

Contribution to the Themed Section: ‘*Marine Protected Areas*’

Food for Thought

No-take marine reserves are the most effective protected areas in the ocean

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Marine protected areas (MPAs) are an essential tool for reversing the global degradation of ocean life. Hence, it is important to know which types of MPAs are more effective, and under which conditions. No-take marine reserves – the MPAs with stronger protection – are very effective in restoring and preserving biodiversity, and in enhancing ecosystem resilience. A new meta-analysis of previous studies shows that biomass of whole fish assemblages in marine reserves is, on average, 670% greater than in adjacent unprotected areas, and 343% greater than in partially-protected MPAs. Marine reserves also help restore the complexity of ecosystems through a chain of ecological effects (trophic cascades) once the abundance of large animals recovers sufficiently. Marine reserves may not be immune to the effects of climate change, but to date, reserves with complex ecosystems are more resilient than unprotected areas. Although marine reserves were conceived to protect ecosystems within their boundaries, they have also been shown to enhance local fisheries and create jobs and new incomes through ecotourism.

Keywords: ecosystem restoration, marine conservation, marine protected areas, marine reserves, resilience.

As of March 2017, 3.5% of the ocean was within implemented “Marine Protected Areas” (MPAs), and only 1.6% was in strongly protected (no-take) MPAs (Lubchenco and Grorud-Colvert, 2015). Despite the recent increase in large MPAs worldwide, we are still short of the United Nations target of 10% of the ocean protected by 2020. Although MPAs are a key tool for ocean conservation, there is some uncertainty regarding when and where MPAs are most effective (Woodcock *et al.*, 2016). Here, we show that no-take MPAs are very effective in restoring and preserving the ecosystems they are designed to protect from human exploitation.

What’s a marine protected area?

There are many MPA definitions, but in summary, MPAs are areas that are intended to protect all or part of a marine ecosystem. At the most protective end of the spectrum are no-take “marine reserves” – areas where extractive activities are prohibited.

The rest are “partially protected MPAs” that allow extractive activities to different degrees. Here we will distinguish between these two groups (NCEAS, 2001; Lubchenco and Grorud-Colvert, 2015) and discuss only areas whose goal is to protect and restore marine biodiversity.

How effective are MPAs?

First, we need to define why are MPAs created. As originally conceived, the main goal of MPAs is to protect and restore biodiversity within their boundaries. “Biodiversity” ranges from species richness and abundance to the structure of ecosystems (Sala and Knowlton, 2006).

The fish come back

A meta-analysis of scientific studies (Supplemental online material) shows that the biomass of the whole fish assemblage is, on

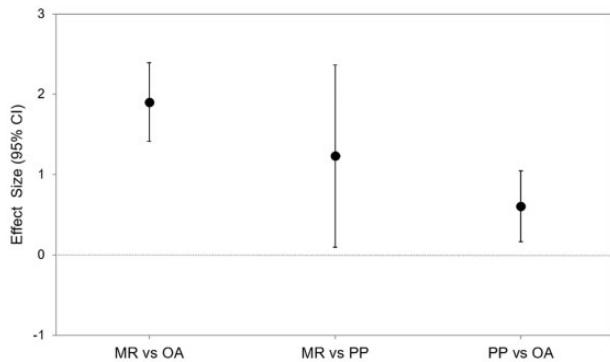


Figure 1. Comparison of ecological benefits between no-take marine reserves (MR) and partially-protected MPAs (PP). Meta-analysis of 10 studies using log-ratios of total fish biomass (see Supplemental online material). OA, Open Access (unprotected).

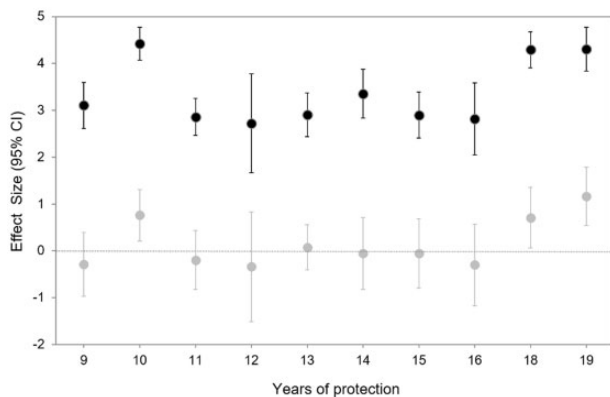


Figure 2. Recovery of fish biomass over time in adjacent marine reserve (MR; black dots) and partially protected MPA (PP; grey dots). Log-ratios of fish biomass relative to open access (unprotected) areas nearby (OA). Modified from Garcia-Rubies *et al.* (2013).

average, 670% greater within marine reserves than in unprotected areas, and 343% greater than in partially-protected MPAs (Figure 1). Fish biomass in partially protected MPAs was only 183% greater than in unprotected areas, and often it was not different from unprotected areas (e.g. Aburto-Oropeza *et al.*, 2011). In addition, fish biomass was restored in marine reserves over time after protection, but not in partially-protected MPAs or unprotected areas (Figure 2).

