

Good Governance and Local Management Improve Marine Protected Area Outcomes

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Accelerating ecosystem degradation has spurred proposals to vastly expand the global extent of large and fully exclusionary protected areas (PAs)^{1,2}, potentially impacting the livelihoods and development of indigenous peoples and local communities (IPLCs) worldwide³. The benefits of multi-use PAs that involve IPLCs in management have long been recognized⁴⁻⁷, however qualitative and context-specific investigations have constrained the development of best-practice recommendations⁸⁻¹⁰. Consequently, quantitative empirical examinations of how governance structures and the decentralization of management rights impact conservation outcomes are critical for the long-term sustainability of multi-use PAs. Here, we use a long-term, quasi-experimental monitoring dataset encompassing 160 sites in 8 Indonesian marine protected areas to demonstrate that multi-use PAs can increase fish biomass, and that governance characteristics are as significant as underlying social-ecological contexts in determining ecological outcomes. Further, we show that the positive impacts of resource governance are amplified where IPLCs have the capacity to exercise autonomous resource-management rights. Our results suggest that multi-use PAs that enhance the autonomy, cultural history, and economic development of IPLCs provide a viable and more equitable alternative to exclusionary PAs.

These findings represent a foundation for the design of effective nature stewardship that can enable both environmental conservation and human development.

Sustaining human well-being without exacerbating ecosystem degradation is a critical challenge in the Anthropocene¹¹, requiring conservation initiatives that empower diverse actors to effectively manage natural resources. Global agreements, such as the Convention on Biological Diversity (CBD), have a critical role in creating the enabling conditions and policy imperatives for this empowerment to occur. As negotiations for the post-2020 CBD targets framework commence, there have been multiple calls for the substantive expansion of exclusionary protected areas (PAs)—those that prohibit all extractive activities—to cover large proportions of remaining “wilderness”^{1,2}. These proposals have been critiqued for their potential to undermine the autonomy and livelihoods of the indigenous peoples and local communities (IPLCs) who often manage these land- and sea-scapes, and for discounting the ability of resource governance systems to accomplish conservation objectives without strict exclusionary management^{3,12,13}. Multi-use PAs comprised of mosaics of exclusionary and regulated-use zones provide an alternative to fully exclusionary PAs that can preserve biodiversity and ecosystem services without increasing social conflict and inequality^{4,11}. Further, multi-use PAs that formally incorporate IPLCs into decision-making and active management (i.e. aspects of co-management) have repeatedly demonstrated the capacity to produce beneficial social-ecological outcomes⁵⁻⁷.

Extensive research has indicated that in these systems, governance—the formal and informal institutions through which authority and power are conceived and exercised¹⁴—can have significant impacts on social-ecological interactions and outcomes¹⁵⁻¹⁷. A multitude of

frameworks and recommendations for good governance exist¹⁸⁻²⁰, with many drawing extensively from common pool resource governance theory (developed by Elinor Ostrom and colleagues¹⁵). Investigations across regions and biomes have highlighted the effectiveness of Ostrom's governance principles¹⁷, particularly the role of inclusive collective choice arrangements²¹. Unfortunately, studies examining governance arrangements are frequently restricted to individual case studies⁸, have been limited by insufficient quantitative governance⁹ or ecological¹⁰ data, or lack the suitable controls and rigorous study design required for causal inference²². As a result, governance literature is predominantly qualitative, correlative, and context-specific, impeding the development of generalized best-practices⁸, and prompting calls for quantitative approaches that more clearly discern causality and allow for integration of findings across studies²³.

