Conserving Biodiversity Coldspots

Recent calls to direct conservation funding to the world's biodiversity hotspots may be bad investment advice

Peter Kareiva and Michelle Marvier

The numbers are chilling. Every year tropical forests covering an area the size of Poland are destroyed. With them, perhaps ten thousand species are wiped out annually, most before they can be so much as cataloged. Some liken the current calamity to the last episode of mass extinction—65 million years ago when a wayward asteroid killed off the dinosaurs along with about two-thirds of the species then in existence.

The rapid loss of tropical forests throughout the world and the widely recognized "biodiversity crisis" have spurred various nongovernmental conservation organizations and international agencies to develop strategies for protecting natural habitats. But the scale of the crisis is so daunting that conservationists widely accept the need for some sort of triage, whereby limited funds go to the places where the greatest good can be done. Experts have explored various ways to set priorities, and almost without exception, rainforests get top billing. The reason is simple: These tropical ecosystems harbor more unique species than any other habitat or place. Identifying and protecting such "biodiversity hotspots" has thus become the reigning scientific paradigm among conservationists.

Biodiversity hotspots are regions with unusually high concentrations of endemic species (species that are found nowhere else on Earth) that also have suffered severe habitat destruction. Norman Myers, an environmentalist affiliated with the University of Oxford, first coined this term in a scholarly paper he wrote in 1988. Now, virtually every textbook on conservation biology contains a map of the world's biodiversity hotspots. Although lush tropical rainforests first leap to mind, oceanic islands and Mediterranean ecosystems such as those found in California, South Africa and Australia are also considered hotspots because they, too, show exceptionally high rates of plant endemism.

The hotspot concept has been extremely effective at directing international funding and philanthropy. Given this success, we think it worth pausing to examine the scientific foundation of this conservation strategy and to consider what the consequences of this concept may be for the huge expanses of the planet that it leaves out in the cold—places we might dub biodiversity "coldspots."

Does it make scientific sense to downplay the world's steppes, the Serengeti, the wild Arctic and other relatively species-poor areas in favor of biodiversity hotspots? Clearly species richness should be considered when deciding where to invest conservation dollars and effort. But there are other relevant factors. We believe that ecological theory, consideration of ecosystem services and sociopolitical realism all argue strongly against placing too much emphasis on biodiversity hotspots. Yet, lamentably, little consideration has been given to alternative frameworks for setting priorities.

Warming Up To the Idea

Before probing the weak points of hotspot-based strategies, we should explain precisely what data and reasoning have been used to define this approach to conservation. Hotspots are meant to represent areas of high biological value that are under severe threat (the menace usually being people's readiness to destroy the natural habitats around them). It is hard to find fault with this general line of reasoning. However, some potential problems become apparent after you realize that there are in fact many different ways to quantify biological value. The hotspot approach emphasizes species richness. More specifically, it calls for tallying up the number of endemic plant species in a region. Although this simple yardstick correlates with other measures of species richness at huge spatial scales (say, tropical versus temperate), several analyses over the past decade have revealed that the hotspots for different taxa do not coincide well with one another, that hotspots often miss rare species and that major animal groups could be lost by devoting too much attention to endemic plants.

Why then just count plants? Because conservationists need some quantitative way to

Peter Kareiva is Lead Scientist for The Nature Conservancy. His current focus is on the examination of different conservation strategies, although he also maintains a program of field research on the invasion of North America by exotic ladybird beetles. Kareiva is also affiliated with the Bren School of the University of California, Santa Barbara and the Environmental Studies Institute at Santa Clara University. Michelle Marvier is a faculty member in the Department of Biology at Santa Clara University. Her research involves the study of parasitic plants and the environmental implications of genetically modified organisms. Address for Kareiva: The Nature Conservancy, 217 Pine Street, Suite 1100, Seattle, WA 98101. Internet: pkareiva@tnc.org

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Figure 1. Faced with limited resources, many conservationists are concentrating their efforts on biodiversity "hotspots," comparatively small areas that each harbor a large number of species that can be found nowhere else. The authors argue, however, that such a strategy is problematic, in part because it ignores the requirements of large carnivores, like this polar bear living near the shores of Hudson Bay. These creatures require vast territories, which may not be particularly rich in species.

gauge species richness, which is likely to be a component of anyone's figuring of biological value, and the available data tend to be more complete for plants than for animals. So counting plants is certainly a reasonable approach. One just needs to recognize the limitations of working with this rather one-dimensional representation of biodiversity.

