Will loss of plant diversity compromise Earth's life-support systems?

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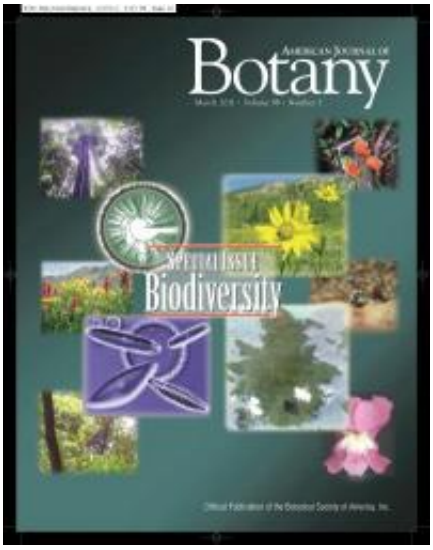

The study of biodiversity is fundamental to our understanding of life on Earth and to confronting some of the problems caused by our own species. Further, we increasingly count on biodiversity for a wide variety of ecosystem functions and services amidst a gauntlet of anthropogenic changes. In fact, biodiversity is disappearing at a rate even faster than the last mass extinction at the end of the Cretaceous Period, 65 million years ago, with possibly two thirds of existing terrestrial species likely to become extinct by the end of this century. This Biodiversity Special Issue looks at taxonomy and systematics, evolutionary biology and biogeography, ecology, and conservation/restoration, and the images on the cover represent these areas of focus. Credit: Various contributors to the Special Issue.

Biodiversity around the world is increasingly threatened by global

warming, habitat loss, and other human impacts. But what does this loss of species mean for the functioning of ecosystems that humans depend on for goods and services? Can ecosystems around our planet survive and maintain their primary functions with fewer species in them? After decades of research on many issues pertaining to life on Earth, are scientists any closer to attaining these answers?

In a Biodiversity Special Issue of the American Journal of Botany, to be published in March, many of the world's experts on biodiversity have come together to present their state-of-the-art analysis of where we stand today regarding the taxonomy, systematics, evolutionary biology, biogeography, ecology, conservation, and restoration of species distributed all over the world.

Understanding the causes and consequences of global loss of biodiversity is the main area of research for Bradley Cardinale, an ecologist from the University of Michigan. In one of the seminal papers in AJB's Biodiversity Special Issue (http://www.amjbot.org/cgi/reprint/ajb.1000364v1), Cardinale, along with several international collaborators, explores how changes to primary producers —plants and algae that are the baseline of the biodiversity network—affect ecological processes that are essential to the functioning of ecosystems around the world.

"Nearly every organism on this planet depends on plants for their survival," Cardinale commented. "If species extinction compromises the process by which plants grow, then it degrades one of the key features required to sustain life on Earth."

To take on such an enormous question, Cardinale and his co-authors conducted a meta-analysis—this entails finding and sifting through hundreds of published studies for appropriate data that can be used to answer larger-scale questions. In some respects, each paper that met their

defined criteria acted as a replicate data set for a particular question, and they were able to use these data sets to then ask if primary producers affected systems in the same way across multiple ecosystems and in multiple parts of the world. This is a very powerful approach because it combines the efforts of researchers all over the world and allows these researchersto zoom out from a small-scale, more traditional, focus on a specific study system or habitat to get a "big picture" perspective.

One of the key questions Cardinale et al. asked was "How does biodiversity of plants influence the productivity and sustainability of ecosystems?" A prevalent idea in the biodiversity scientific community is that species diversity controls how communities capture limited resources—such as nutrients and light—and convert them into new biomass. Using data from almost 400 published experiments in their meta-analysis the authors found overwhelming evidence indicating that the net effect of species loss at the producer level reduces the amount of standing biomass of that community. It also reduces the efficiency by which plants and algae assimilate inorganic resources like nutrients, and reduces rates of primary production (conversion into new biomass).

