COMMENTARY

# Local diversity stays about the same, regional diversity increases, and global diversity declines

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The "fact" that biological diversity—biodiversity—is declining and that humanity is ultimately responsible has become common knowledge among scientists, citizens, and policymakers. Biodiversity loss is the mantra for conservation; we are exhausting biodiversity on the planet at a far greater rate than it can replenish itself (1). Furthermore, these losses could greatly reduce the benefits (ecosystem services) that humans obtain from nature, such as the pollination of crops, absorption of carbon dioxide from the atmosphere, and provision of wild foods (2). However, is biodiversity truly declining? Remarkably, Vellend et al. (3) report that, on average, the local diversity of plants has not decreased in recent decades. If anything, it has increased.

Vellend et al. (3) searched the literature for studies that examined changes in local plant diversity. They found 168 studies from around the world, where the number of plant species had been counted, in over 16,000 plots in total, over periods of 5–50 or more years. They analyzed their global-scale dataset, finding an average 7.6% increase per decade in the number of species present in plots. This average was not significantly different from zero, so they concluded that there has been no overall change in local plant diversity, a finding that is extremely interesting.

The study by Vellend et al. (3) is not the only one to reveal stable or increasing diversity (Table 1). Although introduced animals and pathogens can eradicate native species (4, 5), far more plant species have been introduced to most regions of the world than native species have died out, resulting in net increases in the total number of species per region (6). Humans have also increased regional habitat diversity in some parts of the world by creating new types of anthropogenic habitats, and biological diversity increases with habitat diversity (7, 8). New species can live in the new habitats (9, 10), even though many of the previously native species would have declined as a result. Furthermore, despite the threat it poses to large numbers of individual species, climate change is expected to act as a driver of increasing diversity per unit area in regions where average temperatures and precipitation are increasing (11). Assessing changes in diversity requires proper accounting for these gains, as well as the losses (12).

Is biodiversity actually stable or increasing? The difficulty in obtaining an unambiguous answer arises because of the convenient but ultimately rather confusing adoption of one word "biodiversity" to summarize everything from the genetic differences between individuals and populations of a given species, right up to the number of ecosystems and species on Earth. Almost anything to do with life on Earth can be included within the term "biodiversity." As Vellend et al. (3) point out, different metrics of biodiversity can change in opposite directions (Table 1), and, indeed, the same metric can change in different directions under different circumstances.

Vellend et al. (3) highlight that most of the plot data that they found in the literature comes from locations where the vegetation has remained moderately intact. Few ecologists continue to monitor vegetation plots once they have been converted into corn fields or concrete, and most such transitions would exhibit a steep loss of local diversity. If we were to calculate the average change in number of species over the entire land surface of the world, including areas of tropical forests that have been converted into oil palm plantations and soybean fields, we would presumably come to the conclusion that average local diversity has declined rather than remained stable in recent decades. The Living Planet Index shows an overall decline by around 28% between 1970 and 2008, based on the numbers of individuals of monitored populations of species across the world (13). These declines will incorporate some of the losses attributable to fundamental habitat destruction, as well as changes within surviving habitats. Given that humans appropriate approximately a quarter of the annual growth of vegetation on land for our own purposes (14) (as crops, plants consumed by livestock, wood, etc.), one might expect that the global "bottom-line" loss of wild animal and plant production will be of similar magnitude.

The estimated change in number of species also depends on the plot area used to measure diversity. The plots of Vellend et al. (3) had a median of 44 $m^2$, and they found no overall average change in local diversity; invasive plants can reduce the diversity of other plant species in plots below 2,500 $m^2$ in size (15); and the average number of plant species declined by 8% within 200-$m^2$ plots monitored in Britain between 1978 and 2007 (16). In contrast, substantial increases (generally between ~20% and 100%) in the number of plant species have been reported through time in "plots" that are as large as islands, countries, or states in the United States, mainly associated with the introduction of species to new regions (6). The total number of plant species in Britain has increased by well over a third through introductions (17), despite the losses observed at 200-$m^2$ resolution (16). Increase the plot size to that of the entire Earth and diversity is going down again. Since 2000, the International Union for Conservation of Nature has added 46 plants to its list of species that are globally "extinct" or "extinct in the wild" and a further 1,920 plant species are classified as "critically endangered" (18). Overall, local diversity has increased in some locations and declined in others (usually declined where major land use changes occur), regional-scale diversity has usually increased, and global diversity has declined.

