WHAT TO LET GO

Not all species can be saved from extinction. **Emma Marris** talks to conservation biologists about prioritization and triage.

M. HARVEY/NHPA

Richard Cowling was playing with maps of South Africa on a computer screen when he had his epiphany. He was designing a conservation plan for the Cape Floristic Region, or fynbos, an arid landscape of shrubs and flowers that contains some 9,000 species, many unique to the area. Some of these, such as the mandala-like sunset blooms of the protea flowers, are spectacular. Some — like the geometric tortoises, whose fetching shells help them hide from baboons and secretary birds — are seriously endangered. Cowling, a conservation biologist at Nelson Mandela Metropolitan University in Port Elizabeth, was working on defining a set of reserves that would maximize the chances of conserving all those species. The project was so large that it would end up as a series of 16 papers by 36 authors that occupied all 297 pages of *Biological Conservation*'s July–August 2003 issue. And it was also, Cowling realized as he stared at the screen, "sheer nonsense".

"I had to click on a couple of grid squares and the project would be complete," Cowling says. "And it dawned on me: complete for whom? There was no way that this reserve would ever happen. It had to be linked to some social realities on the ground."

In the preface to his 1981 book, *Extinction*[1], Paul Ehrlich, a biologist at Stanford University in California, provided a powerful parable for conservation biology: the story of the rivet popper. A passenger inspecting the plane he is about to fly in notices someone popping rivets out of the wings. When challenged, the rivet popper says that the passenger shouldn't worry because not all the rivets are necessary. For Ehrlich the rivets represent species and the rivet popper represents humanity, indifferent to the looming danger of ecosystem collapse and the end of the natural processes that supply raw materials of life such as clean water, wild food, carbon sequestration and climate regulation. In the apocalyptic style for which he has become famous, Ehrlich predicted that continuing to pop the rivets of ecosystems would lead to "a crumbling of post-industrial society". He demanded that the rivet popping be stopped.

There aren't many, if any, conservation biologists who would disagree with that conclusion. In principle. The problem is that they don't have the resources to back up such ambition in practice. Spending on conservation by major international and non-governmental organizations has been estimated at around US$2 billion a year[2]. Given constrained resources, the biologists have to set priorities. 'Triage' is a dirty word in some conservation circles, but like many dirty words, it describes something common. Whether they admit it or not, conservationists have long had to make decisions about what to save.

As more and more admit it, open discussion about how the decisions are best made — by concentrating on particular species, or particular places, or absolute costs, or any other criterion — becomes possible. Whichever criteria come into play, one thing remains constant. The decisions have to be made quickly. In the bloody business of conservation biology, the longer you pause to reorder your list, the more species will become extinct.

Superfluous species

Perhaps the most controversial basis for triage is redundancy — prioritizing those species that provide a unique and necessary function to the ecosystem they live in and letting go of those that are functionally redundant. It might seem sensible to lose a few rivets around the plane's over-engineered windows if that saves the rivets actually holding the wings to the fuselage. This idea was raised in the early 1990s by Brian Walker of the Australian Commonwealth Scientific and Industrial Research Organization[3]. "Regrettable as it might be," he wrote, "it is most likely that global biodiversity concerns will ultimately reduce to a cost–benefit analysis. Without knowledge of redundancy, or more broadly, the relationship between the levels of biodiversity and ecosystem function, we cannot estimate either the costs or the benefits."

The majority opinion among conservation biologists today is that they still understand too little about ecosystem functions to say for sure which species are the 'load-bearing' ones whose presence keeps a complex, multi-tiered ecosystem from collapsing into some worst case dull scenario of rats, roaches and invasive grass. "We are so fundamentally ignorant," says Norman Myers, a fellow of the University of Oxford, UK, and adjunct professor at Duke University in Durham, North Carolina. "We cannot afford, by a long, long way, to say which species are dispensable." Andrew Balmford, a conservation biologist at the University of Cambridge, UK, tends to agree: spotting key species is "an interesting exercise intellectually ... but by the time we've figured it out the forest will have gone anyway".

