ECOLOGY

# How much biodiversity loss is too much?

## Widespread biodiversity losses are observed but safe-limit thresholds remain uncertain

*By* **Tom H. Oliver**

How much of something do we need to keep people safe and well? This question is frequently asked by those working in risk management. Across diverse sectors from flood protection to health care, practitioners assess risk as the product of the impact of a given event and the probability of its occurrence. Although these estimates are often uncertain, policy-makers must ultimately make spending decisions aimed at averting these risks, because the costs of inaction to society can be substantial. Biodiversity loss is a similarly critical, yet uncertain, issue. On page 288 of this issue, Newbold *et al.* (*1*) quantify global biodiversity losses, providing much-needed information on the encroachment of proposed "safe limits."

Economic analyses suggest that the total global value of ecosystem services is in the realm of tens of trillions of dollars (*2*). Many of these ecosystem services are underpinned by biodiversity. However, there is currently a lack of coordinated action to halt biodiversity declines, despite repeated setting of international targets (*3*). We know, broadly, the types of actions that are needed. They include habitat restoration as well as limiting human-derived pressures such as habitat loss, pollution, and invasive species. But the opportunity costs of these actions, in combination with the high levels of uncertainty around biodiversity change, appear to hamper commitment to action.

This uncertainty has multiple components. We must ascertain both the current extent of biodiversity losses and the effects of these losses on people's health and well-being. Newbold *et al.* report a crucial advance in tackling these issues. Their analysis is the most comprehensive quantification of global biodiversity change to date, considering over 1.8 million records of abundance from 39,123 species across 18,659 sites. Biodiversity losses vary widely across biomes. The authors find that, on average, the local abundance of each species has fallen to ~85% of its original value in the absence of human land use; that is, there is 85% "biodiversity intactness" (*4*). The authors then go further to relate these losses to a planetary safe limit of 90% biodiversity intactness, as proposed in a recent study (*5*). The hypothesis is that below the safe limit, the wide range of services provided by biodiversity that underpin human well-being—such as crop pollination, waste decomposition, regulation of the global carbon cycle, and cultural services that are central to emotional and spiritual health—are critically threatened (*5*). Newbold *et al.* find that ~58% of the world's land surface, and 9 out of 14 of the world's terrestrial biomes, have fallen below this safe threshold.

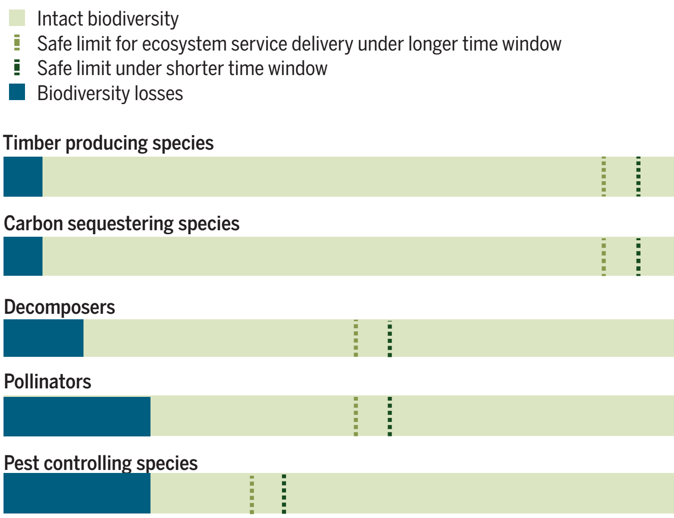
If such a large proportion of land has already passed the safe planetary boundary for biodiversity loss, why have we not already noticed more widespread negative effects on humans? Biodiversity loss can clearly lead to dramatic and rapid effects on ecosystem services. For example, invasion by the spiny water flea *Bythotrephes longimanus* in Lake Mendota in Madison, Wisconsin, USA, caused declines in key algal-grazing zooplankton species and consequent reductions in water quality, which will cost \$86 million to \$163 million to restore (*6*). In many other cases, however, effects may be delayed, with ecosystem services only lost after further perturbation (*7*). By analogy, cumulative structural damage to a bridge may only lead to sudden collapse after an extreme storm. Recovery from such catastrophic "tipping points" can be very costly if the replacement cost far exceeds ongoing repair costs. But the environment may be unique in that the extinction of species is essentially irreversible.

The existence of tipping points in nature has been hotly contested in the ecological literature. Debate is ongoing over whether thresholds for tipping points are planetary or regional (*8*), but they could be both or neither. It is also unclear whether non-native species should be included in the accounting of biodiversity change; it depends on their capacity to replace the roles played by disappearing native species.

To tackle these uncertainties, Newbold *et al.* conducted sensitivity analyses. When they included non-native species as functioning biodiversity, only 48% of the global land area was below the safe limit. The results differed even more markedly, however, when the threshold for safe levels of biodiversity intactness was varied. If the biodiversity intactness safe limit is 80% rather than 90%, about one-third of the global land area falls below the safe limit (and even less if non-native species are included in calculations). Clearly, it is crucial to reduce uncertainty around the existence of tipping points and where we should set safe-limit thresholds. Further research should also investigate whether safe limits are context dependent. For example, the longer the time window of

### Boundaries for biodiversity loss on services

The extent of biodiversity losses varies between groups of species that provide different services (*12*), as may the safe limits beyond which biodiversity loss will have substantial effects on human well-being. The figure only shows a subset of services provided by species. The extent of biodiversity loss and the safe limits depicted are purely hypothetical

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interest, the higher are the chances of a large environmental perturbation, and the greater the level of system resilience needed. Safe limits may also vary between the different ecosystem services provided by species (see the figure).