However, why are local and regional measures of diversity change not closely linked to each other and to changes in the number of species on Earth? The answer, it seems, stems from the fact that when a very

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**Table 1. How several components of terrestrial biodiversity may have changed, averaged across the globe**

| Metric | Overall trend* | Example/process | Ref(s). |
|---|---|---|---|
| Genetic diversity: variation among populations within species | Declining | Loss of genetically distinct populations and races | 20 |
| Local diversity: no. of species per unit area, within habitats | Stable | Changes in local plant diversity show no overall pattern of global increase or decrease | 3 |
| Local diversity: no. of species per unit area after conversion to human-dominated land use | Often declining | Low diversity in agricultural land compared with natural vegetation, such as conversion of rainforest to oil palm plantation | 10 |
| Regional diversity: no. of species per country, state or island | Increasing | More nonnative introduced species establish than native species die out | 6 |
| Global diversity: no. of species on Earth | Declining | High documented extinction rates | 5 and 21 |

*There are often exceptions to the overall trend.

rare species declines toward extinction, it only reduces the local diversity of those few places where it used to occur. In contrast, a species that is initially more widespread that either doubles or halves its distribution will alter the local diversity of many more places and, hence, have a much greater impact on local diversity when averaged over a large geographic region. For example, the number of butterfly species in 20 × 20 km grid squares in Britain increased by 7.6% from the period of 1970 to 1982 to the period of 1995 to 1999 in response to climate warming because a minority of species that were already reasonably common expanded their ranges, whereas most of the rarer species continued to decline because of habitat changes (19). At a larger scale, the total number of species has increased on most of the islands in the Pacific, but the additions are mainly of globally widespread species that have been introduced to many islands, whereas the extinctions have mainly been of native species that were restricted to one or a few islands (5, 6). The number of species per island has increased, but the number of species on Earth has decreased.

Vellend et al. (3) frame their paper in relation to the direct and indirect benefits we obtain from ecosystems—so called ecosystem goods and services, such as the provision of wood, erosion control, and our personal appreciation of nature (2). The authors provide a strong argument that major changes in land use, from one type of vegetation to another, or from vegetation to asphalt, are likely to make far greater differences to ecosystem services than are changes in diversity per se within existing types of vegetation. This argument appears robust, given that the authors did not find any overall change in the number of species per unit area. On the other hand, biodiversity loss could remain important to the loss of ecosystem services. The reason major land-use changes cause losses in ecosystem services could, at least in some cases, be because the new anthropogenic ecosystems lack sufficient biological diversity to provide them.

The overall conclusion that there is "no net change in local-scale plant biodiversity" is based on a global average (3), arising because local gains in some places are countered by local losses in others. These local changes may still matter to ecosystem services. The diversity of flower-visiting insects that benefit local people by pollinating their crops is linked to changes in the diversity of wild plant species nearby, not to the global average. Vellend et al. (3) report that there was a 20% or more decline in plant diversity (a level they regard as potentially damaging to ecosystem services) in 8% of studies, in just a decade. The inhabitants of those places may see a reduction in ecosystem services because of this. The corollary is that ecosystem services might be increasing elsewhere. Ecosystem services may also be affected by the changing identities and relative abundances of the species that are present in a plot, even if the plot still contains the same total number of species. Caution is needed to ensure that the impacts of biodiversity loss and gain are always reviewed (on the basis of evidence) at the spatial scale and in the place appropriate for the delivery of a given ecosystem service.

The study by Vellend et al. (3) is an excellent contribution toward achieving proper accounting for the changes to biodiversity, in which we recognize gains as well as losses, and where we are specific about the metric of biodiversity change that is being considered. In a world where almost all of our species and ecosystems are in flux, such documentation is essential to provide us with the information needed to develop rational, evidence-based strategies for the coexistence of nature and people. The biodiversity crisis has not gone away, but we definitely need to be considerably more precise in identifying which elements of biodiversity are in decline, where, whether and why such declines are concerning, and what we should and can do about it.


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