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KEYNOTE ADDRESS

IT'S A NEW CENTURY: DO YOU KNOW WHERE YOUR ORCHIDS ARE?

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ABSTRACT. Do you know where your orchids are? "Growing well in homes and botanical gardens" is not a sufficient answer, for surely we care about the ecosystems that are—and too often were—their homes. The news is not good: roughly half of all known plant species live in areas that, combined, cover only an eighth of Earth's ice-free land surface, ca. 17 million km^2. These areas, "hotspots," as Norman Myers has called them, are mostly tropical moist forests and include such places as Madagascar, Central America, and the Philippines. Of their original area, less than 10% remains. An additional 10 million km^2 of presently less threatened moist forests in the Amazon, Congo, and New Guinea house another quarter of Earth's plant species. About half of these forests remain, but they also are shrinking rapidly. So what can be done? Protecting the remaining large tracts of tropical forests is not a financially impossible task. Buying out logging leases is cheap, though protecting one's investment is altogether more difficult. Protecting the hotspots is even more difficult—they are more damaged, because more people live within them. Taking one of the richest hotspots, the Atlantic coast forest of Brazil, the presenter examined how to set practical priorities for conservation and the importance of taxonomic, biogeographic, and ecological knowledge in that process. What we do not know, he concludes, can most certainly hinder conservation efforts.

Key words: orchid inventory, taxonomy, biodiversity, conservation priorities

INTRODUCTION: WILL YOU MAKE A DIFFERENCE?

How much of what you do is going to make any difference to the future of biodiversity of our planet? In case this seems an unusually impertinent introduction to a talk, I ask the same question of the work that I do with birds. We all study biodiversity in one-way or another. We all know that it's disappearing fast. We are at this meeting because we care about orchid conservation. My uncomfortable question arises because what we know about biological diversity (including where it is found) might not usefully inform how we prevent its loss.

A few years ago, I decided to write a book about the planet—a modest book from its title—*The World According to Pimm*—but an immodest book by its scope—I simply wanted to know everything about the world (Pimm 2001, FIGURE 1). I wrote the book so that I could assemble "the big numbers"—the summaries of human impacts to the planet—and use them to guide where and how my students and I should prioritize our time and resources.

In this talk, I'll first provide a brief summary of the part of my book that deals with terrestrial environments. I'll show that human impacts are large, but many are at least theoretically reversible. The loss of species, however, is not reversible. Because of human actions, the rate of that loss is ca. 1000 times faster than in the geological past. This is the pressing environmental issue of the century. What we do about this issue is mostly a matter of protecting the places where the most vulnerable species live.

That argument leads me to take a close look at the coastal rain forest of Rio de Janeiro State. At least from my birdwatcher's perspective, I show that it is the most important area in all the Americas. I also will argue that it is likely to be the most important place for your orchids. If you agree with me, than either it's a remarkable coincidence, or else you simply don't know where your orchids are. You and I must find out! We cannot afford to wait to learn all we would like to know about nature, if we are going to prevent its loss. Among other things, we need to know now precisely which areas we must protect. As present trends continue, these priority areas will be gone in a few years.

All of what I will say presumes that the important place for orchids is in nature. Whatever the problems, whatever the misdeeds that have been done in the name of orchids and in the naming of orchids, the greater tragedy would be, if the only place they lived was in somebody's hothouse.

FIGURE 1. IOCC II Keynote Address speaker Stuart L. Pimm warms up the audience of orchid conservationists. Photo credit: Lee Desmon.

Big Numbers, Large Issues

We need to have the "big numbers," those summarizing human impacts, at our fingertips. The first big number is almost 20 years old now (Vitousek et al. 1986). It is a calculation that suggests we already use, one way or another, ca. 40% of the land's annual production of plant growth—the biological interest, if you like, on the biological capital. That was a calculation made with 5 billion people in the world. There are now 6 billion people aspiring to our high standards of living, and the fraction of annual plant growth that we use each year surely increases with both increasing numbers of people and increasing living standards.

