

Fungus focus

A major new report highlighting the importance of fungi to humans and natural ecosystems makes it clear that a coordinated global conservation strategy is urgently needed to ensure that their benefits may continue to be reaped.

Fungi are arguably the most fascinating and enigmatic kingdom on Earth. Current estimates suggest that there are more than six times the number of fungal species than plants, having flourished in every conceivable environment, from deep sea sediments and volcanic vents to the dry valleys of Antarctica. Yet, we have barely scratched the surface of their diversity and value.

For this reason, the launch last month by the Royal Botanic Gardens, Kew, UK, of the first ever *State of the World's Fungi* report should be a cause for celebration among mycologists and the wider public alike. Fungi often get bad press when agriculture battles rusts, smuts and other plant pathogens, and wildlife face deadly threats from diseases such as chytridiomycosis in amphibians and white-nose syndrome in bats. And of course there remains a host of common human pathogens such as *Candida*, *Aspergillus* and *Cryptococcus* species that under certain conditions can prove fatal.

These disservices should not overshadow the enormous range of benefits fungi offer. Although the western world consumes only a handful of edible species, countries such as China have long had a tradition of including a huge diversity in their diet, with more than 1,700 edible fungi recorded in the latest census¹. Meanwhile, *Saccharomyces* yeasts have provided nourishing bread washed down with beer and wine since the dawn of agriculture.

Antibiotics, biofuels, washing detergents and more have all been developed from fungi, while more recently, species able to degrade polyurethane have been identified², offering hope for a solution to the current global scourge of plastic pollution. Each one of these applications started with a free-living fungus, waiting to be discovered. Yet, despite their untold potential, some 93% of fungal species remain undiscovered and unnamed, and the size of the global research community in fungal ecology and conservation remains modest.

The reason for this may partly be historical. In his original taxonomic scheme, Linnaeus classified fungi as 'flowerless' plants, along with ferns, algae and bryophytes. Although he can be forgiven this in light of what we now know about the cryptic nature of many fungal taxa, this classification would continue well into the twentieth century, undermining the status

of fungi as an entirely separate, and equally important, eukaryotic kingdom. Indeed, from what we now know via developments in sequencing, it is clear that most, if not all, life on Earth relies on fungi to varying degrees for its survival. The vast majority of land plants form belowground associations with mycorrhizal fungi, and colonization of the land by plants might not have been possible without the aid of fungal mutualists some 450 million years ago³. Evidence of fungi in the fossil record is hampered by poor preservation of their fine structures, but rare recent evidence suggests that their lineage could stretch back beyond 2.4 billion years⁴.

The pivotal role that fungi play in carbon sequestration and nutrient cycling, in breaking down recalcitrant forms of carbon, and in facilitating the exchange of nutrients between organisms, is becoming more apparent as we try to understand not only fundamental biogeochemical processes on Earth, but how these are impacted by global change. Evidence is accumulating rapidly that fungal diversity, distribution and functioning are all being altered by anthropogenic pressures such as nitrogen deposition and urbanization⁵, and the rapid global spread of plant pathogens such as ash dieback⁶. Large-scale international sequencing efforts such as the *1000 Fungal Genomes Project* may illuminate how they will respond to future environmental change, and more than 1,500 whole genomes of fungi are now publicly available — more than those of both plants and animals combined. These range from the largest organism on Earth, *Armillaria gallica*⁷, to the smallest eukaryotic genome known, the intracellular parasite *Encephalitozoon intestinalis*⁸.

The surge in environmental sequencing over the past decade has meant that the vast majority of new fungal species have been identified by their molecular signatures. However, this also creates a shortfall in the pace at which they may be formally classified. Current estimates suggest that new species would need to be described at an order of magnitude faster than present rates to recoup this shortfall⁹, presenting problems for national biodiversity and conservation assessments that rely on named species inventories for their monitoring programmes. Without significant investment in training a new generation of fungal

taxonomists, or some formal change to the way in which new species are classified, this shortfall looks set to continue.

Perhaps the most shocking figures to come out of Kew's recent report relate to the state of global fungal conservation, with a meagre 56 species currently holding an International Union for Conservation of Nature Red List assessment. This compares with more than 20,000 plants and well over 60,000 animal species. On a national level, some countries are pulling their weight, Chile being a notable example. Thanks in large part to the tireless efforts of *Fundación Fungi* in persuading policymakers of the importance of fungi for wine production (among other things), Chileans can be proud that their country is now the first in the world to enshrine fungal conservation into national law. Other organizations, such as the *International Society for Fungal Conservation*, are also doing crucial work keeping tabs on the extent to which countries signed up to the Rio Convention on Biological Diversity (CBD) are fulfilling their obligations to conserve fungal diversity. However, unlike other CBD programmes such as the Global Strategy for Plant Conservation, no equivalent programme currently exists for fungi.

It seems clear that these conservation shortfalls echo a general mismatch between the ecological and societal importance of fungi, and their perceived importance among the wider scientific community, as well as the public and policymakers. Many challenges still remain, but Kew's report is a crucial step in the right direction towards a coordinated and coherent global strategy on fungal conservation, which becomes increasingly urgent if we are to ensure that the marvels of the fungal world are not lost for future generations. □

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