The degree of threat to an area is even harder to quantify, because there are many kinds of perils facing species and many different ways to evaluate the hazards. Moreover, there is no *a priori* reason for selecting one measure of danger over another. The hotspot approach focuses on the percentage of primary vegetation that has been destroyed. To qualify as a hotspot, a region must have suffered a loss of at least 70 percent of the original vegetation. Again this definition is reasonable, but it has its limits—in particular because the fraction of natural plant life that is already gone is more a statement about land use in the past than a direct indication of future threat. Thomas D. Sisk of Northern Arizona University and his colleagues have argued that the danger may be more accurately reflected in the current rate of human population growth nearby or in the fraction of species in the area that are currently regarded as being at risk.

Clearly, the details of how hotspots are defined are subject to disagreement, but the general concept still appears compelling: Hotspots seem to be a way of directing conservation efforts toward the most cost-effective actions. Indeed, the notion of cost-effectiveness is a top selling point. As Myers and four colleagues argued three years ago in an influential *Nature* article, "44% of all species of vascular plants and 35% of all species in four vertebrate groups are confined to 25 hotspots comprising only 1.4% of the land surface of the Earth." Their basic prescription is to collect as long a list of species as possible in as small an area as possible and target conservation first where people have already destroyed a great deal of habitat. Although these authors (and some others who have taken up the baton) do acknowledge the need for complementary strategies, the hotspot

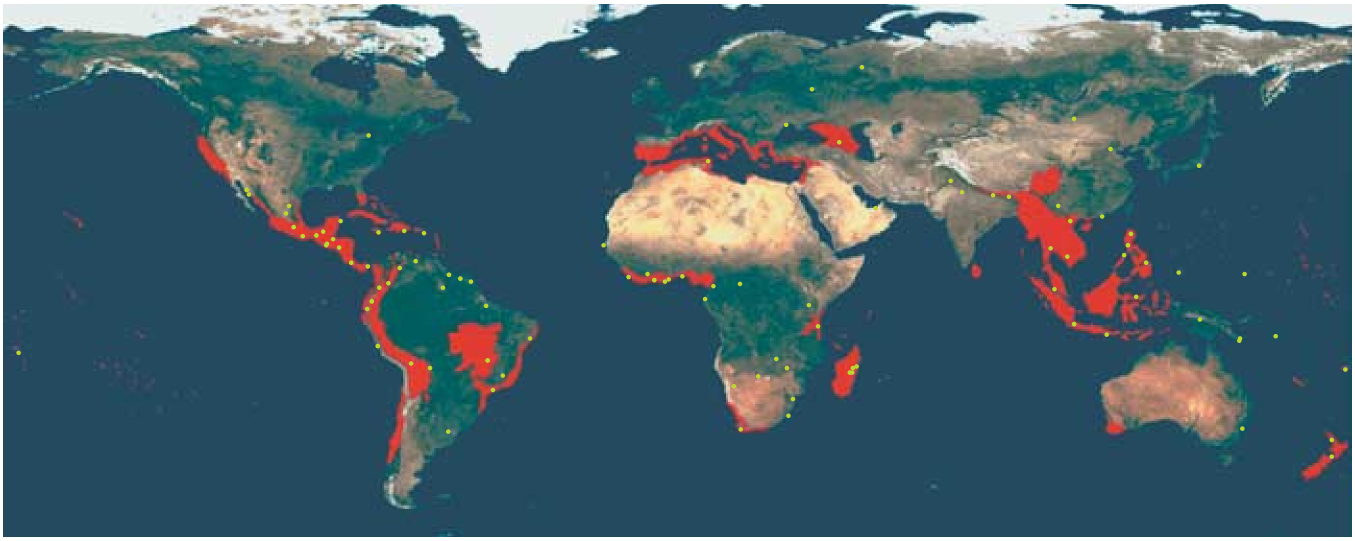

Figure 2. Biodiversity hotspots, as defined by Myers *et al.* 2000 *(red),* span the globe, but they fall mostly in the tropics. The influence of Myers's hotspot concept is evident in the distribution of the office locations for the three largest nongovernmental conservation organizations *(green dots)*—Conservation International, The Nature Conservancy and the World Wildlife Fund—shown here with the many office locations in the United States and Western Europe excluded. (Background colors from satellite imagery, courtesy of ARC Science.)

concept has grown so popular in recent years within the larger conservation community that it now risks eclipsing all other approaches.

