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Finding the novelty in nature

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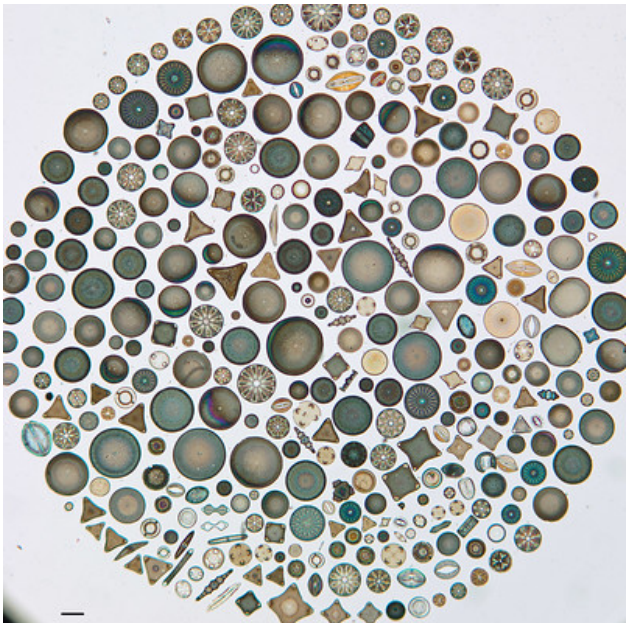
ABSTRACT

Ecosystems change over time. We devised a way to separate rapid and profound ecological changes from the slow, gradual turnover of species. We used fossil graveyards of microscopic marine plankton that were deposited over millions of years to examine patterns in 'novel communities' of the past, where they were driven by climate fluctuations and natural disasters rather than human activities.



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In the 1970s, Nintendo, a company that owned taxis and hotels and made playing cards and instant rice, began to make video games. This changed the company forever. Communities of species that live together in nature are somewhat like a business. Each species is a product. Over time new products are developed and products are removed. This is mirrored by new species evolving, or arriving from other places, and old species going extinct or leaving the community.

Normally this turnover happens gradually. However, sometimes, as with Nintendo's foray into games, the species in a community turn over profoundly and rapidly. We call these 'novel communities', reflecting that they look different from any time in the past. Our impacts on nature are everywhere, through the introduction of diseases, pests and weeds, harvesting of fish and timber, hunting, clearing land for farming and development, pollution and climate change. However, before human civilization, or even before we evolved, natural events such as the rapid temperature changes during the start or end of ice ages, or disasters like volcanic eruptions drove novel communities. Meteorite impacts: the loss of animals as widespread and varied as dinosaurs surely resulted in ecological 'novelty'!

For our work published in Science, we looked to the past to find novel communities in organisms nearly as exciting as dinosaurs: plankton, microscopic organisms that float in the ocean. Fossil records of these plankton, which go back millions of years, sometimes back to the death of the dinosaurs, are available in a global library of sediment cores drilled up from the ocean floor. Looking into the 'deep past', as it's called, is an integral part of our research. To understand how humans have changed nature, and predict what might happen in the future, we need to know how ecosystems changed before we were around.

Toward this goal, we created a way to detect novel communities, comparing what a community looked like to how it looked in the past, and how fast it was changing over time. We then used the speed and size of the change to determine whether these changes were big enough to be considered 'novel'. Importantly, our method can reliably distinguish large novel shifts from normal, slow changes over time in natural communities, and it can work with any time scale, from annual surveys to 66 million year-long deep-sea cores!

We found that novel communities in our marine plankton cores were rare, with only about a 2% chance of occurring. As we were comparing time periods of 100,000 years duration, that translates to, on average, one novel community every five million years. Despite their rarity, we found novel communities were more likely to emerge one after another (so a second novel change in species composition right after the first change). This suggests that a novel community may be susceptible to changing again, something that we want to look more into in present-day, human-altered communities.

As novel communities emerged, we found species were more likely to leave the community forever. These aren't true 'extinctions', as the species might still have been in other places, but rather a 'local' extinction. We also saw more brand new species appear in novel communities, but that makes sense. New species automatically make a community different from the past, and therefore novel. But seeing more species being permanently lost when novel communities emerge was unexpected. We observed higher rates of temporary species losses too, where a species disappeared but eventually came back some time after the novel community occurred. It is the permanent species losses, however, that are concerning when we think about ecosystems today.

We have to be cautious applying results from marine plankton across millions of years to year-to-year changes in today's ecosystems. However, if our results apply to human time frames, then we would expect the novel communities created from human impacts to be more likely to change again, with permanent species losses more likely to accompany each novel change. This could result in species extinctions, or ecosystems changing in unpredictable ways. When a company stops making a product, like Nintendo's instant rice, it can always start making it again. But when a species goes extinct, it's gone for good, making the stakes extremely high. Our work is only a small piece in the grand scheme of species conservation, but any understanding we can gain from the past to help prevent future extinctions is worthwhile.