The search for unknown biodiversity

William F. Laurance[1] and David P. Edwards

Centre for Tropical Environmental and Sustainability Science (TESS) and School of Marine and Tropical Biology, James Cook University, Cairns, Queensland 4878, Australia

In a world being rapidly transformed by human activities, an alarming possibility is that many species might disappear before we have a chance to study or even scientifically describe them. This possibility goes beyond a simple desire to document biodiversity, because unknown species could have important benefits for humanity. For instance, who might have imagined that an obscure herb endemic to Madagascar, the rosy periwinkle (*Catharanthus roseus*), would yield the only known treatment for childhood leukemia (1)?

How prevalent are undescribed species, and where do they occur? Are they largely concentrated in areas that we already consider conservation priorities, or are they often found elsewhere—meaning that we may need to identify additional priority areas? These questions motivated the study by Joppa et al. (2) in PNAS. With considerable pluck in the face of data limitations and important uncertainties, they attempt to estimate the number of undescribed flowering plant species across much of the terrestrial world (2).

Joppa et al. (2) conclude that the bulk of undescribed species are found in so-called biodiversity hotspots. Twenty-five hotspots were initially identified by Myers et al. (3) in a seminal paper that has had a major impact on global conservation strategies (4) and is the most highly cited article in the fields of ecology and environmental science (5). Myers et al. (3) defined hotspots by intersecting areas with large numbers of endemic vascular plant and terrestrial vertebrate species with those areas that had suffered severe (>70%) habitat loss. Remaining native habitats in the hotspots that they identified span just 1.4% of the planet's land surface but sustain nearly one-half of all known plants and over one-third of all vertebrates (3). Hectare for hectare, this finding makes these hotspots the most biologically important real estate on Earth—assuming that large numbers of unknown species do not occur in other locales.

In an effort to discern where unknown plant species occur, Joppa et al. (2) devise a statistical model that estimates, for a total of 50 broad geographic regions worldwide, the rate at which new species are being described scientifically. Based on their earlier work (6, 7) and expert opinion, they estimate that around 15% of all flowering plant species remain undescribed globally (2). The present study suggests that different geographic regions vary widely in the rate of new species discovery (2), and Joppa et al. (2) assume in their analysis that those areas with higher recent rates have a higher proportion of undiscovered species.

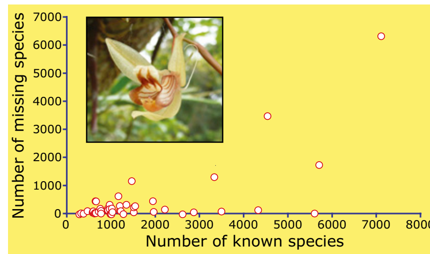

Fig. 1. Among the 50 broad geographic regions defined by Joppa et al. (2), the predicted number of missing (undescribed) flowering plant species is positively correlated with the number of known species (r_s = 0.38, P = 0.006; Spearman rank correlation). Surprisingly, however, some of the most biologically diverse regions are predicted to have few or no missing species. (*Inset*) Orchids are the most species-rich plant family and include many undiscovered species (photo by Felicity Ansell).

It is apparent that the study by Joppa et al. (2) is a prime example of best available data inference. Among the taller hurdles that they face are the following challenges (2).

i) For any geographic region, the rate at which new plant species have been described is influenced not only by the number of undescribed plant species but also substantially by the number of taxonomists working there at any point in time. Joppa et al. (2) partial out the effects of varying numbers of taxonomists (both at different time periods within each region and among different regions) to derive a corrected rate of species discovery. Also complicating matters is that the efficiency of taxonomists, as measured by the rate at which each taxonomist describes new species, seems to have increased during the past two centuries. A variety of factors—such as the advent of molecular phylogenetics, changing species concepts, and vastly improved communication among researchers—might underlay this trend. In their model, Joppa et al. (2) attempt to compensate for this effect by assuming that taxonomic efficiency increased linearly over time.

ii) The analysis was based on only a fraction of the data used in the original study by Myers et al. (3). Terrestrial vertebrates (mammals, birds, reptiles, and amphibians) were not included, and among plants, only about one-third of the vascular species were used. The excluded species included nonflowering vascular plants and far more substantially, many flowering plant families whose taxonomy had not been recently revised or corrected. The decision to exclude many flowering plants was justified scientifically, but it did limit the analyses to certain families whose taxonomy and biogeography were particularly well-known. Are these included groups representative of plant biodiversity writ large?

iii) The geographic areas defined by Joppa et al. (2) align rather loosely with the biodiversity hotspots, complicating efforts to make direct comparisons. The species data used by Joppa et al. (2) largely follow national boundaries, whereas the hotspots were logically based on biogeographic regions that commonly traverse several countries (3). For instance, Myers et al. (3) defined two hotspots in northwestern South America, whereas Joppa et al. (2) define four geographic regions in the same general area based on national boundaries—and in doing so, combine different biomes within a single region and create considerable overlap in species distributions among regions. Joppa et al. (2) also face a sample size problem. To improve confidence in their patterns, they try to limit their analyses to regions with at least 500 known endemic species (2). In a few cases, this limitation requires lumping vast areas, such as the United States and Canada, into a single geographic region that extends far

Author contributions: W.F.L. and D.P.E. wrote the paper.