This fraction comes in three big pieces: croplands, grazing lands, and forests, as well as some smaller pieces that I will not discuss. The earth's ice-free land surface is ca. 130 million km^2, and we use ca. 15 million km^2 for crops (ca. 12%). We have behaved like those awful people you invite over to your house, who sit next to the bowls of mixed nuts—cashews, macadamias, sunflower seeds, and peanuts—and pick out all the macadamia nuts and cashew nuts, leaving behind the less desirable ones. We've high-graded the planet. We have taken the best parts, opting for the flat, lowland temperate and productive parts for our agriculture, avoiding mountains, deserts, and tundra. As a percentage of the planet's productivity, croplands consume much more than 12%. Those 15 million km^2 are also choice real estate for biodiversity.

About 60 million km^2 of the ice-free land surface is grazing land. There remains much rich, productive grazing land. If you look at the distribution of grazing lands around the world, however, you find that the countries that have large fractions include Saudi Arabia and Afghanistan. Remember that the United Nations Food and Agriculture Organization (FAO) has to report what nations tell it to report by way of data. Much of the reported area for grazing represents very wishful thinking on the part of the nations involved. About 40 million km^2 of the planet's grazing lands are badly overgrazed and support much less grazing than their potential.

Finally, we come to the forests. The third piece of our impact on the terrestrial environments is our consumption of forests, but particularly tropical forests. Such forests are disproportionately important for biological diversity, so this is a crucial impact. From ca. 18 million km^2, we have reduced tropical forests to ca. 7 million km^2 in 50 years or so. We presently are clearing tropical forests at the rate of 1 million–2 million km^2 every decade, and we are burning and selectively logging even larger areas of those forests that remain. Our children will inherit a planet where tropical forests will be mere fragments of their former selves. The big forests—the Amazon lowlands, Central Africa, and Papua New Guinea—have barely been touched as yet or relatively so; they've lost about a quarter of their area. I will discuss other important areas, where tropical forests have been shrunk to ca. 5% of their original extent.

These numbers are not as grim as one might have thought. The world's croplands feed most of the human population but occupy only an eighth of the land surface. Biodiversity would have no chance, if our constantly growing population already occupied say ⅞ of the land surface! In principle, we could reverse or reduce our impacts. We could continue to develop more efficient agriculture and could learn to not abuse our grazing lands. We do not have to destroy the world's forests, for cleared forests generate only a tiny proportion of useful agricultural land and often only miserably poor grazing lands. We can have our nature and eat too.

We Do Not Live in Jurassic Park

The final big number is the problem. The biggest of the "big numbers" is that the impacts I have described are accelerating species extinction rates to a thousand times their normal level. Species extinction is irreversible. We do not live in Jurassic Park.

What do I mean by the "normal level" of species extinction? Apart from major catastrophes, such as the one that eliminated the dinosaurs, the geological record shows that on average a species lasts ca. 1 million years. Thus, other things being equal, one in a million species should go extinct every year. This provides a baseline against which to assess what happened when humans first encountered naïve biological diversity, to assess what we're doing now, and what we are likely to do in the future.

Let's go to Hawai'i. It is almost literally the last place on Earth, the place where humans last collided with nature, thus providing us an unfortunate laboratory for studying the effects of first contact. We know the Hawaiians extensively cleared the dry forests of the islands, forests thought to be rich in species. They cleared some of the lowland wet forests too. We don't know how many plant species they exterminated, but we do have an extraordinary record of bird fossils. We know 43 species of birds only from their fossilized bones. Using some statistical witchcraft, we can estimate how many species are missing from the fossil record; it's about an equal number. We know that following the European colonization of Hawai'i, we lost another 20 species of birds, and another 20 are presently teetering on the brink, numbering in one case as few as three individuals. Since the first botanists arrived in the islands, we know that ca. 100 species of plants have become extinct and 100 more we know from fewer than 100 individuals, many from as few as one individual.