Not-So-Hot Consequences

At first glance it may seem self-evident that conservation investment should be funneled into the regions or countries with the most biodiversity. But the hotspot methodology is logical only if the exclusive goal of conservation is to protect the largest possible number of species in the smallest possible area. Using hotspots to set priorities comes into question as soon as one considers a broader range of objectives, such as maintaining functioning ecosystems throughout the world, providing the greatest variety of distinct plant and animal lineages for future evolutionary breakthroughs, preserving spectacular wild landscapes that inspire the human spirit or protecting nature in a way that provides for the well-being of people living alongside.

A hypothetical example reveals some of the unfortunate side effects that arise from emphasizing hotspots above all else. Consider two areas of roughly equal size, the country of Ecuador and the state of Montana. Ecuador is a renowned biodiversity hotspot, harboring 2,466 vertebrate species and 19,362 vascular plant species. In contrast, Montana is a biodiversity coldspot, with only 12 percent of Ecuador's species richness. Clearly, if one measures success as protecting the largest number of species in the smallest possible area, it makes sense to ignore Montana and to concentrate solely on Ecuador. But assume for the moment that we desire some level of conservation effort in both places. Suppose we set a goal of ensuring protection for 20,000 total species from these two areas. We could attain that outcome by preserving 18,000 species in Ecuador and 2,000 species in Montana, or, alternatively, by safeguarding 19,000 species in Ecuador and 1,000 species in Montana. If all that matters is the total number of species protected, these two strategies are equivalent.

In reality these two choices would have vastly different consequences on the ground. Both would leave Ecuador with the bulk of its biodi-

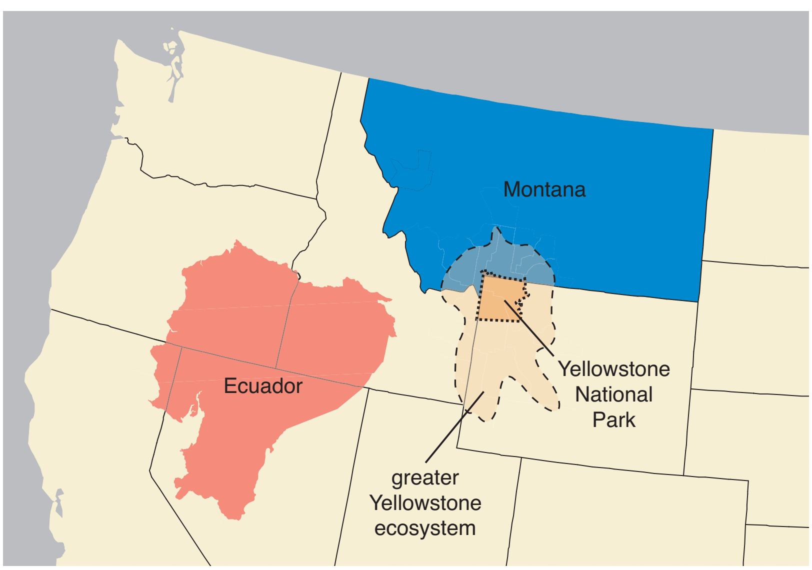

Figure 3. State of Montana and the country of Ecuador cover similar areas, but the latter is home to far more species. In weighing how to address conservation concerns in these two places, should all available resources be focused on preserving Ecuador's richer natural capital? No, the authors argue; it would be better to allow a small fraction of Ecuador's species to perish if this sacrifice would permit the protection of the same number of species in Montana, where they would amount to a larger fraction of the original flora and fauna. Conservation efforts in Montana would also help to protect the greater Yellowstone ecosystem *(dashed line)*, the only place in the lower 48 states where large mammals such as grizzly bears, wolves, bison and elk still roam freely in the wild.

versity intact (82 percent or 87 percent, if, for argument's sake, one considers just vertebrates and vascular plants) and, presumably, with reasonably well-functioning ecosystems. But shifting from the first to the second strategy cuts the fraction of species protected in Montana severely (from 74 percent to 37 percent). You wouldn't have to be a scientist to notice the difference between saving three-quarters versus two-fifths of the species in the state. But even the best-designed scientific monitoring programs would be hard pressed to register the difference between having 87 percent or 82 percent of the species under protection in Ecuador.

