LETTERS

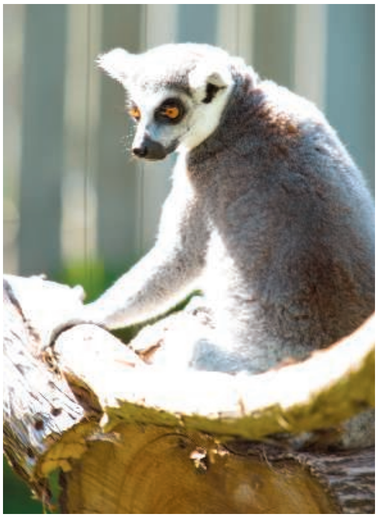
edited by Jennifer Sills

The Cost of Conservation

C. KREMEN *ET AL.* ("ALIGNING CONSERVATION PRIORITIES ACROSS TAXA IN MADAGASCAR WITH high-resolution planning tools," Reports, 11 April, p. 222) proposed a systematic plan for acquiring new protected areas in Madagascar, using extensive new species richness data, but their analysis did not consider the costs of acting in different regions. Costs vary substantially; omitting this important facet of conservation planning can lead to poor biodiversity outcomes.

Conservation agencies are increasingly incorporating realistic costs to optimize future actions, with the help of conservation software (*1*, *2*). Analyses have shown that the including costs can considerably increase the efficiency of conservation plans, by up to a factor of 10, compared with plans that use area as a proxy (*3*–*5*). Estimated land costs in Madagascar (*6*) vary by up to four orders of magnitude (between USD $0.60 and $1785 per hectare), and some areas identified as priorities by Kremen *et al.* are in Madagascar's most expensive regions. The costs of the priority areas identified mirror the overall distribution of costs in Madagascar, whereas a more efficient solution would favor low-cost areas. Given that large areas of Madagascar have relatively low opportunity costs, much more biodiversity could have been protected with the same investment.

In the developing world, such as Madagascar, conservation decisions that do not include the opportunity costs to stakeholders are unlikely to effectively protect biodiversity (*7*–*9*). High-cost sites are usually in demand for other purposes, and targeting these sites for conservation will cause conflict with people who depend on this land. If planners do not attempt to avoid conflict with local stakeholders by including their values throughout the planning process, then reserves will be prone to failure. "Paper parks" are a reality in many developing countries (*8*), including Madagascar (*9*), where disenfranchised local communities ignore park boundaries. Local groups are also more likely to suffer from injudicious protected area placement if costs are not included. The resulting expulsions lead to loss of livelihood and cultural degradation (*10*), while robbing the conservation movement of effective political allies (*8*). Before Kremen *et al.*'s methods are used to guide conservation actions, the varying costs of conservation must be incorporated.



Madagascar's wildlife. Preserving diversity in Madagascar depends in part on pursuing the most effective conservation strategy.

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Conservation with Caveats

C. KREMEN *ET AL.* ("ALIGNING CONSERVATION priorities across taxa in Madagascar with high-resolution planning tools," Reports, 11 April, p. 222) identified the optimal sites for expansion of Madagascar's land area under protection, using advanced conservation planning techniques at an unprecedented level of detail for six taxonomic groups. However, the exhaustive study had caveats.

Conservation planning analyses that incorporate biodiversity value and economic costs, unlike that of Kremen *et al.*, show that limited budgets can achieve substantially larger biological gains than plans that ignore costs (*1*–*3*).

This may seem trivial in Madagascar's exceptional case, as the targets and timeline for conservation are set. But imagine if Madagascar's President Ravalomanana were able to conserve more than 10% land area and preserve more biodiversity, for the same cost, if he focused on getting the most "bang for his buck" (*4*).

In addition, climate change is already causing shifts in species ranges (*5*), which will likely change the future battlegrounds for conservation (*6*). This underscores the desperate need to incorporate climate change into conservation planning.

Finally, as the authors rightly point out, the analysis would benefit from the inclusion of other taxa. In particular, we wonder whether conservation priorities would change if a well-known taxon like birds had been included.

The analysis is an advancement to secure Madagascar's biodiversity at a crucial and opportune time. Still, it should be disconcerting for conservationists that it nonethe-

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less has caveats. These are key areas for future research.