For the birds, we can assemble similar data from other Pacific islands. Counting only extinctions in the Pacific—and so underestimating the global total—roughly one species per year has gone extinct over the last couple of millennia, as the peoples spread across the Pacific. That is a hundred times more extinctions than you would expect, for there are only 10,000 species of birds. Tool users armed with only Stone Age technology were capable of exterminating species a hundred times the geological background rate. Modern technology and the invasive species we take around the world with us, deliberately or accidentally, are capable of doing even greater damage. The awful conclusion must be that the extinction crisis, rather than a matter of some projections about the future, is a part of our recent history.

"Ah!" you say, "you are talking about islands, and island species are simply wimps!" I am reminded of a Wainwright cartoon, where a father, who is consoling his son, as wolves eat the people next door, says, "It's O.K., son, the Wainwrights were weak and stupid people." Some might say these island species had it coming to them. The Oxford English dictionary says of the dodo, "The dodo went extinct." It doesn't say, "The Dutch bludgeoned the poor bloody things to oblivion." The dodo has become the emblem of stupidity.

Perhaps human actions have simply removed the stupid species, poor things! Perhaps what have survived will now be O.K. The reality, however, is that modern day extinctions are not just species on islands. They include fish in the Mississippi River and East African Rift Valley lakes, plants in the fynbos of South Africa, mammals in Australia. All taxonomically well-known groups of plants and animals contain double-digit percentages of species teetering on the brink of extinction. Species dependent on freshwater habitats seem particularly vulnerable. Dodos, as it were, are in many places.

What Can We Do?

A few years ago, Ed Wilson (a long-time leader of biodiversity studies, e.g., Wilson 1988) and Gordon Moore (of Moore's Law fame) asked me to assemble 30 outside experts to think about what would be needed to prevent the loss of biodiversity. The crux of that meeting, "Can We Defy Nature's End?" was published in *Science* (Pimm et al. 2001). Our key recommendations were grouped into three major topics: (1) building local capacity, (2) addressing long-term needs and, most important of all, (3) protecting more of the planet. I'm only going to talk about the last of these three topics. Obviously the critical question is, which areas of the planet do we protect?

An immediate question is, what's it going to cost to save biological diversity? If we have to protect the entire planet, then the cost is prohibitive. The cost question comes with two parts because, very roughly, we can divide the world into those wilderness areas where human impacts are still very low and the other areas where human densities and impacts are high.

To save the wilderness moist forests of the world requires something on the order of $5 billion. Countries sell areas such as the Amazon and the Congo and Southeast Asia to loggers at the rate of ca. $10/ha. So buying out logging leases is a practical solution. A plan being led by Larry Linden (co-chair, Global Compliance and Control Committee, Goldman Sachs & Co., New York) is trying to protect ca. 10% of the Amazon, and the asking price is about a quarter of a billion dollars. The difficult issue is not raising the money, but how to get good value for the money, avoiding corruption and solving a variety of other issues. That is where building local capacity turns out to be vital—substantial local involvement is needed to guarantee the investment. To these moist forests, we also should add large areas of sparsely populated open woodlands in Africa, tundra areas of the Arctic—the driest of deserts. In such cases, land costs are small.

If Fortune were kind, protecting these wilderness areas would be sufficient. Alas, the other part of the cost issue involves areas that have many more people and that already have lost ca. 90% of their forests; land prices in these areas are very much higher. As I shall demonstrate, these areas are disproportionately important for conserving biodiversity. The estimate for protecting these areas, which are much smaller than wilderness forests, is on the order of $20 billion. Even that requires us to act in a sensible way. If we are going to try to protect parts of the Atlantic coast forest of Brazil, parts of the Philippines, parts of the Eastern Ghats (Subba Rao this issue), we've got to know precisely where to act. It is in these places that knowledge of biodiversity of different groups becomes critically important. Sometimes heartbreakingly small conservation priorities can be biologically important, and we biologists have the major role in identifying them.

I accepted the gracious invitation to give this talk, because many people are passionate about orchids, as are many about birds. John Gould, of course, famously painted them together in the 19th century. Orchids are well-known; the existence of this Orchid Conservation Congress speaks to a large international body of concerned scientists.