This example illuminates a major flaw with approaches to conservation that are solely based on hotspots. If we measure success simply by tallying up total species protected, we risk the folly of allowing major ecosystems to degrade beyond repair simply because they do not provide lengthy species lists. For instance, the Yellowstone ecosystem, which includes parts of Montana, Idaho and Wyoming, is species poor, relatively speaking. Yet this region harbors the last assemblage of large mammals and carnivores in the lower 48 states (grizzly bears, wolves, bison, elk and so forth). And because the Yellowstone ecosystem contains the world's first national park, it is obviously an important locale for continued conservation, despite the relative paucity of species that exist there. So by itself, the number of species saved is an inadequate barometer of success. Other dimensions of the problem need to be considered as well, including what environmentalists often describe as "ecosystem services."

Earth's Life-Support System

Society depends on the products and services ecosystems provide to a far greater extent than most of us realize. When asked what nature gives them, most people could name a few foods, drugs and building materials derived from wild species. But they would probably take for granted many other products of nature, including clean air, abundant fresh water, fertile soil and a benign climate. In short, they would fail to recognize the critical role that diverse communities of species play in fostering a healthy and predictable environment.

Would not hotspot-based conservation strategies automatically take such effects into account? Hardly. Investing conservation efforts only in hotspots could lead us to ignore and potentially lose some of our most valuable ecosystems simply because they harbor few plant species. Consider, for example, the fact that hotspot analyses so often point to tropical forests as areas of highest priority. These forests do indeed provide important ecosystem services, such as climate regulation and nutrient cycling, which Robert Costanza, an economist at the University of Maryland, and his colleagues recently valued at about $2,000 per hectare per year. But hotspot analyses overlook the value of wetlands—and it's easy to understand why: A typical *Spartina* marsh has no endemic plants and no more than 20 or 30 plant species total. Still, tidal marshes offer considerable ecosystem services, such as flood regulation, waste treatment and fisheries production, with an estimated annual value of nearly $10,000 per hectare per year. Clearly, marshes are precious resources, not just for people but also for the enormous variety of wildlife that depends on clean water. Yet by any sort of hotspot reckoning, these marshes would come out at the very bottom of the pile.

This difficulty would not arise if the stated conservation goal were to preserve the functioning of the planet's ecosystems to the maximum extent possible. This objective would not necessarily be incompatible with a desire to save species: Many empirical studies have shown that ecosystem services, such as production of plant biomass, retention of nutrients, resistance to drought, pollination of crops and decomposition of organic matter, decline with major losses in biodiversity. But one striking feature of the relation between ecosystem services and biodiversity is that it is not linear. Rather, the benefits of biodiversity are quickly realized with an initial accumulation of species and thereafter remain constant, so that protecting more species does not forever translate into more or better ecosystem services.

Figure 4. Wetlands, such as this one near Mobile, Alabama, provide valuable ecosystem services. Yet these places may host only a small number of plant species. A typical *Spartina* marsh, for example, harbors fewer than 30. (Courtesy of the U.S. Army Corps of Engineers.)

It is not clear how to predict where this saturation effect will manifest itself when one considers a variety of possible benefits. But if we accept that benefit curves do level off, we must accept that there are diminishing returns for protecting ever more species in any particular ecosystem. Given this pattern, a logical goal might be to ensure that no major ecosystem suffers greater than a 10 percent loss, or a 20 percent loss, or a 50 percent loss of diversity.

Although scientists lack the knowledge to assign values to the services provided by the ecosystems in all countries or regions, what matters is obviously not how many species there are as much as what percentage of the native diversity remains sheltered from destruction. The hotspot approach would result in high levels of protection for a few species-rich areas to the neglect of many others. Thus, setting conservation priorities using only hotspots as a guide could well bring on an unfortunate side effect: more degradation of global ecosystems than would take place if a more broadly based strategy were used.