What about the rest of the ecosystem?

Marine reserves can cause indirect effects that restore the structure and complexity of the ecosystem as it was before overexploitation – once predator abundance recovers sufficiently. For example, in the Mediterranean and New Zealand, sea urchin predators reduce sea urchin density and consequently have shifted the ecosystem from a degraded state (sea urchin barren) to a complex, healthy state (algal forests with high biodiversity) (Shears and Babcock, 2003; Guidetti and Sala, 2007). Initial detection of effects on target species was 5 years on average, but detection of indirect effects on other taxa (e.g. sea urchins, abalone, algae) took 13 years (Babcock *et al.*, 2010). In tropical seas,

unfished reefs with very large fish biomass also tend to be associated with greater coral coverage and less coral disease than fished reefs (Sandin *et al.*, 2008), and a microbial ecosystem with less bacteria, viruses and pathogens (Dinsdale *et al.*, 2008). Such effects are not so apparent in places like the Caribbean, however, because most marine reserves have not achieved yet a sufficient abundance of large fishes to exert their significant ecological function.

Can MPAs protect from climate change?

MPAs may not provide resistance against warming, but they can provide resilience. In 2016, a strong El Niño event caused the most severe coral bleaching event in history, which killed 67% of the coral in the northern part of the Great Barrier Reef in Australia in just nine months (Hughes *et al.*, 2017). However, corals in the Line Islands affected by the strong 1997–1998 El Niño recovered in fully protected reefs within a decade, whereas they did not in unprotected islands (Sandin *et al.*, 2008). In Baja California, Mexico, a mass mortality event caused by climate-driven oxygen depletion affected pink abalone populations, but they replenished faster within marine reserves because of large body size and high egg production of the protected adults (Micheli *et al.*, 2012).

Can MPAs help improve fisheries?

In the late 1990s, some fishers and fisheries scientists, mostly in the United States, started to criticize MPAs, arguing that they can harm fishing (Hilborn *et al.*, 2004), and trying to place the burden of proof on conservationists (Dayton, 1998). A flurry of studies followed, focused on whether MPAs produce fish “spillover” that could help adjacent fisheries. Although MPAs were not initially conceived to help catch more fish outside their boundaries, well-enforced marine reserves can increase adjacent fishery catches, ensure the sustainability and increase the long-term profitability of local fisheries (Halpern *et al.*, 2009; Goñi *et al.*, 2011; Sala *et al.*, 2013).

Some studies investigated the trade-offs between protection and displacement of fishing effort to adjacent areas, concluding that there is a risk these areas are depleted faster (Dinmore *et al.*, 2003; Hiddink *et al.*, 2006), and that fishers displaced by protection would suffer economic losses. However, as of March 2017, only 1.6% of the ocean is fully protected from fishing, thus the displacement and the economic loss issues are currently insignificant at the global scale. Locally, the value of marine reserves can also exceed the unprotected counterfactual and offset short-term losses for fishers (Sala *et al.*, 2016). Also, in many places marine reserves also create other business opportunities, mostly through ecotourism, as the growing SCUBA diver population wants to travel to where they will see abundant marine life. In some cases, fishers can offset potential losses and increase their incomes almost immediately (Sala *et al.*, 2013, 2016).

Conclusion

No-take marine reserves are by far the most effective type of MPA. They restore the biomass and structure of fish assemblages, and restore ecosystems to a more complex and resilient state. Partially protected MPAs can have some value by restricting specific activities (e.g. banning trawling to prevent habitat destruction), but in general they are not as effective. Marine reserves are no panacea for the ocean’s problems, but they provide

outstanding ecological and economic benefits within and beyond their boundaries. In other words, they provide more than what they were initially designed for.

Supplementary data

Supplementary material is available at the *ICESJMS* online version of the manuscript.

