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OCEAN

Making waves: The science and politics of ocean protection

Mature science reveals opportunities for policy progress

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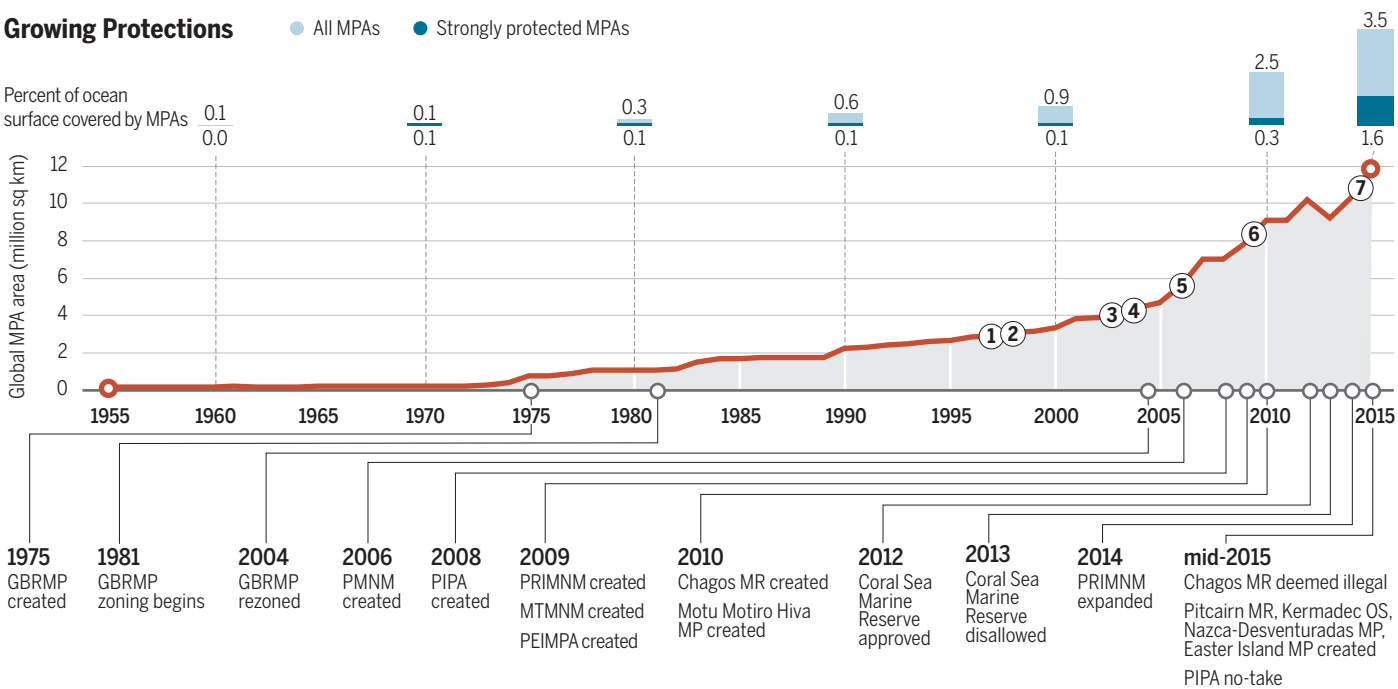
The ocean has recently taken a more prominent role on the international policy stage. In June, the United Nations (UN) initiated development of a treaty for conservation of biodiversity on the High Seas. One of the Sustainable Development Goals (SDGs) adopted by the UN in September focuses on the ocean. In early October, the second Our Ocean Conference (OO-2015) provided a high-profile platform for nations to tout progress or make promises to protect and restore the ocean. We discuss recent progress in creating and enforcing strongly protected areas, and we emphasize the need to accelerate the pace and draw on scientific knowledge.

POLICY

Two new large marine reserves were announced by Chile at OO-2015: Easter Island Marine Park and Nazca-Desventuradas Marine Park. These join other recent reserves, including a sixfold expansion of the U.S. Pacific Remote Islands Marine National Monument (2014); Kiribati's ban on commercial fishing in its Phoenix Island Protected Area (2015); the United Kingdom's Pitcairn Islands Marine Reserve (2015), which will be the world's largest fully protected marine area; and New Zealand's Kermadec Ocean Sanctuary (2015). Each of these new protected areas, if fully implemented and enforced, should bring significant ecological benefit.

These areas contribute to global targets set in SDG Goal 14 and the Convention on Biological Diversity's (CBD) Aichi Target 11 to protect at least 10% of coastal and marine areas by 2020. These targets employ a loose definition of "protection." We find it more useful to distinguish among "lightly protected" (some protection exists but significant extractive activity is allowed), "strongly protected" (all commercial activity prohibited, only light recreational and subsistence fishing allowed), and "fully protected" (no extractive activities allowed; also called "marine reserves"). The term "Marine Protected Area" (MPA) encompasses all three categories, among which ecological benefits vary greatly (*1*).