Thicker Branches on the Tree of Life

Most conservationists emphasize ecological or ecosystem value when discussing the need to preserve biodiversity. But they often neglect an aspect of biodiversity that is just as important: its worth as a resource for future evolutionary innovation. In this regard, one has to consider more than just species. For example, a greater amount of evolutionary history and biological distinctiveness is lost when the last species of an entire genus or family becomes extinct than when a species with many close relatives disappears. Some evolutionary biologists have challenged the current focus on biodiversity hotspots as myopic, because it neglects the unique value of distinct evolutionary lineages, which represent very different life histories and forms. Rather than simply directing efforts toward areas with rich sets of endemic species, conservation organizations might better concentrate on saving higher taxonomic groups under threat.

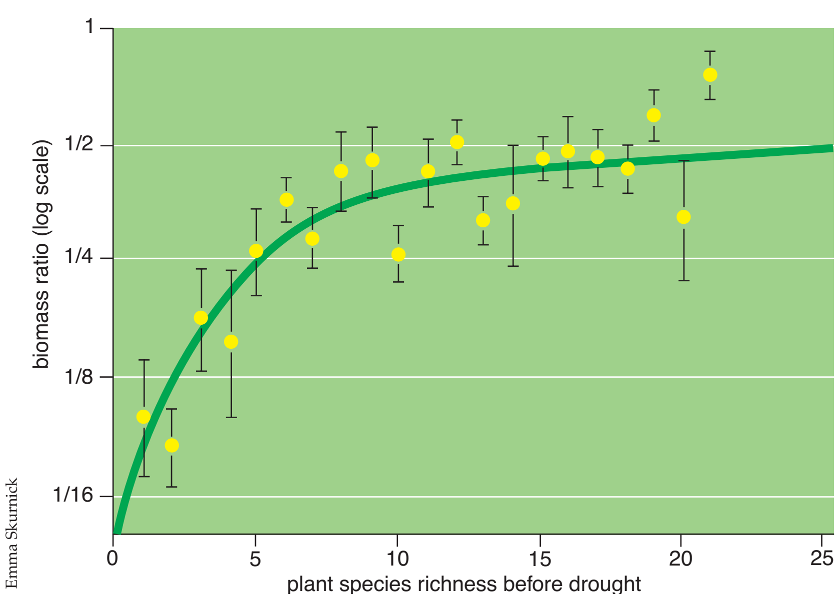

Figure 5. Ecosystem functioning generally improves as the number of species rises, but the relation is not linear. Typically, the benefits of increasing the species count accrue quickly and then level out. Here, one sees that the resistance of an ecosystem to drought, measured as the ratio of biomass after the drought to the biomass before, depends on species number—but only to a point. (Adapted from Tilman and Downing 1994.)

One could, for example, try to rescue genera that are in danger of being entirely lost. To test this idea, we looked at the distribution of mammal and bird genera with more than one species for which the World Conservation Union (IUCN) has listed all their constituent species as critically endangered, endangered, vulnerable or dependent on conservation. For each of the members of these highly threatened genera, we then searched IUCN's latest "redlist" database of endangered species and recorded all countries in which these rare creatures still occur naturally or have been reintroduced. We then ranked the countries according to the number of highly threatened genera that can be found there.

This procedure provides a list that differs greatly from one based solely on the richness of endemic plants. In particular, this exercise points to a greater need for conservation in certain African nations than does a hotspot-based approach. For example, Kenya, with only 265 endemic plant species, has never been identified as a biodiversity hotspot. Yet our ranking suggests that the conservation of Kenyan wildlife should receive urgent attention. After all, this nation is home to species belonging to each of the following eight highly threatened mammalian genera: *Alcelaphus* (hartebeest), *Connochaetes* (gnu), *Hippotragus* (a type of antelope), *Oryx* (another type of antelope), *Otomops* (a type of bat), *Redunca* (reedbuck), *Rhynchocyon* (elephant shrew) and *Surdisorex* (mole shrew).

Another shortcoming of the hotspot methodology becomes apparent when one looks carefully at how it is often applied. Although Myers and his colleagues initially proposed hotspots as a means of setting conservation priorities at a very large scale and in a coarse manner, the notion of getting the most species per unit area of land protected ("efficiency") has been translated to much smaller spatial scales with potentially unfortunate consequences. For example, in the past few years two influential analyses of biodiversity within the U.S. have been used to show how conservationists might efficiently protect species by focusing on just a few small clusters of critical counties. This strategy would, however, fail to protect adequately those species that require large tracts of relatively undisturbed habitat.

