State of the world's plants and fungi report: 3 in 4 undescribed plant species already threatened with extinction

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Scientists estimate that 3 in 4 plants that are yet to be described as new to science are likely already under threat of extinction, according to research published in the latest edition of the State of the World's Plants and Fungi report. Credit: Lydia Shellien-Walker/Royal Botanic Gardens, Kew

RBG Kew's fifth State of the World's report, published today, lays out the current condition of the world's plants and fungi globally. Based on the work of 200 international researchers and covering the content of more than 25 cutting-edge scientific papers in its 11 chapters, the new report examines global drivers and patterns of biodiversity as well as critical knowledge gaps and how to address them.

Plants and fungi underpin all life on Earth, providing valuable ecosystem services that support our livelihoods and provide us with food, medicine, clothing, and raw materials. But the natural world is in a state of imbalance, driven by the dual crises of climate change and biodiversity loss.

In this year's report, with the theme, "Tackling the Nature Emergency: Evidence, gaps and priorities," scientists take an in-depth look at what we know and don't know about the diversity of these fundamental building blocks of ecosystems and the threats they face.

The underlying scientific evidence is published today in a special collection from the journals *New Phytologist* and *Plants, People, Planet*, titled "Global Plant Diversity and Distribution" and in a review of global fungal diversity and conservation published by the journal *Annual Review of Environment and Resources*. The publication of the report coincides with a hybrid symposium held at Kew Gardens in West London. To date, RBG Kew has published four State of the World's Reports, with the 2020 issue being the first of its kind to investigate both plants and fungi together.

Professor Alexandre Antonelli, Director of Science at RBG Kew, says, "Our fifth edition of RBG Kew's State of the World's Plants and Fungi focuses on the latest knowledge on the diversity and geographic

distribution of plants and fungi. It relies on two major advances. Firstly, the recent release of the first geographically complete World Checklist of Vascular Plants—a landmark achievement after more than 35 years of meticulous and highly collaborative work. Secondly, the wealth of information on fungal diversity newly harnessed from the analyses of environmental DNA in soil samples across the world, integrated with other morphological and molecular evidence from fungarium specimens.

"In eleven chapters, we present compelling stories of what we can learn from these and related sources of data, and how these learnings can help us foster future research and conservation. This report is based on groundbreaking original research papers and reviews from many international teams of scientists.

"At a time when plants and fungi are increasingly under threat, we need to act fast to fill knowledge gaps and identify priorities for conservation. An array of tools, technologies and approaches are helping us to speed up this work, including genomics and machine learning. Accelerating our understanding of plant and fungal diversity is crucial to achieving the ambitious goals and targets of the recently agreed Kunming-Montreal Global Biodiversity Framework, with manifold benefits to local stakeholders and global scientific knowledge. In future, we need to better coordinate botanical and fungal research and focus on particular taxa and regions, based on the best available evidence and other priorities."

3 in 4 undescribed plants are under threat of extinction

With some 350,000 species of vascular plants already known to science, researchers are in a race against time to name and assess those still waiting to be described. But the challenge is great—as many as 100,000

are yet to be formally named and scientists fear the odds are stacked against them. New estimates suggest as many 3 in 4 undescribed vascular plants are likely to be already threatened with extinction.

Scientists arrived at this startling conclusion after analyzing data from the World Checklist of Vascular Plants (WCVP) with the International Union for Conservation of Nature (IUCN) Red List of Threatened Species, to examine links between the year a plant species is formally described and its extinction risk.

The researchers found a clear relationship between the year of description and the risk of extinction, with more than 77% of species described in 2020 meeting the criteria to be assessed as threatened. Similarly, they found that species described more recently are more likely to meet the criteria for a higher threat category. Over 59% of species described in 2020 are likely to meet the criteria for Endangered and 24.2% are likely to meet the criteria for Critically Endangered.

Based on these findings, Kew scientists are now calling for all newly described species to be treated as though they have been assessed as threatened unless proven otherwise. Unfortunately, more and more newly described species have narrow ranges (many are described from a single location) and are undergoing population and/or habitat decline. Scientists believe that prioritizing these species for full assessments on the IUCN Red List will aid their conservation efforts, as these, or other formal extinction risk assessments, greatly aid conservation efforts.

