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POLICY BRIEF
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Two Decades of Community-Based Marine Conservation Provide the Foundations for Future Action

Juan Carlos Villaseñor-Derbez[1*], *Imelda G. Amador-Castro*[2], *Arturo Hernández-Velasco*[2], *Jorge Torre*[2] *and Stuart Fulton*[2*]

[1] Bren School of Environmental Science & Management, University of California, Santa Barbara, Santa Barbara, CA, United States, [2] Comunidad y Biodiversidad, Guaymas, Sonora, Mexico

As a member of the "High Level Panel for a Sustainable Ocean Economy", Mexico has committed to expand community-based marine conservation. We draw from more than two decades of experience to outline how existing resources may be leveraged to help inform the country's ambitious conservation plans. A total of 514.12 km^2 have already been protected under community-based marine reserves. 14 years of ecological survey data, more than 130 community surveyors, more than one hundred publications, and an entire digital infrastructure provide a solid platform on which to continue building the community-based marine conservation movement. Parallel and complimentary efforts have advanced regulation, action, data access and transparency, and coordination. Future interventions should innovate, but leverage existing resources and continue to involve communities.

Keywords: human capital, marine reserves, fishing communities, citizen science, small-scale fisheries, knowledge production

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****Correspondence:***
Juan Carlos Villaseñor-Derbez
juancarlos@ucsb.edu
Stuart Fulton
sfulton@cobi.org

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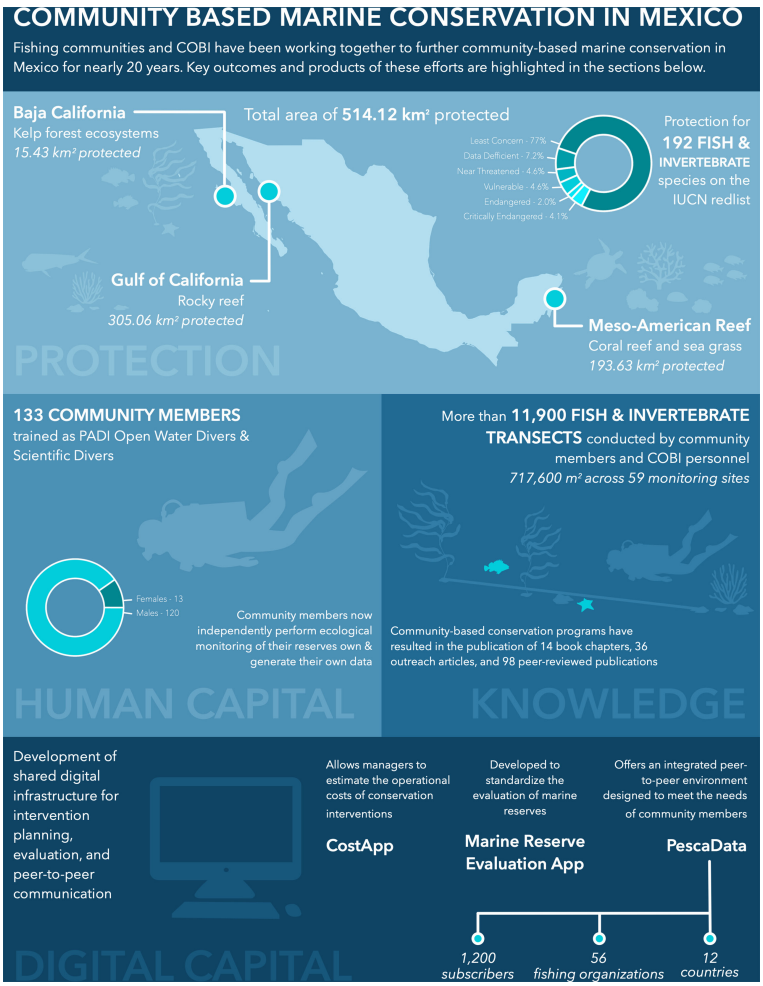
1 INTRODUCTION

The United Nations Decade of Ocean Science for Sustainable Development brings the promise of nations cooperating to make ambitious strides towards conserving the marine environment. The time is ripe to provide innovative solutions that will allow for equitable protection of our oceans (Dinerstein et al., 2019). But as we set to expand marine conservation, it is important that we look back, reflect on the success of previous interventions, and leverage existing resources to further marine conservation.

Marine reserves—spatially delimited areas in which fishing and other activities are regulated—are one of many tools managers have to conserve and protect the marine environment. The intuition is simple: by spatially limiting extractive and damaging activities, we allow for the recovery of biomass, species richness, and the ecological processes that come with them (Halpern and Warner, 2002; Lester et al., 2009). However, a pervasive finding is that compliance (or a lack thereof) is one of the main drivers of reserve effectiveness. Non-compliance can arise when resource users do not agree with or are not fully aware of the regulations (Bergseth et al., 2015), which is especially true in the case of top-down regulatory actions. Seeking to overcome this problem, the marine conservation movement embraced the concept of community-based marine conservation [also known as "bottom-up" or "grassroots" marine conservation; Johannes (2002); Berkes (2004)],



GRAPHICAL ABSTRACT | Two decades of community-based marine conservation and its contributions to environmental protection, human capital, generation of knowledge, and digital infrastructure.

which has gained traction over the past two decades (Gurney et al., 2021). By incorporating users from the onset of the process, community-based interventions allow for the co-design of policy interventions. In turn, this can result in greater compliance with the regulations and even advocacy in support of the cause Quintana et al. (2020).