An added worry surfaces when you take a long-term, evolutionary perspective on the

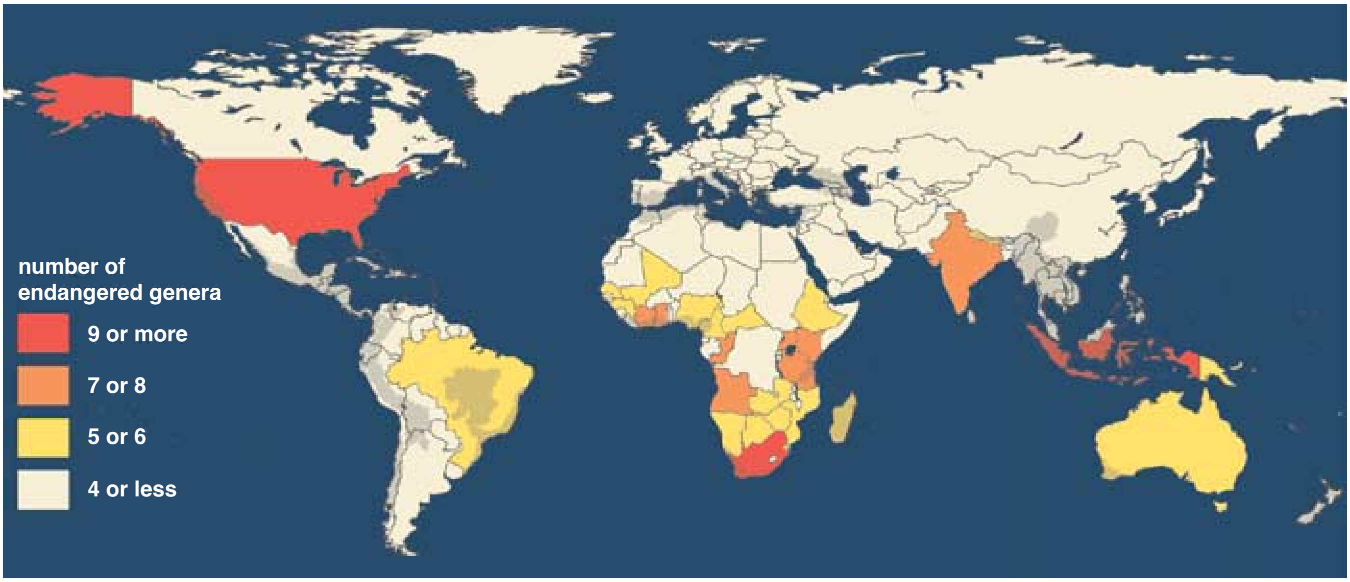

Figure 6. Conservation priorities can be set using any number of different strategies. Here the authors examined the distribution of bird and mammal genera that are in danger of being entirely wiped out and scored countries according to how many of these genera are still found there. The resulting map shows some similarities with the hotspots of Myers *(dark shading)* but also many differences.

problem. By focusing on conserving the most species in the smallest possible area (for the sake of cost-effectiveness), conservationists may inadvertently be altering the course of evolution. How? Protecting hotspots at small scales favors species that can live in relatively restricted areas. Thus we might expect rodents to enjoy high speciation rates relative to extinction rates. At the other extreme, species that require vast territories, and thus cannot be contained in cost-effective hotspots, will suffer disproportionate extinction relative to speciation. Hence primates and large carnivores would be expected to wane relative to their smaller mammalian counterparts. Recent analyses of vertebrate extinction and speciation rates suggest that this is exactly what is happening. Thus, as Donald A. Levin (of the University of Texas at Austin) and Phillip S. Levin (of the National Marine Fisheries Service) argued in these pages not too long ago (*Macroscope*, January–February 2002), the Earth may well end up with a paucity of primates and rhinoceroses, and a surplus of rodents.