"I don't care if something is redundant. I want to save it for all these other reasons." — Kent Redford

Save the genes

Not everyone is quite so convinced the problem is ineluctable. "I think there are a lot of systems where we know more than we think," says Reed Noss, a conservation biologist at the University of Central Florida in Orlando. "If you can get naturalists to open up and talk about what they know, we can at least generate some testable hypothesis and do some manipulation if we have time." Kent Redford, head scientist at the New York-based Wildlife Conservation Society, agrees, up to a point. "Our big problem is that we have been raised to believe that unless you have complete information you cannot make recommendations, and I think that is something we are going to be put on trial for by our children. It's baloney." But his belief that science might make this sort of prioritization possible doesn't mean he approves of it. "I don't care if something is redundant," he says, "I want to save it for all these other reasons."

Perhaps aware of the resistance that functional prioritization might encounter, Walker's forthright paper suggested a complementary approach: taxonomic distinctiveness[3]. This turns out to be less contentious; although there are no organizations dedicated to sorting the load-bearing species from the non-load-bearing, there is at least one that dedicates its resources to saving the mammals that are phylogenetically distinct. The EDGE programme — its intials stand for evolutionarily distinct and globally endangered — of the Zoological Society of London argues for giving priority to endangered species of mammals that are far out on their own on the tree of life, without close relatives.

The EDGE scheme gives each species a score derived from its position on a phylogenetic tree. A lone species out on a long branch gets a higher score because it is the sole bearer of genes that represent a very long period of evolution. Take the three-toed sloths, which parted company with the rest of the sloths some 15 million years ago. "There are two species of three-toed sloth that only diverged 1 million years ago. If one went extinct, we would lose 1 million years, but if we lose both, we lose 15 million years," says Nick Isaac, a research fellow at the Zoological Society who helps to run the EDGE programme[4].

"You could make an analogy with art," says Isaac. "You are in a spaceship leaving Earth with three paintings. Do you take three Rembrandts, or do you take one Rembrandt, one Leonardo and one Picasso?" The group's top five targets for funding — which at this point amounts to paying for a student in the countries where the animals live to study their conservation — are the Yangtze River dolphin (*Lipotes vexillifer*), the long-beaked echidna (*Zaglossus bruijni*) of New Guinea, the riverine rabbit (*Bunolagus monticularis*) of the Karoo desert in South Africa, the Cuban solenodon (*Solenodon cubanus*) and its cousin, the Hispaniolan solenodon (*Solenodon paradoxus*). Similar to each other, but distinct from anything else, the solenodons merit two slots. Conservation favourites such as tigers, pandas and gorillas are noticeably absent from the list.

There are variations on this theme floating about. Redford suggests that when a species is identified as endangered, a priority list of populations within the species should be drawn up based on genetic diversity. And a biologist who considers his idea a little too hot to put his name to suggests putting species that have future evolutionary potential at the top of the list. This means prioritizing current species according to their capacity for future speciation. Big, long-lived species face inherent disadvantages under this idea: such a list would have little room for elephants or whales. Or redwoods.

Battle of the maps

A much more popular alternative to prioritizing species is prioritizing areas. There is less need to know how the ecosystem works — just identify an area of interest and try to preserve it in its entirety.

The first such scheme to gain real influence was Myers' hotspot map, which has been published in several incarnations since its inception[5] in 1988. The original version, which prioritized tropical forests above all other places, was persuasive enough for Conservation International, headquartered in Arlington, Virginia, and the MacArthur Foundation, based in Chicago,

D. WECHSLER/NATUREPL.COM

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Two species of three-toed sloth — 15 million years of evolution.

Illinois, to adopt it as a framework for their efforts. But like all prioritizing, it had its critics: "I was told it was immoral, that all species are equal," Myers recalls.

The criteria he has used to define the hotspots are, Myers freely admits, somewhat arbitrary, and have evolved over time. In the 2000 version an area makes the grade if it contains at least 0.5%, or 1,500, of the world's 300,000 plant species as endemics — that is, species that are seen nowhere else — and has lost 70% or more of its primary vegetation[6]. In this iteration the Brazilian cerrado, the fynbos and other mixed grasslands joined the forests.

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Myers' hotspot map set a trend: it is now practically compulsory for every conservation organization to have its own priority map. The Cape Floristic Region received its journal-filling loving-care from Cowling and his peers in part because it had made it onto so many of these prioritization lists. As well as being an accredited hotspot under Myers's scheme it had also made it into conservation group WWF's 'Global 200' scheme. Birds found nowhere else, such as the protea canary and the orange-breasted sunbird, had propelled the area onto Birdlife International's Endemic Bird Areas list[7].