As a member of the "High Level Panel for a Sustainable Ocean Economy" (oceanpanel.org), Mexico has committed to further expand its marine conservation initiatives, with a strong focus on increasing marine reserves created in collaboration with the fishing sector. While some innovation may be necessary to achieve this ambitious goal, it would be wise to start with successful models that have proven to deliver conservation and social benefits. Here, we document the results of two decades of prolific collaborations between fishing communities and the Mexican non-profit organization "Comunidad y Biodiversidad A.C." (COBI). Our objective is not to provide "best practices" or "design principles" for the implementation of marine reserves, which have been covered elsewhere in the literature (Sala et al., 2002; Halpern and Warner, 2003; Munguia-Vega et al., 2018; Precoma de la Mora et al., 2021). Instead, we pursue the more modest objective of summarizing the achievements from two decades of community-based marine conservation, and to proving future policy makers, managers, and scientists with a foundation on which to continue to develop the marine conservation movement. Both points are particularly relevant to Mexico, but might help inform similar efforts elsewhere.

The text develops as follows. Section 2 provides a brief background on the context in which community-based marine reserves were implemented in Mexico. Section 3 provides a synthesis of outcomes and achievements from the past two decades of collaboration between fishing communities and COBI, and Section 4 summarizes parallel and complimentary efforts from other groups in Mexico. Finally, Section 5 concludes with actionable recommendations for policy makers, funding agencies, and conservation practitioners.

2 COMMUNITY-BASED MARINE RESERVES IN MEXICO

We begin with a brief overview of the institutional setting in which community-based marine reserves developed in Mexico. Whenever relevant, we draw parallels to similar institutions in other countries, in an effort to generalize our insights.

The first community-based marine reserves in Mexico were implemented within Territorial Use-Rights for Fisheries (TURFs) referred to as "Zonas de concesión" (concession zones). This form of spatial property rights dates back to the late 1930's, when Mexico passed an important "general law of fisheries" as part of an agrarian reform (See McCay et al. (2014) for a detailed historical account). In Chile, similar systems of spatial exclusive access are known as "Caletas" [Inlets; Gelcich et al. (2010)], in Brazil as "Reserva Extractivista" [Extractive reserve; Da Silva (2004)], and in Costa Rica "Áreas Marinas de Pesca Responsable" [Marine Area for Responsible Fishing; Fargier et al. (2014)]. Nuances make each of these unique, but they all share an important feature: they confer some form of spatial property rights to a group of fishers.

Implementing the first reserves within TURFs was therefore a strategic decision. A voluntarily-created reserve in an open-access area (*i.e.* outside a TURF) would have been vulnerable to poaching by those who do not recognize the reserve (Cudney-Bueno et al., 2009), while a reserve implemented by a community within a TURF was protected by the same norms governing said TURF. This facilitated the implementation of the first reserves in Isla Natividad in 2006, which represented a convergence of interests from fishers and the NGO. However, there is anecdotal evidence of fishers using rotational closures to manage their resources in this and other communities.

But what to do when a TURF is not available? The "Zona de Refugio Pesquero" or Fish Refuge is a legal mechanism for spatial marine protection originally included in the 1925 Mexican fisheries law, but rarely used before 2012 when civil society organizations began working with fishing communities and the government to scale their implementation (DOF, 2014; Espinosa-Romero, 2021). This novel legal framework enabled fishers that were not part of TURFs to engage in marine conservation, which led to the widespread implementation of community-based marine reserves (**Figure 1**). The communities that have implemented these are considerably heterogeneous; target species and fishing gears range from selective hand-collection of spiny lobster (*Panulirus argus*) in the Caribbean (Espinosa-Romero et al., 2017) to a multispecies fin-fish fishery in the Gulf of California (Karr et al., 2017).

3 SUMMARIZING TWO DECADES OF COLLABORATION IN NUMBERS

How have community-based marine reserves contributed to the conservation movement? Here we summarize the outcomes of two decades of work on community-based marine conservation in Mexico and highlight some of the resources that may be useful to the continued marine conservation movement. We present information on protection status, human capital, production of knowledge, and digital capital. For each section, we outline the outcomes and products, state how these resources may help to support advancements in the marine conservation agenda in Mexico, and provide suggestions for future programs.

