Study finds that ocean cooling over millennia led to larger fish

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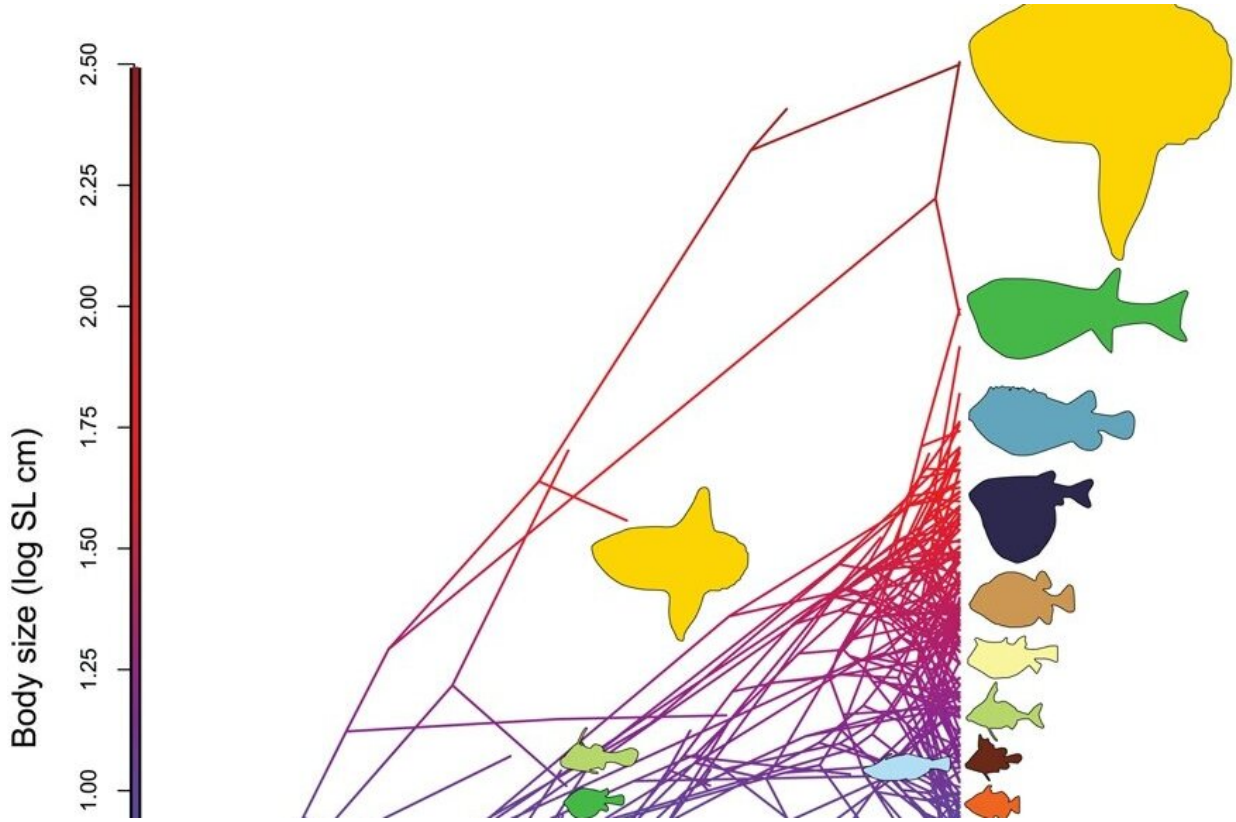

The evolution of tetraodontiform body size over time. Credit: *Proceedings of the National Academy of Sciences*

Earth's geological history is characterized by many dynamic climate shifts that are often associated with large changes in temperature. These

environmental shifts can lead to trait changes, such as body size, that can be directly observed using the fossil record.

To investigate whether temperature shifts that occurred before direct measurements were recorded, called paleoclimatology, are correlated with body size changes, several members of the University of Oklahoma's Fish Evolution Lab decided to test their hypothesis using tetraodontiform fishes as a model group. Tetradontiform fishes are primarily tropical marine fishes, and include pufferfish, boxfishes and filefish, among others.

The study was led by Dahiana Arcila, assistant professor of biology and assistant curator at the Sam Noble Museum of Natural History, with Ricardo Betancur, assistant professor of biology, along with biology graduate student Emily Troyer, and involved collaborators from the Smithsonian Institution, University of Chicago, and George Washington University in the United States, as well as University of Turin in Italy, University of Lyon in France, and CSIRO Australia.

The researchers discovered that the body sizes of these fishes have grown larger over the past hundred million years in conjunction with the gradual cooling of ocean temperatures.

Their finding adheres to two well-known rules of evolutionary trends, Cope's rule which states that organismal body sizes tend to increase over evolutionary time, and Bergmann's rule which states that species reach larger sizes in cooler environments and smaller sizes in warmer environments. What was less understood, however, was how these rules relate to ectotherms, organisms that can't regulate their internal body temperatures and are dependent on their external or environmental climates.

"Cope's and Bergmann's rules are fairly well-supported for endotherms,

or warm-blooded species, such as birds and mammals," Troyer said. "However, among ectothermic species, especially vertebrates, these rules tend to have mixed findings."

A challenge of studying ancient fish is that there are very few fossil records. To supplement that missing information, the researchers combined genomic data of living fish with fossil data.

"When you look across different groups in the tree of life, then you will notice that there are a limited number of groups that actually have a good fossil record, but the larger marine fish group (known as Tetraodontiformes) that includes the popular pufferfish, ocean sunfish and boxfish, is remarkable in that it has a spectacular paleontological record," Arcila said. "So, by integrating those two fields, genomics and paleontology, then we're actually able to bring into the picture new results that you won't be able to obtain using just one data type."

The genomic and fossil data was then combined with data on ocean temperatures, that demonstrated that the gradual climate cooling over the past 100 million years is associated with increased body size of tetraodontiform fishes.

"Based on fossil data, we're showing that these fish started very small, but you can see that living species are much larger, and those changes are associated with the cooling temperature of the ocean over this very long period of time," Arcila said.

While the evolution of tetraodontiform fishes appears to conform to Cope's and Bergmann's hypotheses, the authors add a caveat that many more factors could play a role in fish body size evolution.

"It's really exciting to see support for these two biological rules in Tetraodontiformes, as these trends are less studied among marine fishes

compared with terrestrial species," Troyer said. "Undoubtedly we will discover more about their body size evolution in the future."

The paper was published in the *Proceedings of the National Academy of Sciences*.

More information: Emily M. Troyer et al, The impact of paleoclimatic changes on body size evolution in marine fishes, *Proceedings of the National Academy of Sciences* (2022). DOI: 10.1073/pnas.2122486119

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