Victoria boliviana, the world's largest giant waterlily was among the new species of plant named by scientists since the start of 2020. Credit: RBG KEW

Dr. Matilda Brown, researcher in Conservation Assessment and Analysis at RBG Kew, says, "Ideally, partnerships between taxonomists and experienced conservation assessors would aim to describe and assess species simultaneously, to maximize opportunities for effective conservation action. In the meantime, if accepted, our recommendation could aid in the protection of many tens of thousands of undescribed threatened species, by treating them as threatened as soon as they become known to us."

45% of all known flowering plants could be under

threat of extinction

To better understand the risks faced by flowering plants already known to science, researchers cross-referenced data from the WCVP with the IUCN Red List of Threatened Species. They extracted a dataset of 53,512 assessed species as a baseline for probability-based model predictions for the 275,004 unassessed or Data Deficient flowering plants. These new estimates of extinction risk, along with an estimate of uncertainty for each prediction, paint a more robust picture of the levels of threats facing the planet's plant diversity than any previous attempts.

Worryingly, the estimates indicate that 45% of all known flowering plant species could be under threat of extinction. The plant families Orchidaceae (orchids), Piperaceae, which includes black pepper; Bromeliaceae, which includes pineapple; and Araceae, which includes many important crops, are among the most threatened. Scientists are, however, hopeful these new findings can guide policymakers and conservation efforts to save plants on the brink of disappearing forever by fast-tracking species for extinction risk assessments.

Dr. Steven Bachman, Research Leader in Species Conservation at RBG Kew, says, "We hope that these findings can be used to say, 'These are the species that are predicted threatened and haven't been assessed yet, and we are confident that they are good predictions, so we think that these should be priorities for full Red-Listing.' Then either we develop a project to assess these species or we encourage other people to carry out these assessments."

New estimate of 2.5 million fungi unlocks a frontier of discovery

Very little is known about the diversity of fungi when compared to

plants and animals, both of which have received a greater share of scientific interest over the centuries. To date, only 155,000 species of fungi have been formally named but researchers have long suspected the kingdom of fungi is as diverse, if not more, than those of plants and animals, with past estimates ranging from 250,000 to 19 million species. Now, thanks to a robust analysis of the science and advancements in technologies such as DNA metabarcoding, scientists estimate there are about 2.5 million species of fungi globally.

To put the figure into perspective, scientists have to date only described about 10% of the world's fungal diversity, meaning that many of new discoveries waiting to be made could supply us with new sources of food, medicine, chemicals, and enzymes with useful properties such as plastic degradation.

However, scientists warn the current rate of discoveries is wholly inadequate to tackle the scale of the problem. Since the start of 2020, some 10,200 new species of fungi have been formally described as new-to-science—at the current rate of species description, it would take around 750–1,000 years to describe them all. Researchers are, however, hopeful that focusing on DNA sequencing and molecular data could result in 50,000 new species being catalogued each year from environmental samples.

Dr. Tuula Niskanen, from the University of Helsinki and Former Research Leader in Accelerated Taxonomy at RBG Kew, says, "Naming and describing a species is the vital first step in documenting life on Earth. Without knowing what species there are and having names for them, we won't be able to share information on the key aspects of species' diversity, make any assessments of species' conservation status to know whether they are at risk from extinction, or explore their potential to benefit people and society. It is essential to know what species of fungi we have here on Earth and what we need to do for them,

so that we don't lose them."

More than 18,800 new plants and fungi species named new to science since 2020

Although disruptive to virtually every aspect of modern life, the COVID pandemic and lockdown gave scientists the time and opportunity to work through a backlog of data and unfinished papers. This yielded many new finds for science, raising the tally of global biodiversity. In total, more than 8,600 species of plant have been named new to science since January 2020, including the world's largest giant waterlily, Victoria boliviana.