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Response

BODE *ET AL.* NOTE THAT WE SHOULD INCLUDE cost data in our analysis. Our analysis optimized conditions for biodiversity to produce a pure "biodiversity benchmark" against which plans incorporating other elements can be compared. Only with such a benchmark can one quantify what would be lost when political or socioeconomic constraints are accommodated. That said, we recognize that the costs of conservation are spatially heterogeneous and that high-resolution cost surfaces should be used when available to maximize biodiversity benefits under cost constraints (*1*). Using data from a global-scale analysis of opportunity costs (*2*), Bode *et al.* imply that the existing and proposed protected areas are equivalent in cost to a random sample across Madagascar, rather than to a solution that minimizes cost. However, the global-scale opportunity cost data they used cannot provide a good metric for assessing the cost consequences of the existing plus proposed areas in Madagascar for several reasons: (i) The global-scale data appear to be grossly inaccurate for some regions of the country. For example, the southern and western areas shown as being most productive for crops and livestock (see figure 1A in Bode *et al.*'s ref. 1) are in fact Madagascar's most arid, drought-ridden regions, occupied by its poorest people, and subject to frequent famines. In contrast, some major regions for producing Madagascar's staple crop, rice, are shown incorrectly to have low opportunity cost (e.g., rice-producing regions around Lake Alaotra). (ii) The resolution of the global-scale map of opportunity costs is 100 times coarser than our analysis. It is inappropriate to use global-scale data, whether economic or biological, to develop or to evaluate subregional conservation plans (*3*). (iii) This global opportunity cost layer is based solely on agricultural and livestock production, omitting several high-value potential land uses in Madagascar (mining, timber production, and ecotourism). While Bode *et al.* hint that our efforts might have been better spent generating a spatially heterogeneous cost rather than biodiversity surface, we suggest that it would be rash to generalize from the relatively few studies [e.g., (*4*, *5*)], mostly global scale, that have discussed the relative utility of cost versus biodiversity data for achieving biodiversity outcomes.

Bode *et al.* add that conservation plans will not succeed without making local people central to the strategy. In Madagascar and elsewhere, implementing real conservation plans involves multiple iterations of discussion between policy-makers and both natural and social scientists (*6*). Members of our research team have been actively involved with the multi-institutional body governing such discussions (Système d'Aires Protegées) since its inception. At the national scale, our results [e.g., figure 2B in (*7*)] are being integrated with other, previously generated biodiversity priority areas for Madagascar, expert knowledge of current habitat condition, predictions of deforestation threats and ecosystem service benefits, local stakeholder interests, climate change refugia (from an expert workshop held in Madagascar in January 2008), and consideration of mining and ecotourism interests. After this national synthesis, more detailed, bottom-up planning at the local to regional scale will utilize both additional layers and stakeholder input, before protected areas are finally delimited, zoned, and gazetted [for an example of this process, see (*8*)]. We agree with Bode *et al.* that biodiversity will not ultimately be conserved without taking local and national political, social, and economic concerns into account, and reiterate the value of a quantified biodiversity "benchmark" in multisectoral decision-making for conservation.

Coetzee adds that we omitted the effects of climate change and bird data. We incorporated basic design elements for climate change by maximizing the proportions of species' ranges included and by prioritizing landscape connectivity. Our analysis prioritized small-ranged species (*7*), which are more vulnerable to climate change (*9*). Many of these small-ranged species occur around mountain tops, which are ultimately expected to become climatic refuges (*9*–*12*). Their inclusion in the network builds in some resilience to climate change.

Although we were unable to access bird data suitable for our modeling procedure, Important Bird Areas and IUCN Extent of Occurrence data for threatened birds were heavily used in planning the prior expansion of reserves (2002 to 2006).

Optimization techniques contribute to efficient conservation planning, but it is important to understand the limitations of such products. Solutions, while "optimized," are probably never "optimal."

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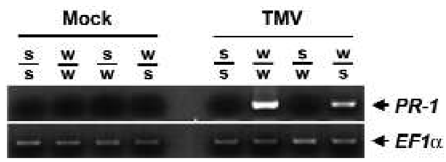
CORRECTIONS AND CLARIFICATIONS

Reports: "ROS-generating mitochondrial DNA mutations can regulate tumor cell metastasis" by K. Ishikawa *et al.* (2 May, p. 661). The 25 February 2008 submission date was incorrect. The correct submission date was 10 September 2007.

Reports: "Methyl salicylate is a critical mobile signal for plant systemic acquired resistance" by S.-W. Park *et al.* (5 October 2007, p. 113). Two lanes in Fig. 1E may have been duplicated. They are S/S and S/W under TMV.



Therefore, the results were independently confirmed in a double-blind experiment. The new data are presented here and confirm the results originally presented. EF1α was used as an internal control. Semiquantitative RT-PCR, rather than RNA blot analysis, was used to quantify PR-1 transcript levels.

TECHNICAL COMMENT ABSTRACTS

Comment on "A 3-Hydroxypropionate/4-Hydroxybutyrate Autotrophic Carbon Dioxide Assimilation Pathway in Archaea"

Thijs J. G. Ettema and Siv G. E. Andersson

Berg *et al.* (Reports, 14 December 2007, p. 1782) reported the discovery of a novel autotrophic carbon dioxide–fixation pathway in Archaea and implicated a substantial role of this pathway in global carbon cycling based on sequence analysis of Global Ocean Sampling data. We question the validity of the latter claim.

Full text at www.sciencemag.org/cgi/content/full/321/5887/342b

Response to Comment on "A 3-Hydroxypropionate/4-Hydroxybutyrate Autotrophic Carbon Dioxide Assimilation Pathway in Archaea"

Ivan A. Berg, Daniel Kockelkorn, Wolfgang Buckel, Georg Fuchs

We proposed that the 3-hydroxypropionate/4-hydroxybutyrate cycle might be important in global carbon cycling based on the abundance of related autotrophic Crenarchaea in the ocean and the high number of gene sequences for a key enzyme of the cycle. Here, we counter the specific criticisms raised by Ettema and Andersson.

Full text at www.sciencemag.org/cgi/content/full/321/5887/342c