Yva Momatiuk /John Eastcott/Minden Pictures/FLPA

The musk ox.

On being the

why big mammals are in big

We know many mammals already face extinction. Can we predict which mammals will be threatened next? **Andy Purvis** and colleagues have identified twenty future conservation battlegrounds.

It's a matter of life and death, not just for individuals but for whole species. One mammal species in four is at significant risk of dying out within a human lifetime; the others seem OK, for now at least. So why are the lion, Iberian lynx and dwarf gibbon threatened but the leopard, Eurasian lynx and Bornean gibbon safe? One old idea is that extinction is like a hail of bullets – a species' survival is just a matter of luck. But there's more to it than that: close relatives of a threatened species are especially likely to be threatened themselves. Understanding why could let conservation move from reactive to proactive, protecting vulnerable species before they even start to decline.

The World Conservation Union (IUCN) is in charge of assessing species' chances of going extinct soon. Their Red Lists place species on a six-step ladder to extinction, using five criteria drawn up originally by Georgina Mace* and Russ Lande (then at the University of Chicago, but now at Imperial College, London), which consider things like population size and trends. In 1996, Georgina asked me to test whether the first comprehensive mammal Red List showed a link between risk and body size. There are lots of sensible reasons why larger mammals might find life tougher in a human-dominated world: there's more meat on them, they need more room to live, they can't hide, their populations are smaller, and their reproductive rate is slower. But our initial analyses, focusing on a few groups for which we had size information, found nothing. What were we missing? As it turned out, quite a lot.

When we looked at more variables in primates, carnivores and (with a NERC small grant) bats, we found that the geographical extent of a species gave the best clue about its population decline: narrowly distributed species are declining faster. On top of geographical distribution, other risk factors were more idiosyncratic: large size in primates, slow reproductive rate in carnivores, and wing shape in bats. We were getting a handle on the danger signs within these groups; now we wanted to extend the approach to all mammals, and to add to the mix the intensity of human pressure that they face. This needed a bigger team. Our collaborator, John Gittleman, secured funding in the US (National Science Foundation) to digitise range maps

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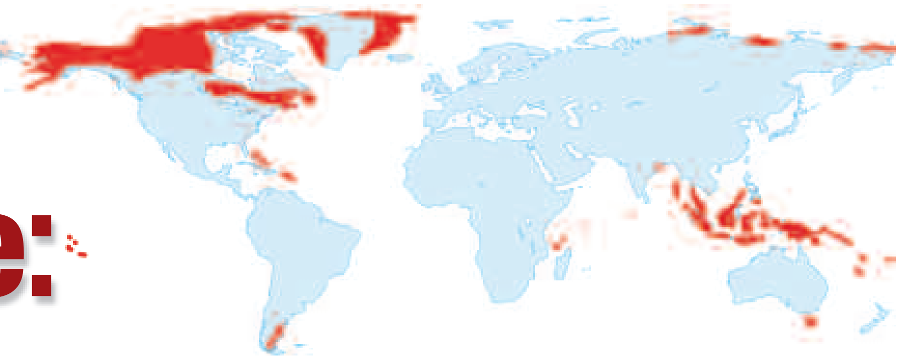
wrong size:

trouble



Future conservation battlegrounds: the red areas represent hotspots of latent risk. Mammals aren't at great risk of extinction in these places, but their biology makes them very vulnerable if human impacts increase.

of the world's mammal species; he employed Kate Jones, who'd previously led on the bat analyses. We obtained a NERC standard grant and employed Marcel Cardillo to do the analyses and Jon Bielby to spend more time in a library than is strictly healthy, populating an ecology and life-history database: this now holds over 100,000 records. We also needed the evolutionary 'family tree' (phylogeny) of all the species, because comparing threatened species with safe close relatives is the best way to pinpoint the differences that matter for extinction. Another collaborator, Olaf Bininda-Emonds, helped Marcel with the tree, and we roped in many others along the way.

Our analyses revealed a much richer, more complex picture than we'd expected. For species smaller than about three kilos, what matters is whether they are in or out of the firing line: threatened species had narrow distributions in places with severe human impacts. These things mattered for larger mammals too, but so did their biology: species with low abundance and slow reproduction are more threatened. What's worse, each factor loads the dice ever more heavily against increasingly large species. They face multiple jeopardy: they're usually less abundant than small species to start with, so are vulnerable to any extra deaths from hunting or habitat destruction; they generally reproduce more slowly, so they can't compensate for any extra deaths as easily; and they also do worse than small species if they're stuck with a small geographic distribution. Big mammals are in big trouble.

These results explained why our over-simple initial analyses didn't find anything, and they suggest that large and small mammals need different conservation approaches. Small species will often be well-served by simply looking after their habitat, but large ones will need specific help.

Now we'd identified the ecological danger signs for mammals, we could spot accidents waiting to happen – species with these characteristics but not yet at high risk. These animals – like the musk ox, Seychelles flying fox and the North American reindeer – get by because their habitats are largely intact, but their populations are likely to crash rapidly if and when people or threats arrive. We identified 20 future conservation battlegrounds (see map) where the mammal faunas are largely intact but whose biology makes them vulnerable. These range from tropical islands like New Guinea and Borneo to cold continental regions like the Siberian tundra. We view these places as real conservation opportunities because they provide a chance to get ahead of the curve, to forestall the conflicts between people and wildlife. Prevention is better than cure and often much cheaper, but the clock is ticking.

As well as shedding light on mechanisms behind the pattern of extinction risk, our project had other spin-offs. The database of ecology and life-history information, PanTheria, will soon be made freely available. The distribution maps have fed into the World Conservation Union's ongoing Global Mammal Assessment, which is refining them prior to making them available. And the family tree of all present-day mammals, developed initially for statistical rigour, contained surprises too. It's long been known that the extinction of the dinosaurs 65 million years ago triggered an explosion in mammalian diversity: the fossil record shows massive speciation then. But our tree shows that the mammals whose descendants are still around didn't join the party. There are about 50 such lineages, but they didn't start to radiate for another 10 million years. Then, in a period of intense global warming, they eclipsed the older groups. Primates, carnivores and modern ungulates came to dominate whereas condylarths, multituberculates and other groups with similarly unwieldy names dwindled and died out. Did the global changes flip the balance, or was it something else? We don't yet know, but hope to find out. We're also looking to extend our approach to look at extinction patterns in other groups, like amphibians, and at smaller spatial scales. The project was a very successful one for all of us and great fun. We found that statistical approaches developed very much for what is normally called pure research were useful in this more applied context, and that combining information on ecology, geography and evolutionary history is a powerful approach for finding out about past, present and possibly future biodiversity. ❖

Big mammals such as the Burchell's zebra are potentially in big trouble.

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The delayed rise of present-day mammals. Nature, *446, 507-512.*

Big mammals in big trouble. Science, *309, 1239-1241.*

Hotspots of latent risk: Latent risk and the future battlegrounds of mammal conservation. Proceedings of the National Academy of Sciences of the United States of America, *103, 4157-4161.*

See also: www.pantheria.org