One hopes that eventuality will not actually come to pass. Indeed, one hopes that society will ultimately prove able to protect habitats and ecosystems throughout the world so that evolution will be allowed to take a natural course. But in the short term it's clear that some tough decisions need to be made in allocating scarce resources. Thus far, most conservationists have focused on biological value as the major criterion for setting priorities. But others have explored different sides of the problem, including the degree of immediate threat to biodiversity, general feasibility and cost-effectiveness. Although there are many ways to go about doing this, it's hard to argue from scientific principles that any simple set of variables can be cast into the ideal metric for scoring urgency. This leaves scientifically minded conservationists with the unanswered question: What then should we do?

One thing is to make sure that the problem is framed properly. In recent times, biologists have achieved a major conceptual advance by realizing that conservation programs must span political boundaries and that for planning purposes biologically defined areas such as "eco-regions" represent natural units. Although this mindset is useful for quantifying biological value, it is not terribly helpful for making decisions about the feasibility or cost-effectiveness of a particular conservation project. When an organization decides to work in a region, it will necessarily have to deal with the regulatory agencies, legal institutions and people of individual nations. Thus, although our conservation goals may be biological, as long as feasibility and cost-effectiveness are important, countries will remain essential units for consideration.

One might thus be tempted to try to identify a comprehensive list of countries having great biological value and where an immediate threat looms—but also where action is cost-effective and feasible. Unfortunately, conservationists typically lack the information needed to assess all of the relevant variables. For instance, ecosystem services have not been widely calculated, current rates of habitat loss are only erratically available, and the uniqueness or irreplaceability of particular environments are complicated to assess. One solution is to investigate many different approaches to see whether certain areas are consistently identified as being of high priority. In other words, are some conclusions robust, no matter which criteria are used?

Clockwise from left: Nigel J. Dennis, Tom McHugh, Tim Davis, Merlin D. Tuttle/Photo Researchers, Inc.

Figure 7. Although it does not appear on any hotspots list, Kenya deserves urgent attention because it harbors members of eight highly threatened mammalian genera, including the four shown here: *Hippotragus* (a type of antelope, *far left*), *Rhynchocyon* (elephant shrew, *middle left*), *Otomops* (a type of bat, *middle right*) and *Oryx* (another type of antelope, *far right*).

In this spirit, we have invested quite a bit of time recently exploring all sorts of methods for setting conservation priorities. And what we've noticed is that some countries seem always to come out on top. A few—such as India, Vietnam, South Africa, the Philippines and Brazil—overlap with the top 25 hotspots that Myers and his colleagues identified. Interestingly, these five countries have relatively small percentages of their land under conservation protection, which suggests that they may be relatively sure bets, given that so much room for progress exists there. Yet other nations appearing on a great many of our priority lists have never been identified as biodiversity hotspots.

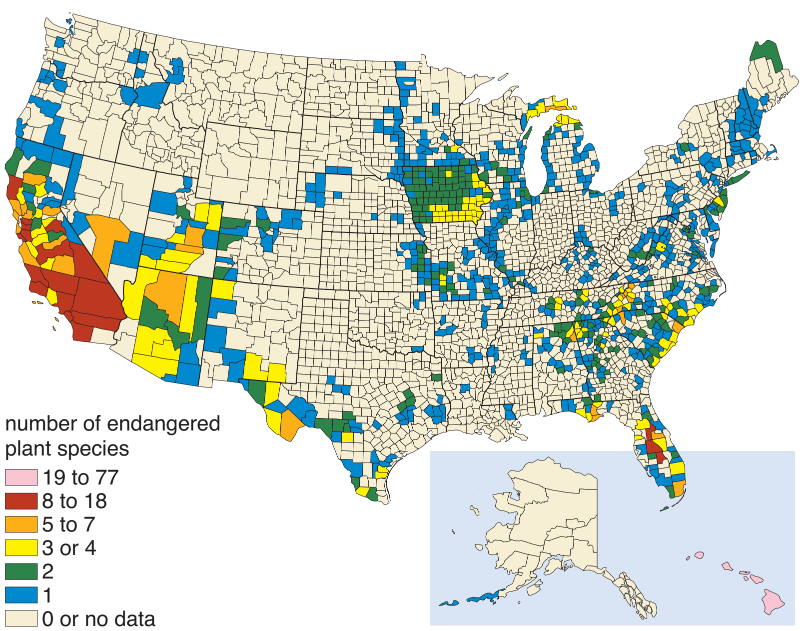

Figure 8. Using the threat to local species to identify certain areas as biodiversity hotspots, a strategy originally intended to establish conservation priorities on a broad, regional scale, has also been employed to evaluate small areas such as U.S. counties—with great potential for misapplication, according to the authors. Although one could economically concentrate conservation efforts using maps such as this one, the "hotspot counties" identified are commonly too small and too disjoint to provide adequate range for highly valued carnivores such as panthers, mountain lions, grizzly bears and wolves. (Adapted from Dobson *et al.* 1997).

