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Biodiversity – a double-edged sword for ecological stability?

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ABSTRACT

Whether biodiversity increases or decreases ecosystem stability has intrigued ecologists for decades, without a final answer yet. Our research shows that both can be true and we present an approach called overall ecosystem stability to resolve this apparent paradox.

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Ecosystems are characterized by a remarkable ability to withstand changes in the environment. Your favorite meadow may look different in hot and dry year, compared to one with abundant rain, because the most common species in each year may be very different. However, you will still recognize the meadow and it will still produce hay for animals to feed on. As the climate changes, extreme years are expected to occur more often, for example with more droughts during summer or increased flooding events in spring. The ability of ecosystems to withstand these changes is called 'ecological stability'. Ecologists have been interested in ecological stability for a long time, especially whether more diverse ecosystems are also more stable.

In the past, the relationship between the diversity and stability of ecosystems has been studied by measuring their resistance or temporal stability. An ecosystem, for example the meadow, is resistant if an extreme year only leads to a small reduction in hay production. Small changes in hay, or biomass production over many years are signs of high temporal stability. There are many more ways for ecologists to measure stability, showing that we can look at ecological stability from many different angles. If we only look at one measure at a time, we may overlook other measures that could be telling a different story. Therefore it is better to study stability from many angles at the same time and to describe whether they change together. This is what

we call overall ecosystem stability. In our own research, we tried to understand whether species richness (diversity) influences overall ecosystem stability in a warming future.

To find out, we created micro-ecosystems in the laboratory, basically jars filled with water and nutrients, which contained different numbers and compositions of small organisms called ciliates. Ciliates are common in fresh water ponds where they hunt and feed on bacteria. They can grow very quickly and their populations can double every couple of hours. This helps us study the dynamics of their populations over many generations. We set up jars with one to six ciliate species to create a richness gradient at the beginning of the experiment. To understand whether ecosystems are stable in the face of climate change, we exposed our micro-ecosystems to warming. Normally, we keep our ciliates at 15°C, but for the experiment we grew them at higher temperatures, up to ten degrees above their normal temperature. We let the ciliates grow in their different ecosystems over two months. Every couple of days we sampled the micro-ecosystems by taking videos with a camera connected to a microscope. This allowed us to measure the number and individual sizes of the ciliates and calculate the total ciliate biomass in each micro-ecosystem. From the total biomass, we calculated the resistance as the difference between the biomass at 15° C and the biomass in the warmed micro-ecosystems with the same species richness and composition. We also calculated the temporal stability over the two-month period.

We found that species richness increased the temporal stability but decreased the resistance of the micro-ecosystem to warming. When combining these two measures into overall ecosystem stability, we observed that the diversity-overall ecosystem stability relationship changed: at the low end of diversity, increases in species led to higher overall ecosystem stability, whereas at the higher end of diversity, increases in species richness led to lower overall ecosystem stability.

Of course, one could ask whether these results from the laboratory can be compared at all to natural ecosystems. We also wondered this and therefore searched for studies that looked at more than one stability measure across a diversity gradient. Whereas many studies found that diversity changed stability measures in a similar way, we also found results similar to our study in communities of algae exposed to herbicides and plant communities under drought. This gives us some confidence that diversity can have opposite effects on stability in natural systems too.

Do our results mean that higher biodiversity is actually bad for ecosystems? Not at all. We only showed that one measure of diversity, namely species richness, can have different effects on ecosystem stability. In fact, species richness does not tell us anything about the diversity of responses to environmental change that different species can show. Many of the species we investigated reacted in a similar way to warming, limiting the capacity of the ecosystem to buffer against environmental change. It is therefore not enough to conserve as many species as possible, but we need to conserve as many species as possible that can cope with environmental change in different ways.