We used a long-term, quasi-experimental monitoring dataset to provide a quantitative understanding of the impacts and interactions of environmental conditions, social contexts, property-rights arrangements, and governance regimes of multi-use marine protected areas (MPAs) on the biomass of coral reef fishes. Most importantly, we did so using methodologies that allowed for robust causal inference²⁴⁻²⁶. Our dataset encompassed 8 MPAs with varying governance regimes, sizes, and compositions of no-take and fishing zones (Figure 1). Although these MPAs are largely controlled by national or local governments, various site-specific agreements have incorporated customary management into zoning and governance arrangements, and we therefore assess the importance of “co-management” through indicators of community-level marine property-rights. Study sites were located in the Bird's Head and Sunda-Banda Seascapes of eastern Indonesia, a region with high coastal marine biodiversity²⁷, heavy reliance on marine fisheries²⁸, and a long history of stewardship by IPLCs under

customary management²⁹⁻³⁰. We calculated logged response ratios ($\ln RR$) of biomass changes within 10 reef fish families (kg/ha) across replicate surveys at 160 treatment and 48 control (non-MPA) sites between 2009-2017 (mean replicate gap: 3.54 years), and statistically matched each treatment site to two controls based on 41 ecological variables and site-level characteristics (Supplementary Table 3). Hereafter referred to as MPA_{Effect} , we calculated the relative impact of MPAs (compared to controls) on fish biomass by averaging differences between response ratios at treatment and control sites. Using household surveys ($n = 1,573$), key informant interviews ($n = 129$), and focus group discussions ($n = 81$) with community members in 81 settlements, we operationalized 26 social and governance indicators at each treatment site. We then used random forest with the Boruta extension to test the significance, relative importance, and interactions of these indicators on MPA_{Effect} .

RELATIVE IMPORTANCE OF INDICATORS

Our initial model included 36 environmental and 3 site-level characteristics, as well as 11 social, 2 property rights, and 13 governance indicators (Supplementary Table 4). Ostrom's common pool resource theory prescribes eight principles for sustainable governance: (O1) resource users can participate in modifying rules; (O2) management rights of resource users are not challenged by external authorities; (O3) resources have clearly defined boundaries; (O4) harvest rules are tailored to local conditions; (O5) monitoring and enforcement is accountable to both resources and users; (O6) graduated sanctions are enforced on rule-breakers; (O7) low-cost conflict resolution mechanisms are readily available; and (O8) governance is organized into multiple nested enterprises. Although we collected data on all eight governance principles, there

was insufficient data (e.g. a high frequency “not applicable” or “I don’t know” responses) for indicators relating to principles O2, O7, and O8.

After eliminating variables that were not significant to model outcomes and those with high multicollinearity, 18 indicators remained, and our model explained 28% of the variation in MPA_{Effect} (Figure 2). The governance indicators associated with increased fish biomass included user-specific rules (O4), rule flexibility to changing social and ecological conditions (O4), and the presence of graduated sanctions (O6). Three governance indicators (user participation in rule- and decision-making (O1), clearly defined boundaries (O3), and the percentage of user groups involved in compliance monitoring (O5)) exhibited inconsistent directional impacts on fish biomass change. Only penalty frequency (O5) was negatively associated with ecological outcomes. Common pool resource theory would predict that increased penalty frequency is likely indicative of strong accountable monitoring structures and therefore improved governance. However, increased penalty frequency may also be representative of (or a response to) similarly high levels of conflict and non-compliance, which can significantly reduce the efficacy of conservation initiatives³¹.

Significant increases in fish biomass were also observed when a large proportion of community members exercised “management rights,” defined as the three collective-choice rights described by Schlager and Ostrom¹⁶: rights to (1) *manage* by regulating internal use patterns and transforming the resource by making improvements; (2) *exclude* by determining who will have access to marine resources, and how those rights may be transferred; and (3) *alienate* by selling or leasing either management or exclusion rights. These rights served as our primary indicator of “co-management,” as they represented the level to which local

resource-users have autonomy over resources. Greater efficacy when resource-users with intimate knowledge of local environments manage resources themselves is likely a consequence of well-functioning and secure customary governance structures continuing to operate underneath formalized MPA management regimes⁴. This provides further evidence that effectively integrating customary management into broader conservation interventions can improve conservation outcomes³².

