LETTERS

edited by Etta Kavanagh

How Protected Are Coral Reefs?

THE POLICY FORUM "CORAL REEFS AND THE GLOBAL NETWORK OF Marine Protected Areas" (C. Mora *et al.*, 23 June, p. 1750) draws attention to the vulnerability of coral reef Marine Protected Areas (MPAs) to human activities. The authors evaluated the exposure of coral reef reserves to poaching and to external threats (pollution, erosion, overexploitation, and shoreline development) using a risk index. Remarkably, neither the authors nor the source of their risk index (*1*) identify biological invasion (the introduction of nonindigenous organisms) as a significant threat. I believe this reflects the conventional wisdom that tropical regions and, in particular, highly diverse systems like coral reefs are largely immune to invasion.

However, the few studies that have investigated nonindigenous species on coral reefs found that, although they comprise a minor proportion of the total diversity, invaders are capable of damaging reef ecosystems. Severe impacts of invasive algae and pathogens have been documented (*2*, *3*), and cases involving other organisms continue to accrue. In recent years, an octocoral from the western Atlantic and a sponge from Indonesia have been overgrowing and killing native corals in Hawaii (*4*). Similarly, a stony coral from the Indo-Pacific has begun to foul reefs off Florida and Brazil (*5*).

The magnitude of the problem is certainly underestimated, as the origins of large numbers of invertebrates, bacteria, and viruses occurring on reefs are unknown. Furthermore, several thousand species are being moved across the world in ballast tanks and on the hulls of ships (*6*), and aquarium releases are contributing to the spread of species in tropical regions (*7*). Hence, the threat posed by biological invasion is unlikely to diminish and should therefore be considered in analyses of the effectiveness of MPAs.

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THE POLICY FORUM "CORAL REEFS AND THE global network of Marine Protected Areas" by C. Mora *et al.* (23 June, p. 1750) underestimates the complexity of the conservation challenge.

First, the analysis does not factor in the impacts of some of the most important pervasive global anthropogenic stressors on coral (*1*) that penetrate Marine Protected Area (MPA) boundaries via terrestrial, atmospheric, and oceanic avenues (*2*). These include increasing sea surface temperatures and associated coral bleaching, contagious coral disease, and potential ocean acidification (*3*).

Second, although Mora *et al.* recognize the inadequacies of management and enforcement within MPAs themselves, they do not integrate the potential impacts of larger, and equally important, political, economic, and sociological forces into their analysis. For example, it is possible to establish a perfect global MPA network using all the best science, but still fail to protect coral reefs if you do not have high and sustained political and community capacity at local and national levels (*2*). Special interest groups that make campaign contributions and gain favorable permit decisions from politicians (low political capacity) can ruin the best scientifically designed MPA network in a short period of time. Likewise, if local residents do not have a conservation ethic (low community capacity), no amount of regulation and enforcement will protect coral reef resources in the long run from stressors like poaching. Low political and community capacity situations are more the rule than the exception in the MPA world.

We all have a vested interest in making MPAs effective tools for conserving coral, enhancing fisheries, and conserving related reef biodiversity, but to make the MPA tool effective for conserving coral, we must reduce the root causes of pervasive global anthropogenic stressors (*4*). This starts with changing our own personal behavior and extends to making larger political, cultural, and economic improvements. These include, but are not limited to, citizens demanding governmental enforcement of existing environmental regulations, voters participating in the political process, and stockholders demanding environmentally responsible business behavior. None of these tasks are easy or ever complete.

Any reassessment of global-scale conservation strategies for coral reefs, in this era of global economies, climate change, and interconnected ecosystems, must focus on reducing the root cause of stressors on coral and on improving political and community capacity, because the effectiveness of any global MPA network is inextricably linked to success in these critical areas.

What the analysis of Mora *et al.* does show clearly is that the use of the term Marine "Protected" Area is truly a misnomer. The term Marine "Managed" Area is more appropriate to describe this conservation tool. The MPA term should only be used if real "protection" can be biologically certified over time (*2*).

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IN THEIR POLICY FORUM "CORAL REEFS AND the global network of Marine Protected Areas" (23 June, p. 1750), C. Mora *et al.* discuss the destruction of coral reefs and international agreements to protect these fragile ecosystems. The authors based their analysis on the 2005 version of the World Database on Protected Areas (WDPA) (*1*). This database is maintained by the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) (*2*) in collaboration with the World Conservation Union on behalf of a consortium of organizations. We suggest that their analysis could have been substantially improved if they had used the more recent WDPA data that are available online from our collaboration with the University of British Columbia Sea Around Us Project (*3*).