Priority actions

The fynbos demonstrates the extent to which maps will agree about things, which raises the question of why there should be so many. "It has been a not terribly profitable exercise over the last ten years to have such a proliferation of schemes that are basically very similar," says Georgina Mace, who runs the Centre for Population Biology at Imperial College in London, UK. "They act as sort of branding for the organizations. It still surprises me that the big conservation organizations have not gotten together under a single banner, like Make Poverty History."

At the same time, partisans can detect — and defend, debate and disparage — various differences in approach. "We have been arguing, or certainly jockeying, to present one piece of science as more legitimate or stronger than another," says Jon Hoekstra, a senior scientist at the Nature Conservancy in Seattle, Washington. These squabbles are framed to suggest that there is one right answer — one most valid way to prioritize areas. But different starting assumptions and different goals mean that many of the schemes are not directly comparable. "We have to remember that they reflect the philosophical decisions made at the beginning," says Hoekstra.

The approach that currently enjoys perhaps the highest level of acclaim, at least scientifically, is that taken by Hugh Possingham of the University of Queensland, in Brisbane, Australia. His one goal is maximizing number of species conserved, and he loathes scoring systems. Instead he uses algorithms that measure real-world costs against benefits in terms of species number, and the resulting papers, colleagues say, are in a league of their own[8].

In his latest work he compares different actions in different places with each other, which is more complex than one might think. Land prices vary around the world, as does species richness. Many investments have diminishing returns over time: once a large chunk of one ecosystem is protected, turning a bit more into a park won't save many additional species. On the other hand, some interventions begin to pay off seriously only after a certain investment threshold is reached. "If you were trying to get all the rats off an island, unless you invest enough to get them all off, you might as well not even bother," explains Possingham. On top of all this is the problem that data on costs are infamously scanty — so much so that many earlier analyses just used land area as a proxy, an astonishing simplification.

"In a sense, it is just about good problem definition," says Possingham. "If you don't do that right, you head down these scoring paths. The people who make them just have a feeling of which facts are important, and they throw them in." Possingham tries to be as rigorous as possible, and sometimes that means not everything gets saved. "A lot of people get upset with that. It basically says some regions aren't working at all. They are too expensive, the threats are too huge, or there are not enough species in them."

Mount Lofty's short straw

Consider, for example, the Mount Lofty woodlands of Australia, where eucalyptus trees shelter rare orchids (pictured), spiny echidnas and cockatoos. Surely it is worth preserving them from the invasive predators such as foxes and cats that threaten them? But in a trade-off between spending on the Mount Lofty ranges and on the montane regions of the fynbos, Possingham's algorithms give the money to the fynbos — among other regional investments. The Australian woodlands get nothing, despite the fact the fact that Possingham, an avid birder, would bitterly regret losing part of the original range of the endangered regent honeyeater (*Xanthomyza phrygia*); he's particularly keen on honeyeaters.

Putting this sort of insight into practice is not simple. Most Australian money isn't transferable to South Africa, any more than money given to preserve pandas can be spent on solenodons. But some of those who administer the sliver that is fungible — people at the World Bank, the Global Environmental Facility and other large foundations — are taking an interest in Possingham's approach. Peter Kareiva, the head scientist of the Nature Conservancy, is one of many researchers who has been co-authoring papers with Possingham on such return-on-investment models of conservation[9]; a few years ago, as it happens, he rubbished the whole idea of hotspots in *American Scientist*[10].

Balmford, too, is excited about these approaches. "Possingham's new techniques on setting priorities dynamically, allowing you to shift from one to another, are really exciting," he says. The difficulty is getting them adopted by managers and decision-makers on the ground. "We have got to get away from conservation scientists handing down ideas from on-high to practitioners and expecting them to be received gratefully. It has got to be through examples, and from realizing from their peers that those things make sense."

This is the dreaded implementation gap, in

J. QUARMBY

Preserving the Mount Lofty ranges might not be as cost effective as spending on conservation elsewhere, despite the charms of its endangered orchids (opposite).

P. FAKLER / ALAMY

which theory ignores practice and practice ignores theory. In the end, it may not matter which prioritization scheme is most scientifically defensible. What matters is that the people carrying out a scheme feel that it makes sense and will save species. On this pragmatic basis, many schemes shouldn't even be considered for implementation, says Hoekstra — including some of his own work. "I wrote this crisis eco-regions paper. It gives some real interesting perspective on the world. It highlights the crisis in temperate grasslands. But I don't think it is as useful to look at the map I generated to decide where to work; you could end up trying to restore something that is lost."