Indicators related to reliance on marine resources demonstrated variable effects. Although lower rates of exercising harvest rights (rights to *access* MPAs and *harvest* resources from them, potentially translating into lower fishing pressure) were associated with improved outcomes, livelihood diversity did not display a consistent directional impact on MPA_{Effect}. Conventional theory would suggest that the presence of alternative sources of income reduces strain on fisheries, as communities have fewer fishers overall and are less prone to non-compliance to rules³³. However, evidence from fishing communities globally has shown that identity and cultural norms and values play a significant role in determining decisions to engage in fishing³⁴, so the presence of alternative livelihoods may not necessarily equate to less pressure on fisheries. However, two metrics that might serve as a proxy for reliance on natural resources did produce strong impacts: (1) distance to markets and (2) land area within 10 km. In the case of market distance, our results contrast global¹⁰ and regional³⁵ studies that indicate increased biomass at remote reefs further from markets. We find the opposite trend, perhaps indicating that in our study sites, a lack of alternative options for sustenance or income may result in heavier exploitation of local fisheries, or that remote areas are harder to patrol and are therefore more susceptible to illegal, unreported, and unregulated fishing. Land area in proximity to ecological

sites was highly correlated with nearby human population sizes, which is congruent with regional studies demonstrating that increased population density places additional pressure on natural resources³⁵.

Contrary to expectations, reef area within 10 km was negatively associated with fish biomass change. It is possible that this trend is the result of fishers preferentially harvesting in areas with expansive reef patches that are easier to locate and provide higher potential yield. Alternatively, it may be the result of the significant correlation between initial coral cover and coral degradation between replicate surveys across treatment sites where replicate benthic cover was available (Pearson's r : -0.47, $p < 0.001$, $n = 149$). Sites with higher initial coral cover, on average, lost a greater percentage of coral over time, potentially driving concurrent declines in fish biomass. If similar coral decline occurred in nearby reefs, fish populations may have decreased across a larger area, producing more pronounced declines in overall fish biomass. These results emphasize the importance of governance in conservation, as coral loss is primarily driven by global-scale environmental stressors that MPAs are ill-equipped to mitigate³⁶, while establishing governance regimes that improve outcomes are within the control of implementing agencies.

INDICATOR INTERACTIONS

We utilized two-way interaction plots to explore the impacts of environmental, social, property-rights, and governance indicators across gradients of one another. Several governance principles exhibited interaction effects that were strong enough to alter outcomes even in unfavorable environmental conditions (Figure 3). These principles included user-specific rules (O4), rule flexibility to ecological conditions (O4), penalty frequency (O5), and graduated

sanctions (O6). This pattern suggests that these principles impacted MPA performance ubiquitously across sites, while other governance and social indicators exhibited more context-specific effects. Further, when multiple governance principles were in place, predicted outcomes were amplified, reinforcing that the establishment of strong, sustainable governance is the result of complex interactions between multiple factors rather than the implementation of any single principle³⁷. For example, Figure 3a illustrates stronger positive predicted outcomes when both graduated sanctions (O6) and rule flexibility to ecological conditions (O4) exist compared to either principle in isolation. The benefits of rule congruency to local conditions (O4) as well as the use of graduated sanctions (O6) are consistent with previous investigations indicating that these principles are critically important across systems and geographies^{7,17,37}. A large body of literature has demonstrated the importance of biophysical characteristics for MPA efficacy (e.g. ³⁸⁻³⁹). Our results reveal that governance has quantitatively similar impacts on the success of conservation initiatives and can help overcome social-ecological conditions that would otherwise produce negative outcomes.

Household-level exercise of management rights (i.e. increased “co-management”) also significantly improved predicted outcomes, and often with greater strength than individual governance principles (Figure 4). In addition, more individuals exercising management rights within settlements had synergistic effects similar to the interaction of multiple governance principles. When beneficial governance principles were in place, their expected ecological benefits were enhanced when resource users were actively involved in managing resources, and management rights dampened the negative repercussions of the absence of good governance principles. The ability of management rights to promote increases in fish biomass regardless of

underlying social-ecological context provides strong quantitative support for previous investigations in Indonesia and elsewhere suggesting that incorporating customary management rights into conservation initiatives significantly improves social-ecological outcomes^{4,40}.