Even lumping all categories together, only 3.5% of the ocean is protected (see the figure). Only 1.6% is "strongly" or "fully" protected. In contrast, the CBD 17% target for terrestrial protection is likely to be met by 2020—it currently stands at ~15% (*2*). Conservation organizations and scientific analyses support ocean protection ranging from 20 to 50% (*3*). Existing MPAs are solely within countries' jurisdictions, leaving the High Seas (~58% of the ocean) without any permanent protection (hence the new UN High Seas process). Protecting the High Seas could bring significant fishery enhancement in addition to the primary goal of biodiversity benefit (*4*). Representativeness of protection across diverse habitats may be more important than total area (*5*), but no adequate measure exists to



Increases in global MPA coverage over time. The line graph shows increasing MPA area. MPAs and year established are shown below the *x* axis. Data include formal commitments for large MPAs made in mid-2015. Bar graphs (decadal from 1960 to 2010, plus 2015) show percent ocean surface area that is strongly or fully protected (dark blue) out of the total percent MPA coverage (light blue). Circled numbers highlight key international events or agreements: **1**) First AAAS Marine Reserves Symposium; **2**) First NCEAS Marine Reserves Working Group; **3**) UN World Summit on Sustainable Development; **4**) Vth IUCN World Parks Congress; **5**) UN Convention on Biological Diversity (CBD); **6**) CBD, Aichi Targets; **7**) UN SDG 14. Chagos MR currently in negotiation (see SM). GBRMP, Great Barrier Reef Marine Park; PRIMNM, Pacific Remote Islands Marine National Monument; MP, Marine Park; MR, Marine Reserve; MTMNM, Marianas Trench Marine National Monument; OS, Ocean Sanctuary; PEI MPA, Prince Edward Islands Marine Protected Area; PIPA, Phoenix Islands Protected Area; PMNM, Papahānaumokuākea Marine National Monument. Pre-2015 data from World Database on Protected Areas and MPAtlas, collated by R. Moffitt, and from (*6*). Mid-2015 large MPA data compiled by authors from data made public as formal MPA commitments are announced. See SM for MPA sizes.

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assess how protection is distributed globally or within nations' exclusive economic zones [see the supplementary materials (SM)].

Despite the low fraction of the ocean protected, significant progress has been made in the last decade (*6*) (see the figure and the SM)—from less than 0.1% to 1.6% strongly protected. This reflects increasingly strong scientific evidence about the social, economic, and environmental benefits of full protection; greater attention to community, stakeholder, and governance dynamics; increasing recognition of the need for more protection due to threats to biodiversity, overfishing, and the lack of assessment for many marine stocks; dedicated campaigns by nongovernmental organizations (NGOs); funding by philanthropies; and new technologies that enable more effective enforcement. Complementary changes are under way in some fishery management to achieve more sustainable fisheries outside marine reserves [e.g., (*7*)].

MATURE SCIENCE. Although the science of MPAs is mature and extensive, political discussions are frequently disconnected from that knowledge, and resistance from resource extractors is often intense. We highlight seven important, relevant findings.

Full protection works. Fully protected, effectively enforced reserves almost always achieve their primary goal of significant ecological gains, including more species in greater numbers and larger sizes [e.g., (*8*, *9*)]. Fully protected areas have ecological benefits up to an order of magnitude greater than partially protected areas (*1*). Strong potential also exists to help recover some depleted fisheries outside a reserve [e.g., (*4*)]. They also provide a control to evaluate the impact of fishing and thus improve fishery management.

Habitats are connected. Networks of reserves that extend beyond coastal waters into deeper waters can protect more biodiversity; many species move among habitats during their life cycles. If seamounts are fully protected within a strategically placed reserve, they can also benefit migratory animals such as tuna and marine mammals.

Networks allow fishing. Connected networks of reserves can protect species while allowing extractive use between reserves. Connectivity occurs through movement of larvae, juveniles, or adults, sometimes across political jurisdictions, leading to greater benefits than from a set of unconnected reserves (*10*). Simply having multiple relatively small reserves within a region, without thoughtful design, does not guarantee connectivity.

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Engaging users usually improves outcomes. Reserves or networks planned with fishers and managers can address both conservation and fishery goals. For example, Territorial User Rights Fisheries (TURFs) can be combined with reserves, as fishing cooperatives with secure access recognize the benefits of creating neighboring "fish banks" to provide spillover into their fishing areas (*7*).