Armchair scientists

"So much of this stuff is done by well-meaning people sitting as it were in their armchairs," says Stuart Pimm, a conservationist at Duke University. Pimm recently eschewed the priority list for his own expertise and invested in some land in the Amazon he knew was ripe for conservation. "You have to do what you think you can do. It is going to be based on imperfect information and it is going to be very, very strongly conditioned by local politics and economics and social conditions," he says.

Pimm aside, the armchair approach can seem deeply entrenched. Redford points out the perennial problem of papers that follow pages of science with a cursory command, "that deadly last paragraph that begins 'managers should'". For Noss, one solution is educating those managers. "We need a system that can provide mid-career training to people who are going to be working in land-management agencies, ocean-management institutions, and in environmental consultancies. Otherwise they are going to keep using these more outdated and less defensible approaches to prioritization."

For an on-the-ground conservationist, such as Stuart Cowell, project coordinator with Bush Heritage Australia, the many different schemes have been influential, but not immediately applicable. "We haven't taken those approaches off the shelf," he says. Bush Heritage buys land with conservation value, but unlike the ideal maps on paper, some land is never going to come up for sale. What Cowell and his colleagues are asking themselves, he says, is: "Is there a benefit to an organization spending the time and resources in doing this sort of prioritization, which looks good in theory but perhaps does not take us as far as just some good expert knowledge?"

There are some small successes. Possingham has had some luck impressing government bureaucrats with the rigour of his analyses; some spending decisions in Australia have been made on the back of his work. And South Africa has had real success in bridging the implementation gap. "The US and European style is that the scientists write it and hope someone picks it up, but the South Africans are trying to get the people who are going to implement it to help with the priorities," says Redford.

"We cannot afford, by a long, long way, to say which species are dispensible."
— Andrew Balmford

The messy reality

Since his conversion experience over the digital maps of the fynbos, Cowling has been one of those attempting to build the input of decision-makers and local people into his schemes from day one. "The plans [I've worked on] were done not because they appealed to anyone's curiosity in an academic sense but because they were needed," he explains. He's more interested in determining the possible than mapping the ideal. "Through the process of negotiation [with stakeholders] you end up with a series of projects, and funding is sought." And sometimes that which is sought is actually found.

Cowling says that getting all conservation biologists to do their prioritization work with both feet on the ground "will require a substantial change in how researchers operate". "Getting involved in the slushy stuff takes time. The kind of research is not likely to appear in the pages of high impact journals. You might get it into the pages of *Ecology and Society*," he says. But his work is not going unrecognized, whatever its impact factor; Balmford singles Cowling out for praise as someone "not just concerned with getting the algorithm to get the best bang for the buck, but with the more messy, more real, more interesting reality".

There is no reason why, in theory, one could not include the slushy stuff of real life as inputs in a prioritization scheme. "People say that this mathematical approach can't account for anything, but it can," says Possingham. "The question is, can you put it in with a plausible number?" Imagine a platonic scheme in which one could include the intransigence of a particular politician, the likelihood of a coup in a certain country, the relative value of the US dollar, the effect of eco-fatigue among the donating public, and the looming spectre of climate change, each quantified and slotted into equations (along with values representing their uncertainty, of course). Such a marvel might give you the best tactics. But it would be no help in setting fundamental goals for future conservation — a subject on which unanimity seems about as likely as a full recovery for the Yangtze River dolphin. ■

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1. Ehrlich, P. R. & Ehrlich, A. *Extinction: the causes and consequences of the disappearance of species* (Random House, London, 1981).
2. Halpern, B. S. *et al. Conserv. Biol.* **20,** 56–64 (2006).
3. Walker, B. H. *Conserv. Biol.* **6,** 18–23 (1992).
4. Isaac, N. J. B., Turvey, S. T., Collen, B., Waterman, C. & Baillie, J. E. M. *PLoS ONE* **2,** e296 (2007).
5. Myers, N. *Environmentalist* **8,** 1–20 (1988).
6. Myers, N. *et al. Nature* **403,** 853–858 (2000).
7. Brooks, T. M. *et al. Science* **313,** 58–61 (2006).
8. Wilson, K. A. *et al. PLoS Biol.* **5,** e223 (2007).
9. Murdoch, W. *et al. Biol. Conserv.* **139,** 375–388 (2007).
10. Kareiva, P. & Marvier, M. *Am. Sci.* **91,** 344–351 (2003).

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