CONSERVATION IN THE ANTHROPOCENE

The widespread degradation of ecosystems combined with growing social and economic inequality requires careful consideration of the future of successful and equitable natural stewardship⁴¹. Large, permanent, and fully exclusionary PAs are seductive means to achieve conservation targets, but often result in greater physical displacement, social conflict, and economic stressors that disproportionately impact communities that are most reliant on natural resources⁴²⁻⁴³. Here, we have provided quantitative evidence that multi-use MPAs that incorporate customary management rights can increase fish biomass, and that: (a) local management rights deliver significant benefits regardless of social-ecological context; (b) management that is adaptive and well suited to local context is critical, especially in the context of a rapidly changing climate, and; (c) conservation initiatives predicated on enforcing penalties on rule-breakers are less effective than those in which resource-users have the capacity to engage in local resource management. These results suggest that large, fully exclusionary MPAs are not a prerequisite for conservation success, and support calls for more inclusive and diverse approaches to conservation initiatives in the Anthropocene.

Nearly 25% (38 million km²) of the world's lands and the majority of remaining intact natural areas are IPLC-managed⁴⁴, and IPLC-controlled lands are degrading more slowly than those managed by other groups⁴⁵. As governments and conservation organizations are likely to expand PAs into these areas to achieve CBD and similar targets, multi-use PAs offer a viable

alternative to large exclusionary zones that are more pragmatic, ethical, and effective at achieving joint biological conservation and socioeconomic development goals⁴². Additionally, as we have demonstrated that multi-use PAs are more effective when actively managed by local communities, present and future conservation efforts need to reinforce—not undermine—the ability of IPLCs to manage resources⁴⁶. This goal can be achieved through developing and strengthening inclusive and participatory governance systems, more purposefully integrating customary and *de jure* management into conservation programs, and supporting strong and secure tenure rights for local communities⁴⁷. Most importantly, these initiatives must ensure that management authority is devolved to local communities through formalized legal policy instruments to assure recognition by governments and private industry¹⁵.

The processes by which this goal can be accomplished will vary across regions, systems, and socio-economic contexts. Successful implementation of co-management will require inclusive participatory processes that prevent governance arrangements from leveraging existing power dynamics to further marginalize vulnerable groups⁴⁸, predict how securing management rights for IPLCs may impact decisions by resource users³², and ensure that management strategies match socioeconomic and cultural conditions and integrate scientific data with local knowledge⁴. Establishing effective co-managed PAs is a complex and nuanced task, but a necessary one, as fully separating people and nature on large scales will be impractical, inequitable, and ultimately incapable of solving the global issues that threaten biodiversity and ecosystem integrity. Long-term sustainability will also require adaptive and evidence-based decision making; necessitating an expansion of research programs aimed at demonstrating quantitative and inference-based links between decisions and social-ecological outcomes. It is

critical that we continue to gain a more thorough understanding of the dynamics of inexorably linked social-ecological systems, and provide a robust evidence base that local managers and communities can use to adaptively and sustainably manage resources.

[Figures 1 & 4](#)

[Figures 2 & 3](#)

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AUTHOR CONTRIBUTIONS

H.F., M.B.M., and F.P. conceived the study. R.Y.F. led the data compilation and analysis with assistance from A., A., G.N.A., C.C., E., L.G., C.H., W.P.L., S.L.M., M.B.M., F.P., S.P., D.A.A.B., S.J.C., K.C., M.D.N., H.E.F., D.G., N.I.H., R.J., D.T.L., P., A.V., and A.R.H. R.Y.F., G.N.A., C.C., L.G., S.L.M., M.B.M., D.G., and A.R.H. wrote the manuscript, with input from all other authors.

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