Scientists estimate there are more than 2.5 million species of fungi globally. Among them, the recently named Queen's hedgehog (Hydnum reginae). Credit: Geoffrey Kibby

Sadly, many novel plant species are already threatened or extinct by the time they are formally named and recognized as new to science, such as the extinct "orchid of the falls," Saxicollela deniseae. This plant, which does not belong to the orchid family but rather a group of plants restricted to waterfalls and shallow, rapid waters, was collected along the Konkouré River in Guinea in 2018 by botanist Denise Molmou.

Unfortunately, by the time the species was formally published in May 2022, satellite imagery dated to November 2021 showed the falls where it was found was flooded by the construction of a hydroelectric dam 30km downstream. Scientists now believe Molmou was the first and likely last person to ever see the species in the wild.

Since 2020, scientists have also named more than 10,200 new to science species of fungi, including the conspicuous Queen's hedgehog mushroom (Hydnum reginae). The species, with its characteristic white quills, was named in honor of Her Majesty the Queen, Elizabeth II, and is found in just one area of Great Britain—the ancient beech forests of White Down in Surrey. It has been known as Hydnum albidum for more than 130 years but genetic research by RBG Kew and partners found it to be a distinct species to its American relative. Despite these recent advances, scientists warn there is still and urgent need to speed up the process of finding and naming new fungi.

Dr. Martin Cheek, Senior Research Leader in Accelerated Taxonomy at RBG Kew says, "My personal observation is that the number of

threatened plants has increased shockingly in recent years. When I started out as a taxonomist 30 years ago, you wouldn't even consider that a species you were publishing might go extinct; you just assumed it was going to still be around in the wild."

32 global plant diversity 'darkspots' identified

An ambitious project undertaken by RBG Kew scientists and partners seeks to shed light on the planet's "biodiversity darkspots"—areas where both geographic and taxonomic data are lacking, leaving scientists in the dark about their biodiversity. At least 14 (44%) of the identified 32 global darkspots were in tropical Asia, giving scientists a useful tool for determining where further fieldwork is necessary.

The study involved predicting the number of species per 'botanical country' (countries or close equivalents) that currently remain unnamed and unmapped. The researchers then examined where these darkspots coincided with the 36 recognized "biodiversity hotspots"—regions of rich and unique flora that are also under threat—as well as how socio-political and environmental factors may impact botanical expeditions and guide future taxonomic efforts.

In total, the work unveiled the presence of 32 darkspots, 14 of which spanned parts of the Asia-tropical region. Nine were in South America, six were in the Asia-Temperate region, two were in Africa and one was in North America. Overall Colombia, New Guinea, and China South-Central had the greatest combined descriptive and geographical data shortfalls globally, in decreasing order.

By continent, New Caledonia and Fiji had the greatest combined shortfall for the Pacific; Western Australia and Queensland for Australasia; New Guinea and Vietnam for Asia-Tropical; China South-Central and Turkey for Asia-Temperate; Madagascar and Cape

Provinces for Africa; Albania and Yugoslavia for Europe; Mexico South-west and Mexico south-east for North America; and Colombia and Peru for South America.

These countries provide the greatest opportunities for shedding light on the plant diversity darkspots of the world. New Guinea was the only darkspot not to overlap with a hotspot, but its exceptional biodiversity, which will increase further as the knowledge gaps are filled, may face rising threats from species overexploitation and the conversion of land to agriculture.

Dr. Samuel Pironon, Research Leader at RBG Kew and Modelling Scientist at the UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) in Cambridge, says, "Resources to undertake new botanical expeditions or to digitize existing collections are limited. So, we need to prioritize collection efforts. Knowing where there are most species remaining unnamed and unmapped, of which many are likely to be threatened, is crucial in this context. Understanding where the unknowns are concentrated could also help us refine our estimates of priority areas for conservation."

Biodiversity conservation falling short

Fungi: Less than 1% of described fungi have been assessed on the IUCN Red List, which equates to about 0.02% of the estimated 2.5 million total species. Of those that have been assessed, over half are estimated to be threatened or near threatened. However, this proportion is not believed to represent the threat to fungi globally as mycologists have so far focused their assessments on species considered most under threat.

Scientists are now calling for a two-pronged approach to prevent the decline of fungal biodiversity: 1) To integrate fungal conservation efforts with those of plants and animals, so conservation efforts are

coordinated; and 2) for areas of particular interest for fungi to be formally protected.

