translates molecularly into the rhythmic contractility that is needed to propel blood around the body. It will be exciting to use genetic models to identify the roles of specific ion channels and calcium-handling proteins in initiating the first heartbeat. Such models might also help to reveal the molecular underpinnings of the parameters of the SNIC bifurcation, including how the thresholds for induction and amplification of the Ca^{2+} waves are determined and coordinated. Finally, investigating the molecular basis for periodicity dynamics and LOI drift could provide insight into the pathology of cardiac arrhythmias in adult humans: many of the same genes and biophysical phenomena might function in the adult heart.

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Ecology

Measuring the benefits of protected areas

Ana S. L. Rodrigues & Marie-Morgane Rouyer

Are protected areas slowing down global biodiversity declines? A global analysis provides evidence that they are, although effects vary across groups of species, and what happens outside protected areas matters, too. **See p.101**

Protected areas — defined, recognized geographical spaces that are managed to try to achieve the long-term conservation of nature — are the cornerstones of national and global efforts to slow biodiversity loss[1]. They already occupy nearly 17% of the planet's land and inland water surface and 8% of the oceans[1], and most nations have committed to expanding their protected-area coverage to 30% by 2030, under the Kunming–Montreal Global Biodiversity Framework of the United Nations Convention on Biological Diversity[2]. For such a fundamental conservation tool, the amount of evidence available to assess whether protected areas are effective at limiting biodiversity declines is surprisingly scant[3]. On page 101, Nowakowski *et al.*[4] address some of this shortfall through a global-scale analysis that shows that populations of terrestrial vertebrates inside protected areas decline more slowly than do those in comparable unprotected sites. However, the authors found wide variation in the mitigating effects of protected areas, raising questions about the factors that explain the effectiveness of this conservation tool and the uncertainties associated with quantifying this effectiveness.

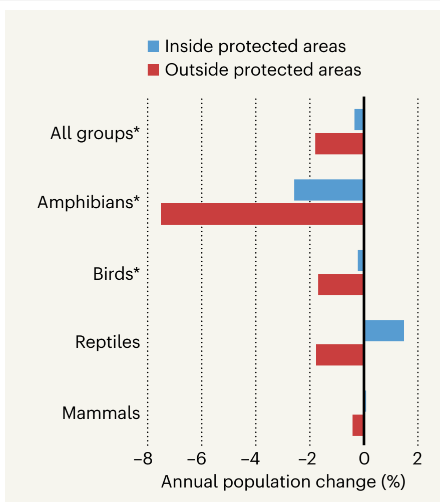

Figure 1 | Assessing the effectiveness of protected areas for vertebrate species. Nowakowski *et al.*[4] analysed data for 1,032 vertebrate species from around the globe to determine whether protected areas affected population trends. Asterisks indicate groups of species for which there was a statistically significant lower rate of change in the number of individuals inside protected areas than outside such areas.

If effectively implemented through appropriate regulation and management, protected areas work by buffering the biodiversity inside their boundaries against human-driven pressures, such as habitat destruction and the overexploitation of species. In practice, it is challenging to demonstrate formally that such protective effects do take place, because it is seldom possible to carry out controlled experiments on the scale of protected areas. Instead, studies contrast protected versus comparable unprotected areas in terms of either the intensity of pressures or the state of biodiversity[3]. Analyses of the effects of protection on the state of biodiversity are particularly rare, because they require large biodiversity data sets. For their study, Nowakowski *et al.* combined the two largest global data sets on wildlife population trends — Living Planet[5] and BioTIME[6] — to obtain data consisting of 2,239 population trends for 1,032 bird, mammal, amphibian and reptile species at more than 1,000 protected areas and at a similar number of comparable unprotected sites.

The results are both reassuring and puzzling. Nowakowski and colleagues found that, on average, the populations declined significantly faster outside protected areas (−1.8% per year across all studied species groups) than inside them (−0.4%; Fig. 1), indicating that area protection substantially mitigates population losses. Furthermore, average declines in protected areas were statistically indistinguishable from zero, suggesting that protected areas almost completely offset the drivers of population declines outside those areas.

This mitigation effect varied, however, across different taxonomic groups. It was strongest for amphibians (−2.6% inside protected areas, compared with −7.5% outside them) and birds (−0.3 versus −1.7%). It was positive, but non-statistically significant, for mammals (0.0% versus −0.4%) and reptiles (1.4% versus −1.8% per year). With much conservation attention focused on birds, it is unsurprising that they are benefiting from such efforts, as was also found in a previous analysis of the effect of conservation on species' risks of extinction[7].

It was less predictable that the effects of protection would be so strong for amphibians, although it is consistent with the authors' finding that this group is particularly sensitive to changes in land use. A previous study[8] found that conservation of wetland habitats under the United Nations' Ramsar Convention has been effective at slowing down declines in bird populations[8], and amphibians, too, might have benefited from this international treaty.

It is less easy to explain why no measurable effect of area protection was found for mammals, given their popularity as conservation targets. Even more puzzlingly, Nowakowski *et al.* found no evidence of significant population declines outside protected areas for either mammals or reptiles. Taken at face value, this would indicate not so much that protected areas do not work, but rather that they are not needed in the first place. It is difficult to reconcile this result with the knowledge that about 27% of mammal species and 21% of reptile species are at risk of extinction[9], mainly because of threats – such as hunting, trapping and habitat loss through agriculture and logging – that can be tackled through effective area-based conservation.

This counterintuitive result more probably reflects limitations of the Living Planet and BioTIME data sets. Given that these data sets compile published population time series, they are biased towards temperate regions that have experienced, on average, slower population declines than have tropical areas[5], where most species are found[9]. Accordingly, Nowakowski *et al.* found stronger effects of protected areas in tropical than in temperate regions, although this difference was not statistically significant, perhaps because of the paucity of data from tropical regions.

Protected areas are embedded in wider landscapes, as well as in climatic and socio-political contexts, and Nowakowski *et al.* found that these factors significantly affect population trends. Changes in land cover (corresponding to vegetation changes indicating a change in land use) had negative effects on the population trends of amphibians, tropical reptiles and threatened birds. Climate change (as measured through average temperature increases) also negatively affected the population trends of reptiles and of amphibians in tropical regions. Strikingly, national governance (as measured through an index that captures how stable, effective and free from corruption a nation's government is) was as important at slowing population declines as was the contribution of protected areas themselves. These results reinforce the need to consider protected areas in their wider contexts, ensuring that effective management and governance extend beyond the boundaries of protected areas.

"These results reinforce the need to consider protected areas in their wider contexts."

Nowakowski and colleagues' findings reinforce urgent calls for greater efforts to be made regarding conservation, including an expansion of the global area covered by protected areas and of other effective area-based conservation measures[2]. The authors also demonstrate the need for adequate monitoring of biodiversity, particularly in tropical areas. Indeed, even for the best-studied animal groups, the data are still too sparse for a clear picture to emerge of the effectiveness of the most fundamental of the conservation tools.

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