Orchid biologists would now seem to have a major role to play in international conservation. With a reasonably complete taxonomic catalogue of a plant family that generates so much interest, it would seem likely that orchids might provide detailed answers to the questions of where are the conservation priorities.

For birds, we can simply go to a book, *The Threatened Birds of the World* (Stattersfield & Capper 2001), and look up which species are teetering on the brink of extinction and where they are to be found. Simply, we know the places where conservation actions are vital to prevent bird extinctions.

Yet, we cannot do this for orchids! The 2003 Red List of Threatened Plants (IUCN 2003) lists a mere 23 species out of 24,500 orchid species worldwide (Dressler this issue). The number 23 is obviously wrong; I will argue that threatened orchid species are likely 60 times this number in the Americas alone. Looking up the global list of threatened orchids and where they are found is obviously not the right way to go about setting priorities. We have to find an alternative.

Many mechanisms drive species to extinction. People steal orchids—likely the reason why orchid biologists are so tight-lipped about where they occur. We all understand, however, that the predominant driver of extinction is habitat loss; and from that, we can begin to set conservation priorities. An indirect way to set priorities is to estimate where species are most likely to become extinct from looking at where species are most numerous and where little natural habitat remains.

Cookie-Cutter Extinction

So what do we know about the distribution of species and how can we put that information together with the destruction of the habitat to produce a map of orchid conservation priorities? A bird distribution map of North America, providing detailed range information, shows that Canada has few species and the USA a few more, but things become exciting when you get down to Central America, and they become spectacular when you get to South America (Pimm 2001). There is, for birds, about a tenfold increase in the number of species per latitude-longitude degree from Canada to the Amazon.

No such map exists for orchid species, but the general patterns seem to be broadly similar. The *Flora of North America* (Vol. 26, 2002) records that the United States and Canada have 202 native orchid species. Guatemala and Belize have 527 native orchid species; Ecuador ca. 3000; and Brazil has slightly fewer. Too many of the places where many orchids (and birds) are found have become massively fragmented habitats, where deforestation has removed 90%, 95%, sometimes 99% of the original landscape. We have a very good idea about what fragmentation does to species. Small fragments lose most of their species; and, from the few studies that have followed species loss after fragmentation, they lose their species quickly. For birds, for example, studies show that fragments less than 1 km^2 tend to lose most of their species within a decade or so (Ferraz et al. 2003).

So how can we combine species distribution data with that of habitat destruction to produce a prediction of where the most species are likely to be going extinct? The answer is not simply going to depend on the number of species, that is, more extinctions where there are more species, for any given level of habitat destruction. If that were true, one would have very few extinctions in Hawai'i, because there are not a lot of species on the islands (indeed, islands in general). Rather, species differ significantly in their vulnerability to extinction. In *Science,* no less, I have called the model that works the best the "cookie-cutter" model of extinction (Pimm et al. 1995). Imagine habitat destruction as a giant cookie-cutter that cuts out the areas where species live. In areas where species have large geographical ranges, you are not going to lose many species, for those species will survive outside the destroyed area. In contrast, if the cookie-cutter comes down where a concentration of species have small ranges, then you likely will lose the many species found only there. In other words, endemism matters. Map out where endemic species are concentrated, that is, where species with small ranges live. These are the places where, for a given degree of human impact, we are going to cause the largest number of extinctions.

If we look at birds in the Americas, we can map out such areas in some considerable detail. We can see the Caribbean, Central America, the Andean cordillera, and the Atlantic coast forest of Brazil as potentially vulnerable areas, where small-range species are concentrated.

For plants, Norman Myers, has identified the world's hotspots (Myers et al. 2000)—where small-range species are concentrated in places with disproportionate loss of habitat. Such are the places where extinctions should be most frequent. Not everyone understands that Norman's definition of hotspots has two parts, because very few places have concentrations of small-range species but only low levels of habitat destruction. New Guinea is one.