Plants: Less than half of the world's country endemics, that is, species that only occur in a single country or landmass and account for 64% of all plants, have been assessed for their extinction risk, highlighting a major conservation priority to address. Due to their small range, scientists fear climate change is becoming an increasing risk to endemics, meaning efforts to assess their conservation status need to be accelerated.

The report identified 32 darskspots where knowledge of biodiversity is severely lacking. Credit: RBG Kew

Scientist leads compilation of first global checklist of plants

The World Checklist of Vascular Plants (WCVP) came together after some 35 years of research by Belgian botanist Rafaël Govaerts, who heads the Plants and Fungal Names team at RBG Kew. Prompted by the destruction of rainforests in the late 1980s, Rafaël set out to catalogue all plants known to science. Today, his efforts have resulted in an expert-reviewed, global consensus of plant taxonomy and the most comprehensive database of the vast majority of plants on Earth, though his work is far from complete—on average, scientists still formally name about 2,500 new plants each year.

Rafaël Govaerts, Senior Content Editor—Plant and Fungal Names at RBG Kew, says, "More than 160 years ago, Charles Darwin dreamt of a complete list of plant species from every corner of the globe. This has been my dream too, prompted by the rampant destruction of the rainforests and biodiversity in general that I witnessed as a student in the 1980s, and it's exhilarating to see it finally come together. The World Checklist of Vascular Plants is the product of more than 30 years of global collaboration and an invaluable tool for scientists to explore the patterns, spread and extinction of all plant species known to science."

The WCVP has been used in the plant studies included in the report and has been crucial for a new RBG Kew project in partnership with IKEA to sequence the DNA of all 500 species of rattan—the spiny, climbing palms used in the manufacture of cane furniture. Rattans are harvested extensively from the wild, leaving the commercially valuable species vulnerable to over-harvesting and extinction.

Scientists at Kew are developing a comprehensive DNA-based identification toolkit that can be used by manufacturers like IKEA to

check the identity of rattan in the supply chain and ensure it has been responsibly sourced. RBG Kew and IKEA hope this will promote the sustainable use of rattan and conserve the species for future generations.

DNA sequencing and analysis of fossil records unlocking the secrets of the past

Before the advent of DNA sequencing, botanists relied on physical and chemical characteristics to describe plants and how they are related. However, harnessing ever-advancing genomic techniques and adding data from fossils and other sources are helping to fill gaps in the plant family tree of life, challenging and rewriting previously held beliefs about plant relationships and shedding new light on the evolution and distributions of plants. For example:

Plants: New data from studies suggests the orchid family (Orchidaceae) originated in the northern hemisphere around 83 million years ago, and not in Australia as it was previously thought. Scientists have also found that most of the orchid species known to science today originated fairly recently in Earth's history, around 5 million years ago. The orchid family is the largest in the plant kingdom.

Cycads: A study by scientists in France and Austria combined fossil and genetic data to reveal these ancient plants originated some 360 to 300 million years ago and occurred much higher latitudes than today. Extinction has been a common theme throughout the history of cycads, from the age of the dinosaurs to the modern day—today only 370 species of the cycad remain, and studies report 68% are threatened with extinction. Conservation efforts are particularly hampered by illegal trade and poaching.

Scientists call for more open access sharing of

scientific knowledge

A new study by researchers at RBG Kew, Meise Botanic Garden and the Natural History Museum, London has found only 23% of peer-reviewed studies have been published in open access publications between 2012 and 2021, despite most of the globe's species-rich areas being in low- and middle- income countries.

To fill data biases in these regions, unlock a wealth of critical knowledge, aid conservation efforts and help build taxonomic capacity, scientists have urged journals to waive publishing fees for authors from low- and middle-income countries. All papers featured in the State of the World's Plants and Fungi 2023 report are open access.

More information: *New Phytologist* (2023). nph.onlinelibrary.wiley.com/hu … n-special-collection

Annual Review of Environment and Resources (2023). www.annualreviews.org/doi/10.1 … nviron-112621-090937

Provided by Royal Botanic Gardens, Kew

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