BIODIVERSITY

8.7 Million: A New Estimate for All The Complex Species on Earth

With apologies to Jonathan Swift's famous flea-ridden 1733 poem, biologists typically do not believe life on Earth proceeds "ad infinitum." The planet must hold a limited, not infinite, number of plants, animals, fungi, and other complex species. But as scientists have tried to pin down that number for close to 2 centuries, their estimates have ranged wildly from fewer than a million to about 100 million. Now, a novel type of analysis, which takes advantage of an apparently natural mathematical pattern in the biodiversity produced by evolution, has settled on a tally of about 8.7 million eukaryotic species, give or take a million.

Many researchers find the case for this latest estimate, outlined online 23 August in *PLoS Biology*, convincing, though not the final word. "It's definitely an imaginative new method," says Robert May of the University of Oxford in the United Kingdom, who wrote a commentary accompanying the study and has previously put forth his own predictions regarding the extent of the planet's biodiversity. "But all methods are necessarily approximate."

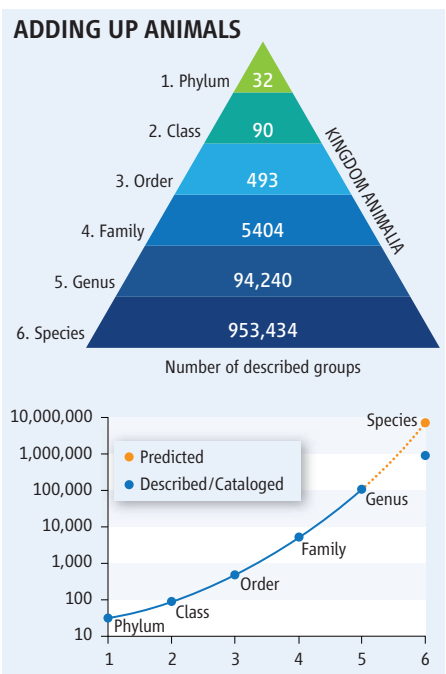
Biologist Edward O. Wilson of Harvard University suggests that the study might undershoot the mark, however, although he admires the attempt to provide an innovative way of calculating the planet's total biodiversity. "We should keep doing it, but we should be always suspicious," he says. Undiscovered species tend to be undiscovered for a reason, Wilson notes—they're rare, isolated, and, consequently, probably a lot more diverse than many suspect. Exploring this unknown diversity will be "one of the greatest areas of biology awaiting us this century," Wilson adds, especially because scientists are in a race to discover species before they go extinct.

One of the first to pursue scientific estimates of species numbers was Oxford entomologist John Obadiah Westwood in 1833. He surveyed the extrapolations of many of his early colleagues, based on current taxonomic collections, reporting an estimate that about half a million insect species possibly lived on Earth.

In 1982, Terry Erwin, a taxonomist at the Smithsonian National Museum of Natural History, took a new, experimental tack and got a much bigger number: He and his colleagues gassed 19 trees in a jungle in Panama, collecting about 1000 unique beetle species. Using a set of assumptions still hotly debated today, Erwin calculated that tropical beetles and their arthropod relatives alone constituted 30 million species.

Erwin launched a boom of research into biodiversity, but his analysis and similar ones that followed suffered from the same flaw, says marine biologist Boris Worm of Dalhousie University in Halifax, Canada: They couldn't be tested. There's "no way unless you go out and count all the beetles," Worm says.

While trying to tally the number of organisms in the sea as part of the Census of Marine Life, Worm and his colleagues stumbled on a taxonomic pattern that seemed to resolve this dilemma. With each step down in Linnaeus's famous classification system, the number of classes, orders, and so on tended to creep up in a predictable manner, his team realized. The kingdom Animalia, for instance, hosts 32 recorded phyla, 90 classes, 493 orders, 5404 families, and 94,240 genera. Extending that growth curve out, Worm and his colleagues predicted there should exist some 7,770,000 animal species—even though taxonomists have identified only about 950,000 so far. Plants, fungi, and other eukaryotes total about 1 million other species, they also predict.



Predictive pyramid. Given the number of animal phyla, orders, families, and genera, researchers predict that the kingdom has 7,770,000 species.

The researchers validated their taxonomic approach by comparing estimates made this way with real species counts from well-known evolutionary branches, such as mammals and birds. "Our predictions were very, very close to the true numbers," says study co-author Camilo Mora, a marine ecologist at the University of Hawaii, Manoa. If their 8.7 million species estimate is valid, Mora and his colleagues note, taxonomists have yet to catalog nearly 90% of land- and ocean-dwelling eukaryotes. (The team strayed away from crunching a total for bacteria and archaea because scientists still puzzle over how to categorize species for the microbes.)

Mora and Worm's study highlights that scientists are getting closer to pinpointing Earth's vast biodiversity, says Nigel Stork, a biologist at Griffith University in Queensland, Australia. Last year, he and colleagues used a combination of beetle counts made in New Guinea and complex mathematical modeling to estimate that there are some 3.7 million arthropod species on Earth. Despite the radically different method, much more akin to Erwin's early work, Stork's estimate falls in line with what Mora and Worm found: "We are beginning to home in," Stork says.

Many still argue that a tally of 8.7 million species sells our planet short. Taxonomists have only brushed the surface of the diversity of many microscopic organisms such as yeasts, cautions Steven Stephenson, an ecologist who specializes in fungi at the University of Arkansas, Fayetteville. He suspects that the *PLoS Biology* study underestimates the diversity of these and other eukaryotic microbes.

And the analysis may have a more fundamental flaw, some suggest. The relationship between levels in Linnaeus's classification system is a statistical pattern, not one based on sound scientific principles, says Lucas Joppa, a conservation ecologist at Microsoft Research in the United Kingdom. "There's no inherent ecological rationale for why kingdom should be to phylum as phylum is to class," Joppa says.

Erwin agrees and says that he's inclined not to set a limit on species numbers at all. The more he digs into the Amazon, the more it looks like the insect species there, like Swift's fleas, don't have a finite end. "Biodiversity is infinite," he says. "And there is no way to estimate the infinite."

–DANIEL STRAIN

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