For the Americas, Myers identifies four hotspots that are partly or entirely the tropical humid forests that, as such, are likely to be rich in orchid species. Two other hotspots involve dry forests or shrub ecosystems. The tropical Andes retain ca. 25% of their original forests, Meso-America ca. 20%, the Caribbean ca. 11%, and the Atlantic coast forest of South America, 7%. The numbers of plant species found only in these areas (i.e., the endemics) are 20,000; 5000; 7000; and 8000 respectively.

We can derive a rough estimate of how many threatened species should be in each area. A broad relationship exists between area and species, and it is nonlinear. If we lose 50% of the forest, we should expect to lose ca. 15% of its species. (I have spent a considerable amount of time over the last decade, demonstrating this rule to apply to a variety of vertebrate groups in species-rich parts of the world.) Deforestation is an accelerating destroyer of biological diversity, for obviously, if you lose the second 50% of the forest, you lose all of the species.

So let me make some outrageous extrapolations, taking the number of endemic species in these areas, looking at the habitat left, and then predicting how many should be threatened. I'll also assume that since ca. 10% of all the world's plant species are orchids, that 10% of the known endemics are orchids. These extrapolations suggest that the tropical Andes, Meso-America, the Caribbean, and the Atlantic coast forest of South America, should have roughly 600, 150, 300, and 400 species of orchids teetering on the brink of extinction.

I'm particularly pleased that the Andes get the attention they deserve from this conference, including from Jorge Orejuela of Colombia, with whom I shared a house in graduate school and now clearly share a concern for both orchids and birds (Orejuela this issue). My emphasis—as with that of several other papers at this conference—will be the Atlantic coast forest. Despite the considerable uncertainties in my numbers, it is almost certain that large numbers of orchid species are threatened there.

The World Wildlife Fund map of the Atlantic coast forest eco-region shows that the moist forest was originally ca. 1 million km^2 in size. According to our analyses of satellite data, forest cover is now down to 6.5%—slightly less than the Myers estimate (Myers 1992). So little forest remains that surely all of what remains must be a conservation priority. Certainly, so, but the practical reality for my colleagues at the State University of Rio de Janeiro is to advise their state government on which areas demand immediate attention. Thinking about this challenge is what exercises me so much. Can I provide any advice that is helpful? Considering orchids alone, the lives of hundreds of species may depend on getting the answer right.

Orchid Priorities

One solution is to assemble a large number of experienced naturalists and ask them to draw on maps the various areas they think are important, then work toward a common set of priorities. I took part in such an effort at setting priorities sponsored by Conservation International (CI). With my Brazilian friends, I found that all the different points of view really aren't helpful at all. In fact, it's worse than that. The designated CI conservation priority areas total 360,000 km^2, about six times the amount of forest left in the entire region! Also, the typical designated conservation priority area was about ten times larger than any national park that the Brazilians have been able to establish. Obviously, the CI expert-systems approach does not help very much. So