The WDPA is a primary source of protected areas information for many research activities. It serves a wide range of stakeholders, including governmental and intergovernmental bodies, policy advisors, researchers, managers, and private-sector decision-makers. The WDPA is compiled from protected areas information provided by competent agencies, with additional input from researchers and professional experts in the field. It now contains standardized data for 233 countries and territories, including marine and coastal areas, and is freely available for noncommercial purposes in keeping with the principles of the Conservation Commons (*4*). Although annual updates are released on CD for distribution at relevant international fora, users can access the most up-to-date information online. Given the complexity of the WDPA content, we encourage users to seek our advice directly to ensure that they are using the most recent data sets and that it is interpreted appropriately. In return, we welcome access to any relevant new data that researchers can provide so that we can improve the resource for other researchers and decision-makers.

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IN "CORAL REEFS AND THE GLOBAL NETWORK of Marine Protected Areas" (Policy Forum, 23 June, p. 1750), C. Mora *et al.* suggest that only 2% of the world's coral reefs are adequately protected. We believe that the authors have set impossibly high standards for "adequacy" and have misdirected attention from the real problems facing coral reefs and the even greater needs for marine protection of other habitats. For example, Australia's Great Barrier Reef is described as "partially protected." The only recent published global reef map (*1*) suggests that this reef represents almost 14% of the world's coral reefs, and over one-third of it has been designated as strictly protected. Although this reef is still subject to pressures from climate change and runoff from the mainland, a simple classification of this flagship MPA as inadequate seems to be making a statement to policy-makers that they can never succeed.

Coral reefs are, in fact, the best protected of all marine and coastal habitats. Using the World Database on Protected Areas (*2*), together with recent updates, we estimate that approximately 22.6% of all reefs fall within some classification of legal protection, while 11.4% fall within classes of stricter management regimes (IUCN management categories I to IV). These are crude measures and the effectiveness of many sites may be called into question, but we cannot doubt that considerable progress has been made. In fact, there has been a high positive selection for reef areas—overall, only 4.3% of shelf areas (above 200 m) fall within some level of protection and only 1.9% within stricter levels of protection. Other critical marine habitats—such as kelp forests, deep coral communities, seagrasses, seamounts, and the vast expanses of the high seas—are far less protected.

We remain far from the goal of achieving representative networks of MPAs by 2012 (*3*), even for coral reefs, but attention also needs to be focused more broadly than simple coverage statistics. We should be trying to design MPA networks that are resilient to the many ex situ influences that do not respect liquid boundaries in the ocean (pollution, disease, overharvesting of entire fish stocks, and the many influences of climate change). Such MPA networks further need to be placed into a more integrated framework for management, covering, inter alia, watershed-based management, ecosystem-based management of fisheries, and globally targeted policy changes in carbon emissions.

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Response

WE PROVIDED A GLOBAL AUDIT OF THE MANagement effectiveness of Marine Protected Areas (MPAs) containing coral reefs. We found that less than 0.01% of the world's coral reefs are within MPAs that fully protect reef diversity from threats due to poaching, overfishing, coastal development, and pollution. Ricciardi and Jameson suggest that we overestimated the protection received by coral reefs because invasive species and climate change were not considered. We agree that those two threats are likely adding to the worldwide vulnerability of coral reefs. However, our paper was not intended to quantify this vulnerability, but to assess the effectiveness of MPA management.

Many threats to coral reefs are local (e.g., overfishing, pollution, and coastal development) and can be policed as part of the management plan of MPAs. However, there are other threats (e.g., climate change and invasive species) that are not local and thus are more difficult to police or even monitor from a MPA. Controlling the effects of climate change and invasive species is unlikely to be an effective function of MPAs, but if we consider them as such, that will only worsen the current management situation of MPAs worldwide. Jameson further suggests that our analysis failed to consider political, economical, and sociological data, which do influence MPA effectiveness. We agree. However, these factors are likely to be reflected in the levels of

Letters to the Editor

Letters (~300 words) discuss material published in *Science* in the previous 6 months or issues of general interest. They can be submitted through the Web (www.submit2science.org) or by regular mail (1200 New York Ave., NW, Washington, DC 20005, USA). Letters are not acknowledged upon receipt, nor are authors generally consulted before publication. Whether published in full or in part, letters are subject to editing for clarity and space.

poaching inside MPAs, which we did quantify.

MPAs have proven effective at reducing the effects of fishing. However, they have to be complemented with additional approaches to reduce other human pressures. Increasing general public awareness of environmental problems is important. It is likely that if we overcome the indifference of governments and the general public to environmental issues (*1*), we could reduce the impact of human stressors and achieve a broader protection of biodiversity.

McManus and colleagues suggest that our analysis "could have been substantially improved" if we had used their most up-to-date version of the World Database on Protected Areas (WDPA). We recognize the great value of this database, acknowledge that it was important for our analysis, and were aware of the current attempt to verify and update it. However, we realized that such a new database was not going to be ready in time for our analysis and therefore decided to carry out an independent review of the database. For this process of verification, we used recent reports and contacted over 1000 researchers and managers in 103 countries. Our analysis included these corrections (verification and updating) to the 2005 WDPA relevant to coral reefs, and therefore we doubt that waiting for a new and better database would have "substantially" improved our results.

