New research reveals extinction is key to terrestrial vertebrate diversity

November 24 2015

Dinosaur hall with Brachiosaurus brancai, Museums für Naturkunde Berlin. Credit: Antje Dittmann, MfN Berlin

Periods of high extinction on Earth, rather than evolutionary adaptations, may have been a key driver in the diversification of amniotes (today's dominant land vertebrates, including reptiles, birds, and mammals), according to new research published today in *Scientific Reports*.

The new study reveals that mass extinctions among some groups of amniotes coincide with numerous and large diversifications in other closely related groups.

Conducted by scientists from the Museum für Naturkunde in Berlin, Germany, and the University of Lincoln, UK, the research challenges commonly held views that support a relationship between the evolution of "key innovations" in a group and the rapid increase in its number of species. The researchers behind the new study suggest the evidence for such a relationship has only ever been circumstantial.

The new study examined the issue of adaptive radiations among early amniotes, from 315 to 200 million years ago. This time period witnessed some of the most profound climate changes on a global scale, including the dramatic shrinking of the southern polar icecap, the disappearance of equatorial rainforests, a substantial increase in temperature, and prolonged drought conditions. The time period under study also included the largest mass extinction in Earth's history, about 252 million years ago.

The concept of adaptive radiation is central to modern evolutionary biology. An adaptive radiation is an extremely rapid increase in the number of species in a group, often as a result of a key evolutionary innovation, which gives the group an advantage over its competitors or allows it to exploit a new resource. Often, if the appearance of an evolutionary novelty coincides temporarily with a large increase in species richness, it is assumed that the innovation is responsible for this pattern.

The scientists used statistical methods to identify which of the amniote groups present during this time were significantly more species-rich than their close relatives, and attempted to identify the factors responsible for this diversity imbalance. The results suggest that, usually, large differences in diversity between two closely related groups are not because more species evolve in the larger group, but rather because more species of the smaller group go extinct.

A key finding of the research is that even the appearance of an important innovation in the larger group does not trigger a large proliferation of species until a major new extinction takes place.

Dr Neil Brocklehurst, a postdoc at the Museum für Naturkunde in Berlin, is the lead author of the paper. He said: "It appears that these 'key innovations' do not promote massive increases in species richness, but instead buffer against extinction when times get tough."

As part of their study, the scientists examined the evolution of the dicynodont therapsids, a group of extinct plant-eaters closely related to mammals. About 270 million years ago, dicynodonts evolved a toothless beak and a back-and-forwards motion of the lower jaw, all of which are clear functional adaptations to help them process plant material. However, it was not until 10 million years later, during a minor extinction event, that dicynodonts began to outcompete their close relatives and became hugely diverse.

A similar pattern is seen in sauropodomorph dinosaurs, the group which would go on to produce the largest land vertebrates of all times, such as the celebrated Brachiosaurus housed at the Museum für Naturkunde Berlin. The large-bodied members of this group do end up becoming significantly more diverse than their close relatives, but not until a mass extinction event that took place at the end of the Triassic, almost 30 million years after their first appearance.

Co-author Dr Marcello Ruta, Senior Lecturer in the School of Life Sciences at the University of Lincoln, UK, explained: "Using large-scale tree diagrams to depict the evolutionary relationships of various groups of organisms, it is possible to address major evolutionary questions that Charles Darwin, and many generations of biologists after him, asked. How did life become so diverse? What triggers major diversification events? How do animals and plants respond to global catastrophes?"

Co-author Jörg Fröbisch, Professor for Palaeobiology and Evolution at the Museum für Naturkunde and Humboldt-Universität zu Berlin, added: "Surprisingly, when these early terrestrial vertebrates evolved a novel structure or function, they did not undergo a dramatic increase in species number. Instead, an adaptive radiation usually occurs much later in the history of these groups, during one of the many extinction events or during times of climate stress".

Co-author Johannes Müller, Professor of Palaeozoology at the Museum für Naturkunde and Humboldt-Universität zu Berlin, said: "We really did not expect any of these patterns. Our results go against many of the traditional predictions from evolutionary biology, and show that the scientific views about the relevance of key innovations should be carefully reconsidered."

More information: Neil Brocklehurst et al. Elevated Extinction Rates as a Trigger for Diversification Rate Shifts: Early Amniotes as a Case Study, *Scientific Reports* (2015). DOI: 10.1038/srep17104

Provided by University of Lincoln

Citation: New research reveals extinction is key to terrestrial vertebrate diversity (2015, November 24) retrieved 20 March 2024 from https://phys.org/news/2015-11-reveals-extinction-

key-terrestrial-vertebrate.html

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