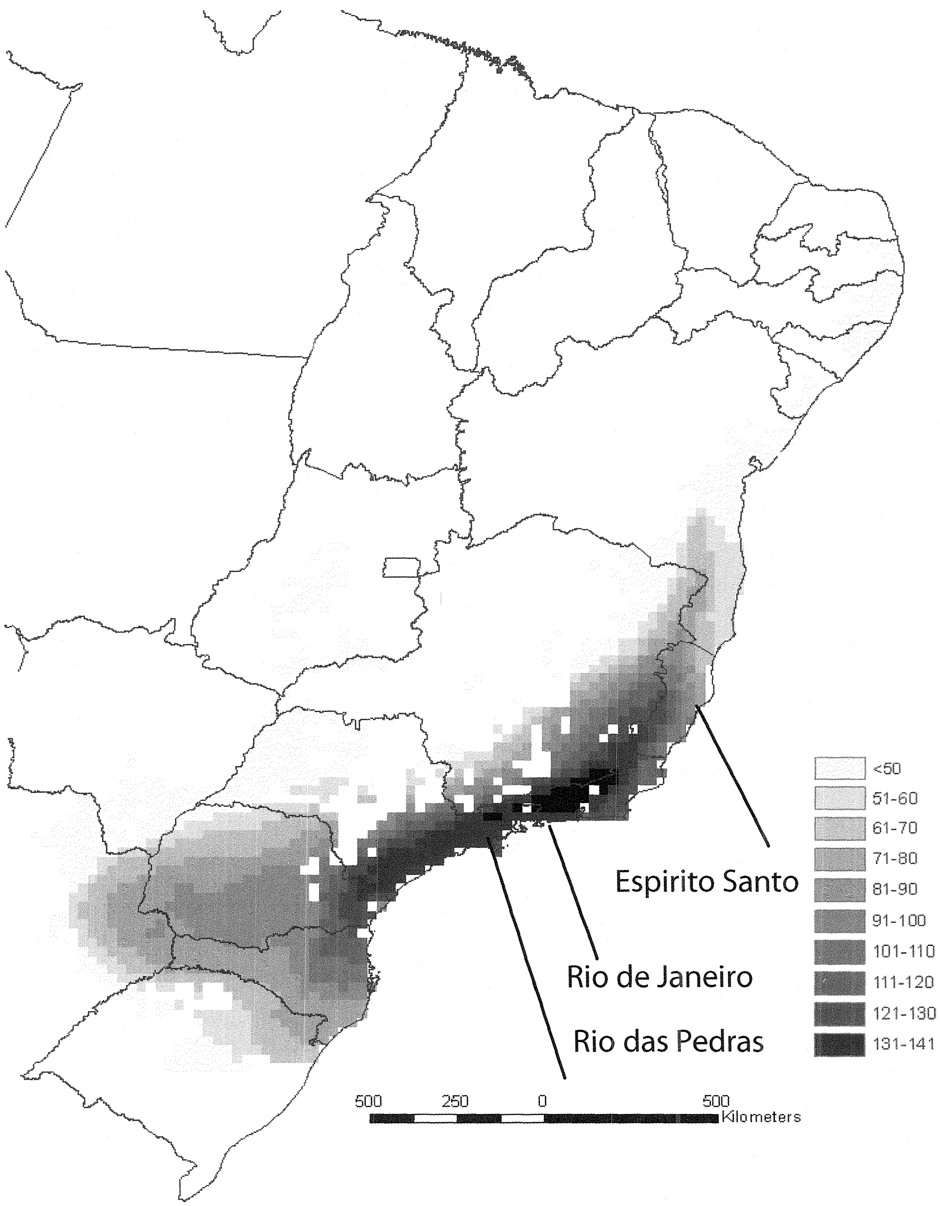

FIGURE 2. Species richness of endemic birds in the humid forests of the Atlantic coast of South America.

let's try to find out what we know about ranges to employ a more quantitative approach.

For birds, I can go to a database and plot out the distribution of all the species endemic to the Atlantic forest. FIGURE 2 shows that the state of Rio de Janeiro has a large concentration of such species. Can we do this for orchids?

The New York Botanical Garden has a database for eastern Brazil. It contains 1628 records on 591 orchid species. I know absolutely nothing about orchid taxonomy, so I have taken their taxonomy at face value. Despite having access to excellent gazetteers for coastal Brazil, I only was able to find data for about half the locations. (In the database, I immediately truncated all locations to the nearest latitude-longitude degree, a roughly 100 km square, because I know how very sensitive orchid location data are.) Of those 591 orchid species, 284 are known from only single locations. Of those found in more than one location, I conservatively connected the locations to produce a putative range for the spe-