The authors declare no conflict of interest.

See companion article on page 13171.

[1]To whom correspondence should be addressed. E-mail: bill.laurance@jcu.edu.au.

beyond the original hotspot, the California Floristic Province.

Taken at face value, the study by Joppa et al. (2) suggests that biodiversity hotspots do indeed contain the lion's share of undiscovered flowering plants. Many of these missing species are likely to be rare and have small geographic ranges (2). These attributes, in concert with the fact that they often occur in regions that have already suffered severe habitat loss and have rapid human population growth (8), indicate that many are likely to be endangered. This finding suggests that global estimates of endangered plant species in the International Union for the Conservation of Nature Red List (9) might well be considerably too low, especially for biodiversity hotspots.

There are, however, enough loose threads in the study by Joppa et al. (2) to suggest that some caution is needed in interpreting their findings. For instance, Joppa et al. (2) infer that just 6 of 25 hotspot regions—especially those regions in Central and South America, southern Africa, and Australia—contain 70% of all missing species. This figure seems too high, partially because several other key hotspots, especially in the Asia Pacific region, are predicted to have remarkably few missing species (Fig. 1). Sumatra and the Philippines—both stunningly rich in biodiversity—are projected to have no unknown species at all. Clearly, this finding is hard to believe.

A key conclusion of the work by Joppa et al. (2) is that existing biodiversity hotspots sustain the bulk of undescribed species—hence, there is little need to define additional hotspots. However, Joppa et al. (2) emphasize that New Guinea, a tropical island known to have large numbers of endemic species, might need to be added to the list. The island was originally excluded from the original 25 hotspots, because at the time of the study by Myers et al. (3) in 2000, habitat destruction there was relatively limited. Today, however, habitat disruption in New Guinea is occurring apace (10, 11).

Joppa et al. conclude that the bulk of undescribed species are found in so-called biodiversity hotspots.

New Guinea merits attention for another reason. According to the model of Joppa et al. (2), virtually no undescribed species are expected to be found on the island. This model is clearly at odds with prevailing wisdom. In just the past decade, 218 new plant species and 191 terrestrial vertebrate species have been discovered there (12). New Guinea presently has ~13,500 described vascular plant species, but some experienced botanists believe that this figure could ultimately double, with new species still being discovered even in the best-surveyed areas.

In the context of the study by Joppa et al. (2), the example of New Guinea provides some important cautionary caveats. At a broad, subcontinental scale, the conclusions of Joppa et al. (2) seem roughly valid: most undescribed species are indeed likely to be found in existing biodiversity hotspots, and many of these species are almost certainly endangered. When scrutinized in finer geographic detail, however, the specific predictions of missing species for some regions seem questionable at best. There are many potential sources of error in an analysis such as the one by Joppa et al. (2), and ultimately, one must give this team credit for attacking one of the most daunting research problems imaginable. We conclude that, when it comes to quantifying what we do not know, there is still much that we do not know.

ACKNOWLEDGMENTS. The authors were supported by an Australian Laureate Fellowship awarded to W.F.L.

1. Applequist WL (2011) *Catharanthus roseus* (L.) G. Don. *Encyclopedia of Life*. Available at http://www.eol.org/pages/581125. Accessed July 2, 2011.
2. Joppa LN, Roberts DL, Myers N, Pimm SL (2011) Biodiversity hotspots house most undiscovered plant species. *Proc Nat Acad Sci USA* 108:13171–13176.
3. Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GA, Kent J (2000) Biodiversity hotspots for conservation priorities. *Nature* 403:853–858.
4. Dalton R (2000) Biodiversity cash aimed at hotspots. *Nature* 406:818.
5. Sciencewatch.com (2008) *The 20 Most Cited Papers in Environment & Ecology, 1998–2008*. Available at http://sciencewatch.com/inter/aut/2008/08-oct/08oct20PaprsENV/. Accessed July 2, 2011.
6. Joppa LN, Roberts DL, Pimm SL (2011) How many species of flowering plants are there? *Proc Biol Sci* 278:554–559.
7. Pimm SL, Jenkins C, Joppa LN, Roberts DL, Russell G (2010) How many endangered species remain to be discovered in Brazil? *Natureza e Conservação* 1:71–77.
8. Cincotta RP, Wisnewski J, Engelman R (2000) Human population in the biodiversity hotspots. *Nature* 404:990–992.
9. Baillie JEM, Hilton-Taylor C, Stuart SN, eds (2004) *2004 IUCN Red List of Threatened Species. A Global Species Assessment* (IUCN, Gland, Switzerland).
10. Shearman PL, Ash J, Mackey B, Bryan JE, Lokes B (2009) Forest conversion and degradation in Papua New Guinea 1972–2002. *Biotropica* 41:379–390.
11. Laurance WF, et al. (2011) Predatory corporations, failing governance, and the fate of forests in Papua New Guinea. *Conservation Letters* 4:95–100.
12. WWF (2011) *More Than 1000 New Species Found in New Guinea*. Available at http://www.wwf.org.uk/what_we_do/press_centre/?5041/More-than-1000-new-species-found-in-New-Guinea. Accessed June 27, 2011.