"This summary provides unequivocal evidence that declining diversity of plants and algae in the world's ecosystems will decrease the biomass of plants in natural ecosystems, and degrade their ability to use biologically essential nutrients from soil and water," Cardinale says. "Preliminary evidence also suggests that declining diversity may reduce the ability of natural ecosystems to produce oxygen, and to remove carbon dioxide from the atmosphere."

While the overwhelming majority of studies in their data set showed that diverse communities of plants and algae are more productive and efficient than their average species, the authors also examined whether a more diverse community is more efficient or productive than the single "best" species in that community. This is a question that agriculturalists

and forest managers have had for quite some time. Out of 375 observations, 37% suggested that diverse polycultures ultimately attain more biomass than even their single highest-yielding species (such as a species that would produce the largest crop or the most wood) when grown in a monoculture. This is probably a highly conservative estimate since the analyses also showed that effects of biodiversity tend to grow stronger as studies run for longer periods of time, or as they are performed at larger spatial scales.

The authors explain that there are two reasons why diverse communities are more productive and efficient. Part of the explanation is that diverse communities are more likely to contain "super-species"—that is, species that are highly productive and efficient at regulating ecological processes. But there is even greater evidence that species play unique and complementary roles in their environment. This "division-of-labor" allows diverse communities to be more productive. One of the co-authors of the study, Lars Gamfeldt, illustrates the concept with an analogy: "Plant communities are like a soccer team. To win championships, you need a star striker that can score goals, but you also need a cast of supporting players that can pass, defend, and goal tend. Together, the star players and supporting cast make a highly efficient team."

So where do scientists go from here? What areas need improvement? How can we develop better, more predictive models detailing the consequences of biodiversity loss?

"Species extinction is happening now, and it's happening quickly. And unfortunately, our resources are limited," says Jarrett Byrnes, another co-author of the study. "This means we're going to have to prioritize our conservation efforts, and to do that, scientists have to start giving us concrete answers about the numbers and types of species that are needed to sustain human life. If we don't produce these estimates quickly, then

we risk crossing a threshold that we can't come back from."

Cardinale et al. suggest that future experiments need to manipulate biodiversity at multiple scales and incorporate spatial and temporal heterogeneity; quantify how effects of biodiversity loss compare with those due to other environmental change such as pollution, habitat fragmentation, climate change, etc.; and conduct experiments that manipulate diversity at multiple levels, such as the genetic or landscape level, to see at which level ecological functions are best measured.

"We need to translate the insights gained from simple experiments into the 'real-world,' where things get considerably more complex," Cardinale notes. "But infusing more reality to experiments will greatly enhance our ability to predict the impacts of extinction."

"We'll then be in a position to calculate the number of species needed to support the variety of processes that are required to sustain life in real ecosystems," adds Cardinale. "And we don't mean "need" in an ethical or an aesthetic way. We mean an actual concrete number of species required to sustain basic life-support processes."

Finally, Cardinale indicates that we need to know how biodiversity impacts products and processes that are relevant to our daily lives. "For example, how does biodiversity affect the yield of food crops, the control of pests and disease, the purification of water, or the production of wood, fiber and biofuels?"

Emmett Duffy, a co-author, summarizes the paper with an emphatic conclusion: "The idea that declining diversity compromises the functioning of ecosystems was controversial for many years. This paper should be the final nail in the coffin of that controversy. It's the most rigorous and comprehensive analysis yet, and it clearly shows that extinction of plant species compromises the productivity that supports

Earth's ecosystems."

More information: Cardinale, Bradley J., Kristin L. Matulich, David U. Hooper, Jarrett E. Byrnes, Emmett Duffy, Lars Gamfeldt, Patricia Balvanera, Mary I. O'Connor, and Andrew Gonzalez (2011). The functional role of producer diversity in ecosystems. *American Journal of Botany* 98(3): 572-592. DOI: 10.3732/ajb.1000364

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