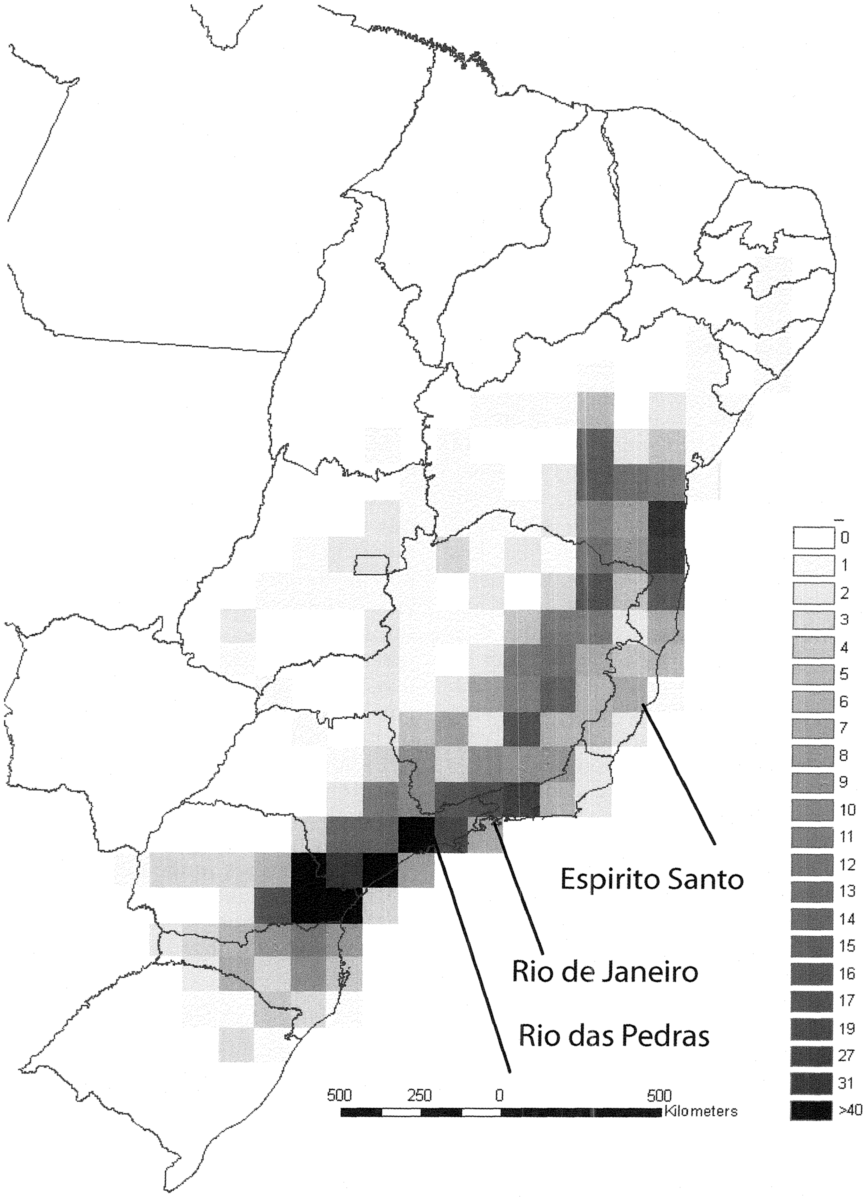

FIGURE 3. Species richness of endemic orchids in the humid forests of the Atlantic coast of South America.

cies. FIGURE 3 is the result. How good is this map?

Unfortunately, the answer is likely to be "Not very!" There are a couple of benchmarks against which to compare it. One is the extensive taxonomical treatment by Ruschi (1986) for the orchids of the state of Espirito Santo. He reports 600 species with about 150 endemic ones. Also a poster (Saddi et al. this issue) was memorable for three key pieces of information: 22 degrees S, 44 degrees W, and 88 species. Indeed, this was one location, not the entire one-degree cell. The total species count for that cell would be larger, of course. It is clear from comparing these benchmarks that the orchid map has far too few species present in each cell relative to what detailed studies show to be present. In short, the database is woefully incomplete. It might represent an unbiased sample, of course. If so, it suggests that coastal forests—particularly in the State of Sao Paulo and maybe into Rio de Janeiro State—are where the greatest numbers of orchid species will be found.

At best, this is a very vague answer, I see no way of making it more finely resolved, and it provides little if any help to my Brazilian colleagues. At worst, the sample may be a very biased one, for there may be many species missing from the database. Such missing species will surely be the rarest species, the very ones for which we need range data.

Do Bird Priorities Work for You?