"An accelerated pace of protection will be needed..."

Reserves can enhance resilience. Large and strategically placed reserves with their full component of trophic levels and greater genetic and species diversity are likely to be more resilient to some environmental changes and could be important tools in climate adaptation [e.g., (*11*, *12*)].

Planning saves money. Thoughtful planning can minimize the costs of reserves, including foregone revenue [e.g., (*13*)]. Reserves can increase economic benefits, such as through spillover of adults to fished areas or enhanced tourism revenues; in some cases, the value of the reserve can exceed the pre-reserve value (*14*).

Ecosystems matter. Complementary efforts beyond reserves and MPAs are needed to fully protect and restore ecosystem functioning. Smart planning using science- and ecosystem-based approaches can enable a combination of sustainable uses (fishing, aquaculture, energy generation, recreation, and the like) and protected places (*15*).

POLICY CONNECTIONS. Cognizant of the disparity between existing protection and policy—or scientific—targets, we offer six recommendations.

Embrace options. MPAs have been implemented using myriad top-down (politically mandated) and bottom-up (citizen-driven) approaches (see SM). Both are needed to achieve adequate protection.

Bring users to the table. Involving stakeholders during all stages can assist successful MPA planning, improving outcomes of resource protection while minimizing the effects on resource users (see SM).

Change users' incentives. Push-back is understandable from those who bear the immediate costs, especially if there is no guarantee of direct benefit. This has been the single biggest impediment to the creation of reserves. Good reserve design and explicit transition strategies can help minimize economic and social effects (e.g., fisheries buyouts, phasing out fishing over time, or training for alternative livelihoods). Even more powerful approaches turn losers into winners—for example through TURF-reserves or other rights-based fishery management (*7*) or by treating reserves as a new business, with users as investors and shareholders, and a return on investment expected in future years (*14*).

Use new technologies for enforcement. Partnerships between NGOs, the technology industry, and agencies use satellite tracking to visualize boat traffic, identify potential illegal fishing, and direct law enforcement to offenders. These complement international initiatives to reduce what has been a major threat to fishery management and biodiversity protection: Illegal, Unregulated, and Unreported (IUU) Fishing.

Integrate reserves with other management measures. Reserves cannot address all stressors affecting the ocean. Complementary management, ideally integrated with reserves, is necessary to address issues such as bycatch, unsustainable and IUU fishing, climate change, and ocean acidification.

Expect surprises and use adaptive management. When reserve goals are identified, so, too, should plans be laid for accommodating unexpected changes. Monitoring is key to track progress and signal when management plans should be reviewed. Management agencies need the capacity to effectively evaluate reserve outcomes and use sound data for adapting appropriately.

An accelerated pace of protection will be needed for the ocean to provide the full range of benefits people want and need. ■

REFERENCES AND NOTES

1. S. E. Lester, B. S. Halpern, *Mar. Ecol. Prog. Ser.* **367**, 49 (2008).
2. Secretariat of the Convention on Biological Diversity, "Global Biodiversity Outlook 4" (Montréal, Canada, 2014).
3. K. Grorud-Colvert, J. Lubchenco, A. Barner, in *Science for Parks, Parks for Science: The Next Century*, S. R. Beissinger, D. Ackerly, H. Doremus, G. Machlis, Eds. (University of Chicago Press, Chicago, in press).
4. C. White, C. Costello, *PLOS Biol.* **12**, e1001826 (2014).
5. B. Pressey *et al.*, *Nature* **515**, 28 (2014).
6. R. J. Toonen *et al.*, Big Ocean Think Tank, *Mar. Pollut. Bull.* **77**, 7 (2013).
7. A. K. Barner *et al.*, *Oceanography* **28**, 252 (2015).
8. S. E. Lester *et al.*, *Mar. Ecol. Prog. Ser.* **384**, 33 (2009).
9. J. E. Caselle, A. Rassweiler, S. L. Hamilton, R. R. Warner, *Scientific Reports.* **5**, 14102 (2015).
10. K. Grorud-Colvert *et al.*, *PLOS ONE* **9**, e102298 (2014).
11. A. D. Olds *et al.*, *Glob. Change Biol.* **20**, 3050 (2014).
12. F. Micheli *et al.*, *PLOS ONE* **7**, e40832 (2012).
13. C. J. Klein *et al.*, *Conserv. Biol.* **22**, 691 (2008).
14. E. Sala *et al.*, *PLOS ONE* **8**, e58799 (2013).
15. K. L. McLeod, H. Leslie, *Ecosystem-Based Management for the Oceans* (Island Press, Washington, DC, 2009).

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SUPPLEMENTARY MATERIALS

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