Newbold *et al.*'s study marks an important step in our ability to quantify biodiversity loss. But further work is still needed. For example, the authors used statistical models to estimate local biodiversity changes by downscaling land cover changes and inferring the proportion of non-native species. Further data collection, especially in data-sparse countries, is essential to reduce uncertainty in these models. However, the most pressing knowledge gap now is to move from documenting biodiversity changes to understanding their effect on people's health and well-being. Quantitative risk assessments are urgently needed to prompt commitment to potentially costly actions. For example, the UK government only committed to action in combating climate change after the likely economic impacts were quantified through meticulous analysis combining climate science and economics (*9*).

It may be impossible, however, to reduce the uncertainty regarding consequences of biodiversity loss to levels achieved in other sectors that deal with risk management. The challenge is to take decisions in the face of this uncertainty while factoring in other social considerations, such as the fair distribution of risks across demographic groups and generations. Furthermore, some level of natural resource exploitation, with inevitable biodiversity loss, may be essential to raise the living standards of the world's poorest (*10*). Taking decisions in the face of such uncertainty is not easy. It is a tricky problem to say how much biodiversity loss is too much. However, we can be certain that inaction commits us to a future with substantial costs to human well-being (*2*, *11*). ■


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FERROELECTRICS

# *Ferroelectric chalcogenides–materials at the edge*

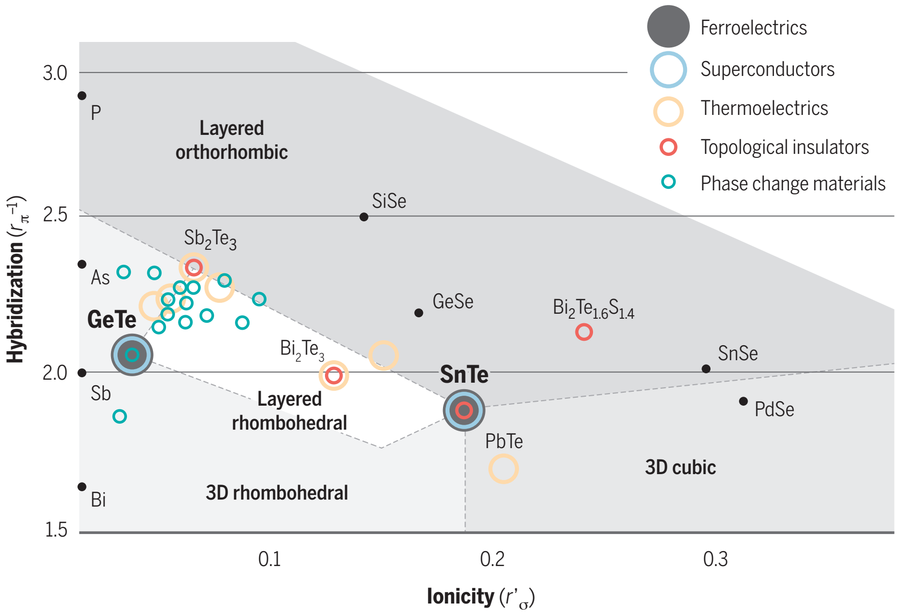
## Tin telluride becomes a more robust ferroelectric as an ultrathin film


*By* **Bart J. Kooi** *and* **Beatriz Noheda**


A ferroelectric material possesses an intrinsic electric dipole (polarization) whose direction can be reversed with an applied field. Applications of ferroelectrics include nonvolatile memories and sensors, but for high-density electronic devices or nanoscale devices, a limitation has been that as a ferroelectric film gets thinner, the maximum temperature for retaining the dipole—the Curie temperature $T_c$—decreases (often well below room temperature). On page 274 of this issue, Chang *et al.* (*1*) show that ultrathin layers of tin telluride (SnTe) can display robust, room-temperature, ferroelectric properties with higher $T_c$ than that of the bulk material.

This unusual behavior arises because SnTe and related chalcogenide materials (materials based on S, Se, or Te) can accommodate characteristics that are typically "conflicting" if the phases they form are at the edge of stability. The interplay of ionic and covalent bonding can lead to structural instabilities, so that the structure can change (for example, with temperature) between a rock-salt structure (a nonpolar atomic arrangement) and a rhombohedrally distorted structure (which is polar and can form a ferroelectric phase). Materials of this family often display asymmetric weaker and stronger bonds, in which the weak interactions can become van der Waals interactions and create layered materials that can be exploited as two-dimensional (2D) materials. These changes in bonding also underlie the variety of electronic structures in these materials, which can range from metallic to insulating.

Most chalcogenides have a clear separation between the *s*- and *p*-orbitals, and only the latter are involved in the bonding. The rock-salt structure is typically associated with ionic bonding, but GeTe, which is closely akin




**Balancing on the edge.** The type of crystal formed by chalcogenide materials and their properties depend on the interplay between *s*-*p*-orbital hybridization (reflecting covalent bonding with the amount of overlap between *s*- and *p*-orbitals) and ionicity (reflecting their tendency to form a salt) (*6*, *7*). Only a couple of these materials are known to be ferroelectric at low temperatures: GeTe, which is at the stability edge between two crystal phases, and SnTe, which is at the edge corner between all the known chalcogenide phases. Chang *et al.* show that few-atoms-thick films of this material stabilize the ferroelectric phase even at room temperature, which make such SnTe films interesting for real devices. [The figure is based on the hybridization versus ionicity plots of (*6*, *7*).]

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