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References

- Aburto-Oropeza, O., Erisman, B., Galland, G. R., Mascarenas-Osorio, I., Sala, E., Ezcurra, E. 2011. Large recovery of fish biomass in a no-take marine reserve. *PLoS ONE*, 6: e23601.
- Babcock, R. C., Shears, N. T., Alcalá, A. C., Barrett, N. S., Edgar, G. J., Lafferty, K. D., McClanahan, T. R., *et al.* 2010. Decadal trends in marine reserves reveal differential rates of change in direct and indirect effects. *Proceedings of the National Academy of Sciences*, 107: 18256–18261.
- Dayton, P. K. 1998. Reversal of the burden of proof in fisheries management. *Science*, 279: 821–822.
- Dinmore, T., Duplisea, D., Rackham, B., Maxwell, D., and Jennings, S. 2003. Impact of a large-scale area closure on patterns of fishing disturbance and the consequences for benthic communities. *ICES Journal of Marine Science: Journal Du Conseil*, 60: 371–380.
- Dinsdale, E. A., Pantos, O., Smriga, S., Edwards, R. A., Angly, F., Wegley, L., Hatay, M., *et al.* 2008. Microbial ecology of four coral atolls in the Northern Line Islands. *PLoS ONE*, 3: e1584.
- García-Rubies, A., Hereu, B., and Zabala, M. 2013. Long-term recovery patterns and limited spillover of large predatory fish in a Mediterranean MPA. *PLoS ONE*, 8: e73922.
- Goñi, R., Badalamenti, F., and Tupper, M. 2011. Effects of marine protected areas on local fisheries: evidence from empirical studies. *In Marine Protected Areas: A Multidisciplinary Approach*, pp. 72–98. Ed. by J. Claudet. Cambridge University Press, Cambridge.
- Guidetti, P., and Sala, E. 2007. Community-wide effects of marine reserves in the Mediterranean Sea. *Marine Ecology Progress Series*, 335: 43–56.
- Halpern, B. S., Lester, S. E., and Kellner, J. B. 2009. Spillover from marine reserves and the replenishment of fished stocks. *Environmental Conservation*, 36: 268–276.
- Hiddink, J., Hutton, T., Jennings, S., and Kaiser, M. 2006. Predicting the effects of area closures and fishing effort restrictions on the production, biomass, and species richness of benthic invertebrate communities. *ICES Journal of Marine Science: Journal Du Conseil*, 63: 822–830.
- Hilborn, R., Stokes, K., Maguire, J.-J., Smith, T., Botsford, L. W., Mangel, M., Orensanz, J., *et al.* 2004. When can marine reserves improve fisheries management?. *Ocean & Coastal Management*, 47: 197–205.
- Hughes, T. P., Kerry, J. T., Álvarez-Noriega, M., Álvarez-Romero, J. G., Anderson, K. D., Baird, A. H., Babcock, R. C., *et al.* 2017. Global warming and recurrent mass bleaching of corals. *Nature*, 543: 373–377.
- Lubchenco, J., and Grorud-Colvert, K. 2015. Making waves: the science and politics of ocean protection. *Science*, 350: 382–383.
- Micheli, F., Saenz-Arroyo, A., Greenley, A., Vazquez, L., Espinoza Montes, J. A., Rossetto, M., and De Leo, G. A. 2012. Evidence that marine reserves enhance resilience to climatic impacts. *PLoS ONE*, 7: e40832.
- NCEAS 2001. Scientific consensus statement on marine reserves and marine protected areas. National Center for Ecological Analysis and Synthesis. <https://www.nceas.ucsb.edu/consensus/consensus.pdf>.
- Sala, E., Costello, C., Dougherty, D., Heal, G., Kelleher, K., Murray, J. H., Rosenberg, A. A., *et al.* 2013. A general business model for marine reserves. *PLoS ONE*, 8: e58799.
- Sala, E., Costello, C., Parme, J. D. B., Fiorese, M., Heal, G., Kelleher, K., Moffitt, R., *et al.* 2016. Fish banks: an economic model to scale marine conservation. *Marine Policy*, 73: 154–161.
- Sala, E., and Knowlton, N. 2006. Global marine biodiversity trends. *Annual Review of Environment and Resources*, 31: 93–122.
- Sandin, S., Smith, J., Demartini, E., Dinsdale, E., Donner, S., Friedlander, A., Konotchick, T., *et al.* 2008. Baselines and degradation of coral reefs in the northern Line Islands. *PLoS ONE*, 3: e1548.
- Shears, N. T., and Babcock, R. C. 2003. Continuing trophic cascade effects after 25 years of no-take marine reserve protection. *Marine Ecology Progress Series*, 246: 1–16.
- Woodcock, P., O’Leary, B. C., Kaiser, M. J., and Pullin, A. S. 2016. Your evidence or mine? Systematic evaluation of reviews of marine protected area effectiveness. *Fish and Fisheries*, doi:10.1111/faf.12196.

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