In our analysis, each MPA was classified in one of four categories of effectiveness ranging from adequate to very limited conservation status. The category defined as "adequate" included MPAs that were mostly no-take with no or low levels of poaching and low to medium risk and were variable in size and isolation. We found that only 2% of the world's coral reefs are within MPAs categorized as adequate. Spalding and colleagues claim that this category includes quality standards that are impossible to achieve and therefore our results are a message to policy-makers that they can never succeed. We disagree. First, compelling evidence suggests that MPAs have to be no-take and have to be minimally affected by external risk to provide appropriate protection to coral reefs (*2*, *3*). So we consider that the attributes we define as "adequate" should be the minimum characteristics that an MPA should have to be effective. Second, we do not believe that the standards we set as adequate are impossible to reach. The recent upgrade to no-take status of the Northern Hawaiian Islands is a good indicator that setting aside large areas from the effects of fishing is possible. Reductions in the impact of external risks such as runoff are also achievable, and advances are being made in large areas like the Florida Keys and the Great Barrier Reef.

Spalding and colleagues claim that our study "misdirected attention from the real problems facing coral reefs and the even greater needs for marine protection of other habitats." We did not make any claim about the status of MPA effectiveness in other marine habitats. It is very likely that the situation we described for coral reef MPAs is occurring in other habitats, but what that suggests is the great need for effective conservation of all marine habitats. MPAs are one of the main approaches used for the conservation of coral reefs worldwide, and our paper "directs" attention to the problems they have in achieving effective protection. That is not to say that MPAs alone are going to prevent the large plethora of threats affecting coral reefs and that other approaches should not be used.

Finally, Spalding and colleagues argue that coral reefs are the best protected of all

marine and coastal habitats. One of the main messages of our paper is the need to differentiate between quantity and quality of protection by MPAs. Establishing parks on paper can easily increase the quantity of protection, but that coverage is not effective and may provide a false sense of security. Our study shows that this is the case for coral reefs. Therefore, the statement by Spalding and colleagues that "[c]oral reefs are, in fact, the best protected of all marine and coastal habitats" should be taken with care, because although 18.7% of the world's coral reefs are within MPAs, only 2% are adequately protected. This suggests that MPAs worldwide are, for the most part, poorly effective and that current efforts to reverse the existing crisis of coral reefs fall far short of what is required to save these most diverse of all marine habitats.

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CORRECTIONS AND CLARIFICATIONS

News of the Week: "On your mark. Get set. Sequence!" by E. Pennisi (13 Oct., p. 232). Ewan Birney is not at the Wellcome Trust Sanger Institute as stated, but at the European Bioinformatics Institute, which is a part of the European Molecular Biology Laboratory.

News of the Week: "Perelman declines math's top prize; three others honored in Madrid" by D. Mackenzie (25 Aug., p. 1027). The article identified Richard Hamilton's affiliation incorrectly as the State University of New York at Stony Brook; he is at Columbia University. Also, the manuscript by Bruce Kleiner and John Lott appeared May 25, not in June, and the manuscript by Huai-Dong Cao and Xi-Ping Zhu was dated June 2006, not April.

TECHNICAL COMMENT ABSTRACTS

COMMENT ON "Rapid Uplift of the Altiplano Revealed Through ^{13}C-^{18}O Bonds in Paleosol Carbonates"

T. Sempere, A. Hartley, P. Roperch

Based on stable isotope measurements, Ghosh *et al*. (Reports, 27 January 2006, p. 511) concluded that the Bolivian Altiplano uplifted 3 to 4 kilometers between ~10.3 and ~6.7 million years ago as a result of gravitational loss of dense lithosphere. This result stands at odds with current geological knowledge of the Central Andes, and we propose a test for the reliability of the paleoaltimetry method.

Full text at www.sciencemag.org/cgi/content/full/314/5800/760b

RESPONSE TO COMMENT ON "Rapid Uplift of the Altiplano Revealed Through ^{13}C-^{18}O Bonds in Paleosol Carbonates"

John Eiler, Carmala Garzione, Prosenjit Ghosh

Clumped-isotope thermometry measurements of carbonate samples deposited in the Bolivian Altiplano as early as 28.5 million years ago and buried up to ~5000 meters deep exhibit no relationship between burial depth and apparent temperature, and largely yield temperatures within error of plausible Earth-surface conditions. These results counter the predictions of Sempere *et al*. and support our previous conclusions regarding the uplift of the Altiplano.

Full text at www.sciencemag.org/cgi/content/full/314/5800/760c