Brave new reptilian world

The collapse of the Earth's first rainforests 305 million years ago caused reptile diversity to explode. Howard Falcon-Lang, Mike Benton and Sarda Sahney explain how 'island theory' may shed light on the evolution of life on land.

Three hundred million years ago, the world was a very different place. All the continents were joined together as a single landmass called Pangaea. The fragment of the Earth's crust that would become Britain lay on the equator and was covered by steamy rainforests.

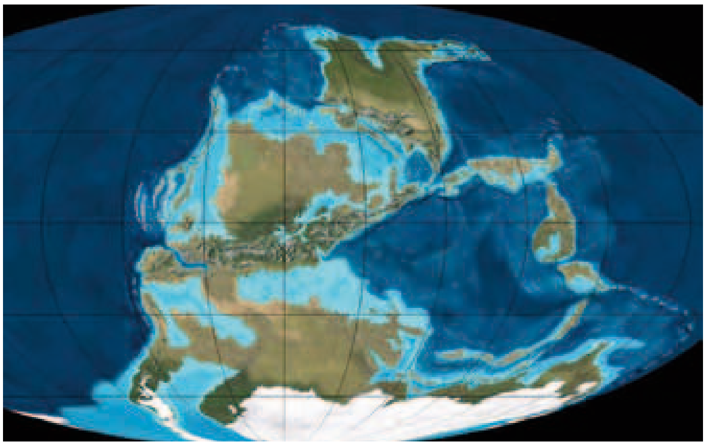
In this Carboniferous Coal Age – so called because the compacted remains of its dense vegetation formed coal seams – life on land was experiencing its first golden age. Tropical rainforests were alive with giant dragonflies, millipedes, cockroaches and our own closest ancestors – the amphibians and reptiles.

Then, suddenly, something happened. Right across the tropics, the rainforests started to collapse. No one is sure exactly how quickly this happened, but it must have been only a matter of a few thousand years at most. The cause of the collapse is much better understood than the rate it took place at. First, the Earth was gripped by a major ice age. Sea level dropped by a hundred metres and the tropics dried out.

When rainforests collapsed 305 million years ago small gecko-like reptiles experienced a major evolutionary leap forward.

James Robins

Ron Blakey



During the Carboniferous Period, all the continents were joined together as a single landmass called Pangaea and Britain lay on the equator.

New Mexico Museum of Natural History

A skull of an Early Permian reptile called Sphenacodon from New Mexico. Spectacular fossils like this have helped to track reptile evolution.

Only 'islands' of rainforest survived this initial climate crisis, mostly confined to wet valleys that crisscrossed the tropics. But when a brutal period of global warming reversed this climate trend, the remaining rainforests were finally wiped out.

Over the past year we've been investigating how the abrupt collapse of the Carboniferous tropical rainforests affected populations of amphibians and reptiles. To do this, we constructed a database of the many spectacular sites that have produced fossils from this time period. These include places like the Joggins Fossil Cliffs on Nova Scotia's Bay of Fundy, which is now a UNESCO World Heritage Site.

Sir Charles Lyell, father of geology and mentor to Charles Darwin, discovered some amazing fossil skeletons in these crumbling sea cliffs in 1852. Later, in 1859, his colleague William Dawson discovered the oldest known reptile, *Hylonomus lyelli,* a small, scampering gecko-like animal. Over the century and a half since, hundreds more skeletons have been found at odd intervals. So we know that Joggins, and sites like it, provide reliable information about the kind of animals that lived at a given place and time.

The initial impact of habitat fragmentation is devastating, with most of life dying out from lack of resources.

To find out how amphibians and reptiles responded to rainforest collapse, we studied 22 fossil sites that dated from before and after the event. The results were startling. Before the collapse, the same species existed everywhere across tropical Pangaea, including much of what is now Europe and North America. But afterwards each surviving rainforest 'island' developed its own unique mix of species. We also found that reptiles fared much better than amphibians. While the reptiles diversified into more species, many amphibian species became extinct. Not only that, but reptiles also started to develop more diverse tastes, eating plants and meat when before they had only eaten fish and insects, like their amphibian cousins.

So how can we explain these evolutionary changes? Ironically, a theory that was originally developed for oceanic islands has helped us make sense of this key phase in the evolution of life on land. 'Island theory' is a concept that explains how evolution progresses when populations are restricted into isolated pockets.

It applies equally to oceanic islands separated by seas and to traffic islands separated by motorway carriageways – as well as, of course, to rainforest islands separated by dry savannah, as in our Carboniferous study. In each case, the initial impact of habitat fragmentation is devastating, with most of what lives there dying out from lack of resources. Then, as surviving animals re-establish themselves, they adapt to their restricted environment to take advantage of the new allotment of resources – and diversify.

The new evolutionary pattern we've discovered, as the Carboniferous rainforest collapsed, is totally consistent with 'island theory'. For example, rainforest collapse would have divided populations, and each pocket would have evolved in its own way, resulting in a unique species mix which ecologists call 'endemism'.

And in the drier, more seasonal environments that followed, early amphibians would have found themselves like fishes out of water. These animals must return to ponds to lay eggs, and were probably unable to cope outside the rainforest belt. In contrast, reptiles – whose eggs have a hard shell and can therefore be laid on land – were better adapted to the brave new world, and diversified to take advantage of the new resources available.

As a global community, we are right to be deeply concerned about the combined way that climate change and deforestation are devastating tropical rainforests today. At the current rate of decline, it seems likely that modern rainforests will disappear much more rapidly than their Carboniferous counterparts, resulting in massive loss of biodiversity.

But, while the scale of this catastrophe should not be underestimated, the deep history of our planet gives us some interesting insights into how ecosystems have responded to such abrupt environmental shocks in the past. For the Carboniferous at least, rainforest collapse triggered an evolutionary spurt that laid the foundation for the dinosaurs and everything that followed, including us. Only time will tell whether we will be even half as lucky.

MORE INFORMATION

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FURTHER READING

Sahney, S, Benton, MJ, and Falcon-Lang, HJ, 2010. Rainforest collapse triggered Pennsylvanian tetrapod diversification in Euramerica. *Geology* 38 (12), 1079-1082, doi: 10.1130/G31182.1