Dispensing with Lists

Biodiversity hotspots represent an initial and pioneering effort at establishing conservation priorities. But by relying too much on counts of plant species, this approach loses sight of whole ecosystems, habitats and the needs of people. To work the metaphor a little harder, you might say that biodiversity hotspots leave too many places and people out in the cold.

Because many conservation threats are now global in their origin and scope (for example, climate change and invasive species), place-based priorities risk disenfranchising too many people from the challenge at hand. Indeed, on reflection, we worry that the initially appealing notion of getting the most species or greatest biological value per unit area is, in fact, a thoroughly misleading strategy. How much of a victory would it actually be if people did manage to conserve only the 1.4 percent of the Earth's land surface that contains almost half the world's vascular plants? The reality is that people must make conservation progress everywhere. Doing that requires not a ranking of theoretically deserving places but a prioritization that takes into account the effectiveness of past conservation efforts. A performance-based system would not only hold conservation organizations more accountable, it would also provide incentives to countries attempting to implement conservation measures, so that those nations demonstrating successes on the ground would be more likely to receive funding in the future. Anyone who has worked for a while in conservation knows that certain people and certain leaders can overcome enormous obstacles and do wonders in the most unlikely places. Yet none of the established priority-setting schemes recognizes such human factors.

We believe that the officers and directors of all too many foundations, nongovernmental organizations and international agencies have been seduced by the simplicity of the hotspot idea. Perhaps that's why, for example, 10 percent of the World Bank's biodiversity projects are located in a single country: Brazil. This fact is particularly noteworthy because the World Bank is the largest investor in biodiversity conservation. And collectively, the three largest nongovernmental conservation organizations (The Nature Conservancy, World Wildlife Fund and Conservation International) cluster a dozen offices in Mexico and put many also in Brazil, Indonesia, Madagascar and the Philippines. Meanwhile, countries with vast biological resources such as Russia and Argentina together host only three offices. Russia, in fact, rarely gets mentioned in conservation circles—perhaps because information on plant diversity in that sprawling country is so lacking that it is ineligible for hotspot lists.

Unwavering support for the protection of hotspots oversimplifies the difficult decisions that must be made in deciding which projects to fund and where to invest money. Although biodiversity hotspots are indeed an academically appealing idea, blind adherence to this mantra runs the risk of leaving the world with a sizable collection of species in a few areas but with an environment that is otherwise largely degraded. Rather than trying to identify dense concentrations of species on a map, we and other conservationists should be more flexible and should be prepared to reward effective actions on the ground as they happen. If we do so, we will surely discover plenty of coldspots deserving of our attention.

Bibliography

Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R. Raskin, P. Sutton and M. Van den Belt. 1997. The value of the world's ecosystem services and natural capital. *Nature* 387:253–260.

Dobson, A. P., J. P. Rodriguez, W. M. Roberts and D. S. Wilcove. 1997. Geographic distribution of endangered species in the United States. *Science* 275:550–553.

Levin, P. S., and D. A. Levin. 2002. The real biodiversity crisis. *American Scientist* 90:6–8.

Myers, N. 1988. Threatened biotas: 'Hotspots' in tropical forests. *The Environmentalist* 8:187–208.

Myers, N., R. A. Mittermeier, C. G. Mittermeier, G. A. B. da Fonseca and J. Kent. 2000. Biodiversity hotspots for conservation priorities. *Nature* 403:853–858.

Prendergast, J. R., R. M. Quinn, J. H. Lawton, B. C. Eversham and D. W. Gibbons. 1993. Rare species, the coincidence of diversity hotspots and conservation strategies. *Nature* 365:335–337.

Sisk, T. D., A. E. Launer, K. R. Switky and P. R. Ehrlich. 1994. Identifying extinction threats. *Bioscience* 44:592–604.

Tilman, D., and J. A. Downing. 1994. Biodiversity and stability in grasslands. *Nature* 371:363–365.

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