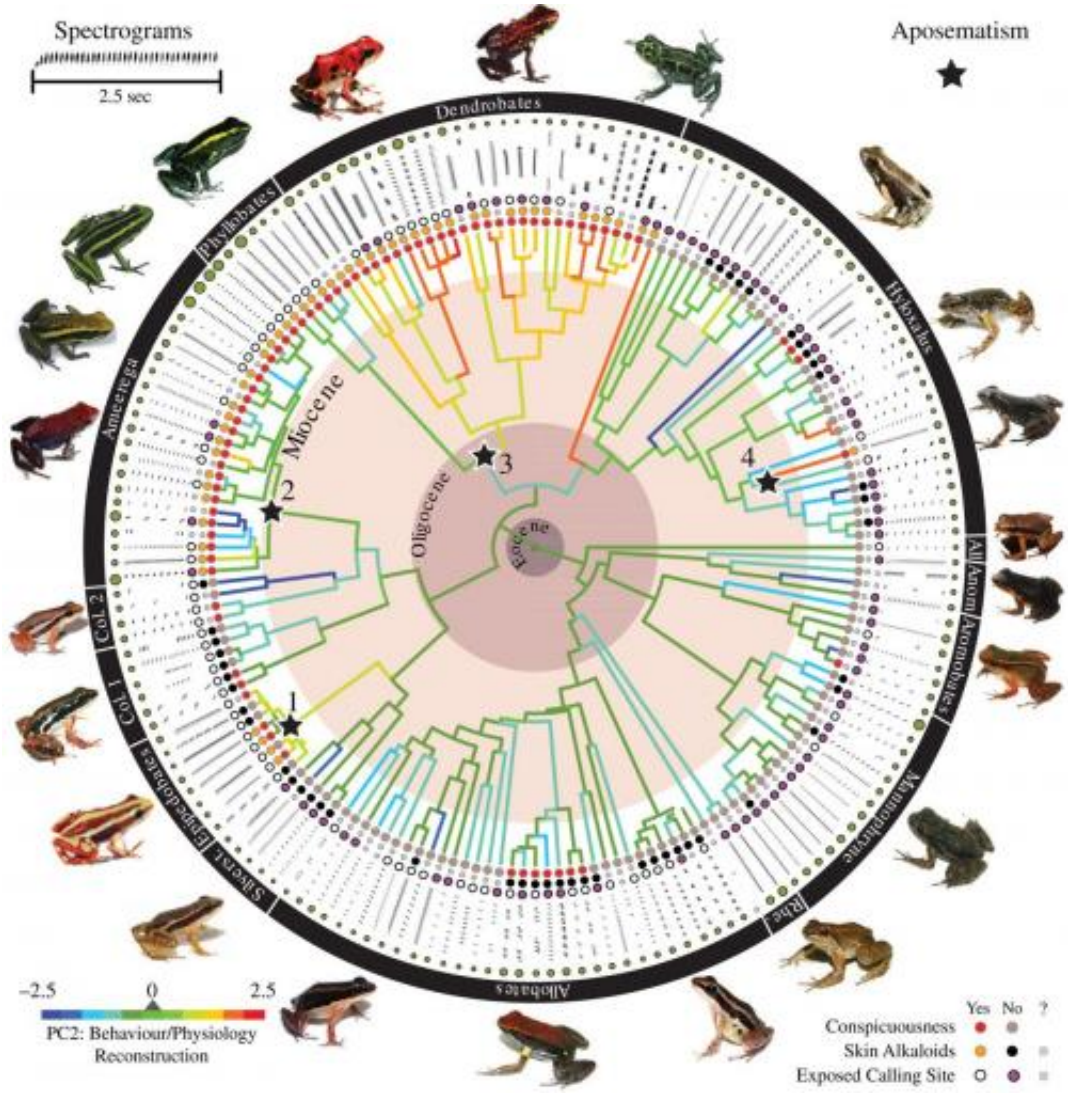
Zoologists at the National Evolutionary Synthesis Center (NESCent), the University of British Columbia, and other research universities assembled an acoustic database to analyze more than 16,000 calls from 172 species within the poison frog family, Dendrobatidae. The paper, which will appear in the December issue of the *Proceedings of the Royal Society B*, is now available online.

The study included both frogs that display bright colors and others that rely on camouflage for protection. Each call was examined in terms of pitch and duration, and researchers also factored in the size of the frogs and their visibility to predators. They found that because warning coloration protected them from predators, they were better able to attract a mate with low-pitch, pulsing vocalizations in plain sight than their quieter, darker-hued relatives.

"This allows the frog to have a unique type of call—a noisy call," said lead author Juan C. Santos, formerly of NESCent and now at the University of British Columbia. "These noisy kinds of calls, in general, are what the females really like."

Scientists already understood that predators shied away from brightly colored frogs because of visual cues, but Santos and his colleagues hypothesized that some species evolved to include audio signals, as well. Such a warning system is not unprecedented: Tiger moths emit ultrasonic chirps to communicate their unsavory taste to bats. Without a similar

ability, frogs navigate a precarious dilemma in which they must either risk detection by predators or forgo possible courtship.



This chronogram illustrates the diversity of mating calls based on species toxicity, visibility, call location and body size. Credit: Juan C. Santos

Initially the researchers expected that audio warnings predated coloration, but the results indicate the opposite. Using molecular data

and statistical analyses, they were able to infer a phylogenetic tree and pinpoint which trait came first. Their findings indicate that visual traits established the frogs as poisonous and cleared the way for louder, more elaborate calls.

Species relying on camouflage for defense will not invite attention with boisterous calls, while their protected relatives—including nonpoisonous frogs that mimic the appearance of their toxic counterparts— can be loud and more nuanced.

"The type of color they have is in the range of the noisy ones," Santos said. "When you're mimicking somebody that's already protected, you have some freedom to be found by potential mates."

These calls require high energy expenditures, but the boon of attracting females without predatory threats makes it a rewarding behavior for males. Less is known about the reasons females are attracted to the noisier males and how they appraise the various calls. Santos explained that if the females are being especially picky, it will drive male diversity by pushing them to create even more complex songs.

"What can the females get from this information? Maybe females— by being very picky— increase male diversity," Santos said. A more diverse pool of potential mates increases the likelihood that their offspring will have more advantageous genes over time.

More information: Santos, Juan C. et al. (2014). "Aposematism increases acoustic diversification and speciation in poison frogs" *Proceedings of the Royal Society B*. rspb.royalsocietypublishing.or … 96/20141761.abstract