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WHEN PRODUCTIVITY GOES UP, DIVERSITY GOES DOWN

Until modern times, usable (fixed) nitrogen was hard to come by in many ecosystems. Plants adapted in various ways to overcome this limitation, but since people began using fertilizers and burning fossil fuels, the amount of nitrogen available in ecosystems has increased dramatically. Much of this nitrogen can't be absorbed, and the excess washes into waterways, causing eutrophication in aquatic systems. The nitrogen that is taken up in terrestrial ecosystems has major impacts there: primary productivity increases, but plant diversity declines.

How does nitrogen enrichment cause species to disappear? Katharine Suding of the University of California–Irvine, Scott Collins of the University of New Mexico, and six of their colleagues have addressed this question through experiments at multiple sites in nine temperate ecosystems across North America. Their study, which was published in the 22 March issue of *Proceedings of the National Academy of Sciences*, ranged from arctic tundra to annual grassland to salt marsh.

Over 900 species at 34 experimental sites were characterized and counted in plots with and without nitrogen fertilization. The researchers examined the patterns of fertilization-related decline in the different ecosystems to determine whether the relative abundance of species plays a significant role (random-loss hypothesis), or whether there are functional traits of species related to their decline (mechanism-based hypotheses). The six functional categories included broad groupings: photosynthetic pathway (C_3 or C_4 grasses), association with nitrogen-fixing symbionts, annual or perennial life history, height with respect to the canopy, type of growth form (clonality), and native or nonnative origin.

Increased productivity from nitrogen fertilization had the greatest impact on rare species. More than 60 percent of the species that were least abundant initially were lost, while only 10 percent of the more abundant species disappeared, though there were local extinctions in this group as well. The abundance-based loss of species was nearly universal for all ecosystem types. Fertilization in the arctic tundra, for example, gave a single species an enormous boost and reduced diversity dramatically.

Some functional mechanisms also played a role, after initial abundance was taken into account, but they were more system specific. Added nitrogen in tallgrass prairie favored a shift from herbaceous plants (forbs) with nitrogen-fixing bacteria to those without. But there was not a concomitant shift to competition for light, as one hypothesis predicts: lower-canopy species were not more likely to be lost than upper-canopy species, once initial abundance was taken into account. Some trait categories, particularly when taken together, were indicative of the species likely to be lost: species of sand prairie plants that are perennial, clonal, and native were more likely to be lost than faster-growing nonnatives when fertilized.

These findings, the authors conclude, can be used to counteract the effects of increases in production and halt declining plant diversity. Management strategies to protect and enhance abundance of rare species should be applied on a global scale, and strategies to preserve functional groups should be applied locally.

FLORAL DIVERSITY PRESERVED IN FOSSILS

The rich floral diversity of South America is legendary, but the conditions that gave rise to such diversity have been a mystery. Now the Patagonian desert is providing glimpses of the lush forests that existed long ago, revealing a richer past than previously recognized.

Patagonia, Argentina, has long been known for its fossil troves, but until recently few scientists have studied the assemblages in detail. Peter Wilf, of Pennsylvania State University, and his colleagues from North and South America have excavated thousands of new specimens from two major sites in Patagonia and begun to identify the large variety of species found there. Their quantitative methods and analyses, published in *American Naturalist* this month, help to draw a more detailed picture of life in subtropical regions of South America 50 million years ago (mya).

The more than 4000 fossil specimens collected at Laguna del Hunco [Lake of Reeds], including leaves, fruits, seeds, and flowers, have so far yielded 186 species. From estimates based on the growing number of species that were found as the sampling effort increased, this represents a much greater diversity yet to be recovered. The Laguna del Hunco sites have been dated to about 52 mya, and 160 kilometers to the northwest, the sites at Rio Pichileufu [Little River] have been dated to 47.5 mya. The intervening 4.5 million years show that the high diversity found at these locations persisted for a very long time.

The large sample size and high number of species allow scientists to estimate the mean annual precipitation and mean annual temperature within a few degrees. The estimates from these sites indicate a moist climate with ample rainfall year-round and average temperatures around 16 degrees Celsius, with winter temperatures well above freezing. The diversity of species preserved also indicates these forests were a mix of tropical and temperate plants, a wealth of biodiversity reaching back to the period of warming between the Paleocene and Eocene epochs.

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