For birds I can provide a much more specific answer. Landsat satellite images make it immediately obvious that a very significant amount of what forest remains is in tiny forest fragments. By using computer witchcraft, I can take out those forest fragments smaller than 100 ha. I know for birds that anything smaller than this has no conservation value—smaller fragments losing most of their species within a decade (Ferraz et al. 2003). Do fragments smaller than 100 ha have conservation value for orchids? I am certain that the answer could be found with no more than a few weeks of work surveying orchid lists from fragments. It might already be known. The answer to this question is vital, because it sets a limit on what we can hope to protect and what might have some value.

Using simple GIS techniques, we can combine the map of forest cover with the small fragments removed, a map of the broad geographical range of a species, and (based on knowledge of the elevational range of the species) a map of areas of the right elevation. The resulting intersection is a prediction of where a species should live. We can sum these maps to produce a prediction of the areas that hold the greatest number of endemic species.

What emerges from this process is a set of small areas east of the city of Rio de Janeiro. They are the remaining areas of lowland forest, and they are fragments isolated from larger areas of upland forest nearby. I find these predictions compelling: they are small, compact; and thus conserving them is practical. They suggest an immediate course of action: acquire the land and allow the forest to recover on it. As global warming unfolds, the species in the lowland patches will need to creep up the nearby hillsides, something not possible if the forest patches are isolated. Those forest islands represent what I believe to be the most important conservation priority in all of the Americas, because I know these isolated forest islands have more endangered bird species than any other place of comparable size.

Although based entirely on birds, my conclusion is likely taxonomically robust, simply because the lowlands likely have more species of everything than the uplands, and there is much less of the lowlands left than the uplands. It is not impossible that this could be the single most important priority for orchids.

I find one of these forest islands, in particular, to be heartbreaking, because the strip that isolates it is only ca. 100 m wide and 1 km long. Only something on the order of 10 ha needs to be acquired, if we are to protect its species. Such a purchase would not challenge the resources of a large, international conservation group; and a small, local NGO does express as much passion about this place as I do.

My question for you: is this the most important priority for orchid conservation in the Americas? Much might be wrong in claiming this to be a priority for orchids. There may be more orchid species at higher elevations. This may be too dry a habitat, although many of Brazil's clearly endangered orchids occur in the dry forests along the coast that are under such desperate stress from people who want to build houses there. Figure 3 also suggests that this area is too far east of the main concentration of orchid species.

I know that you will now rise up and tell me that you have your own particular preference. Naturally, it happens to be exactly where you are presently working. The cold, hard reality is that we who work in the field must make a clear case, an unmistakable case, for setting priorities for the foundations that are going to have the financial wherewithal to implement them.

Conclusion

The maps of orchid species diversity are not good enough! So, show me some better ones. You have to answer my question, "Do you know where your orchids are?"—the answer being, "Yes, and here's why it matters,"—if you are to have a place at the table in saving biological diversity. If you cannot answer that question, you can't tell me why my priority is not your top priority.

I didn't think for a minute that mine would be a comfortable address. You will argue that, if we are to conserve orchids, there are other things we must do besides mapping their ranges. Of course, you are right, but you know my argument for protecting more areas for orchids (and everything else) is a powerful one.

In case you think I have been unusually punishing to orchid people, I have been even more callous to those who study birds. Even our knowledge of such well-known taxa might not matter. In the lowland coastal forest of Brazil, with most of the remaining forest in isolated islands, taxonomy doesn't matter, and perhaps biogeography doesn't matter either. Perhaps we should just simply recognize that whatever forest remains of whatever forest type is represented the least, has to become the conservation priority.

Stated that way my audiences fight back. Some tell me, "Wait a minute, I know more than that. I know that there are places that matter more than other places. I know that there are elevations that matter more than other places, that we differ in our evaluation of whether a small fragment is as useful as larger fragments, that detailed knowledge of natural history can be important!"

I tend to agree: I think it is likely that geography, ecology, natural history, and taxonomy matter. Simply wishing that they do is insufficient. Some of what we know may not be important. Ignorance of what we need to know, but don't, condemns species to extinction.

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