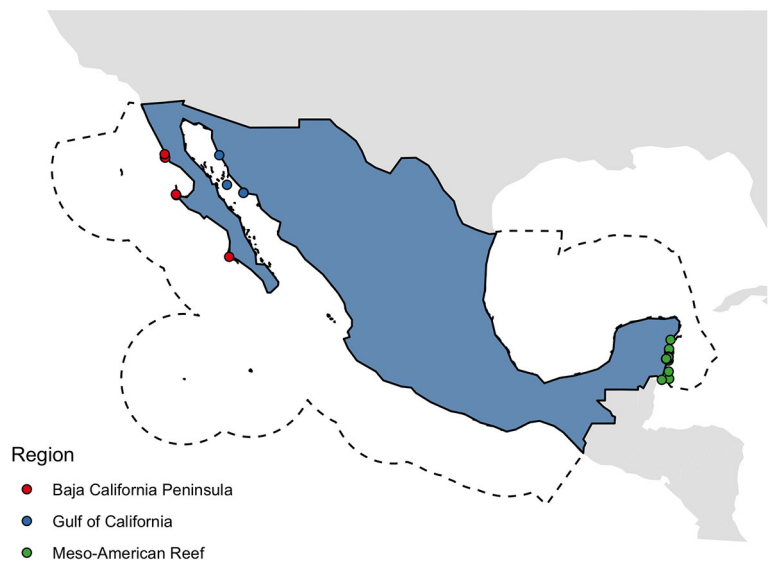


FIGURE 1 | Map showing the general locations of all community-based marine reserves implemented as part of collaborations between fishing communities and COBI. Points are colored by region, and the dashed line shows the Mexican Exclusive Economic Zone.

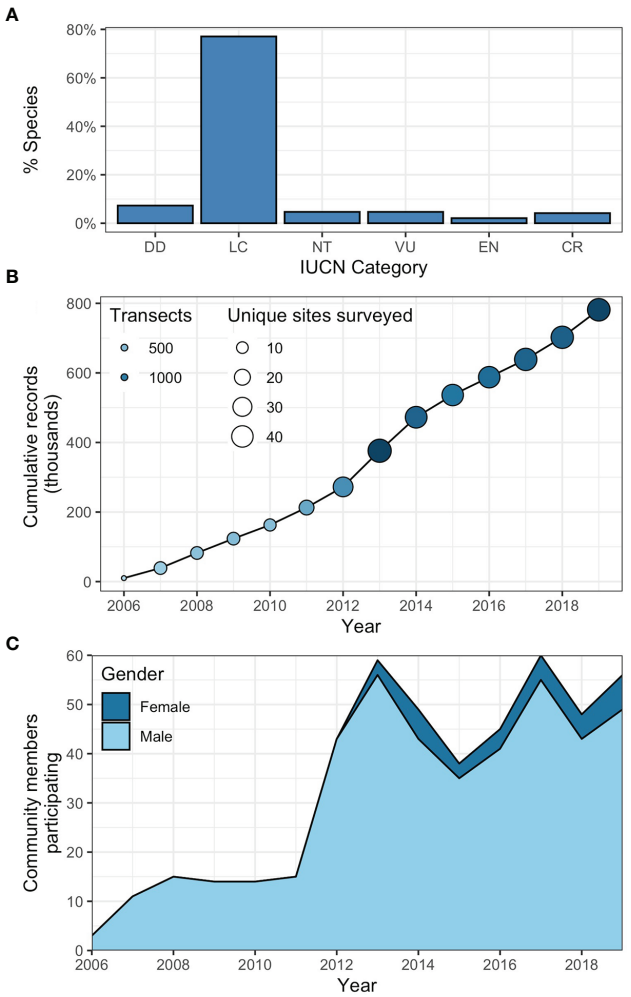


FIGURE 2 | Fourteen years of standardized ecological monitoring data. Panel **(A)** shows the distribution of species protected in Mexico's community-based reserves by IUCN category (DD: Data deficient, LC: Least concern, NT: Near threatened, VU: Vulnerable, EN: Endangered, CR: Critically endangered). Panel **(B)** shows the cumulative number of organisms recorded by divers participating in the ecological monitoring program. Marker size indicates the number of unique monitoring sites surveyed in any given year, and marker color indicates the number of individual transects performed. Panel **(C)** Shows the number of community members trained in SCUBA and scientific diving methods. Together, these data provide a reference point for future marine conservation interventions in Mexico.

3.1 Protection

The joint effort by fishing communities and COBI resulted in the creation of 26 marine reserves in 10 communities (**Figure 1**). These reserves protect 193.63 km^2 of coral reef and sea grass in the Meso-American Reef, 305.06 km^2 of rocky reef in the Gulf of California, and 15.43 km^2 of kelp forest ecosystems along the Baja California Peninsula. Together, these amount to a total of 514.12 km^2 protected, and provide protection to 268 invertebrate and fish species recorded in the monitoring data. Most of these species (N = 192) are also recorded in the Red List, compiled by the International Union for the Conservation of Nature (IUCN). From this subset, most (77%) have been identified as Least Concern or Data Deficient (7.2%), but a number are classified as Near Threatened (4.6%), Vulnerable (4.6%), Endangered (2%), or Critically Endangered [4.1%; Chamberlain (2020); IUCN (2021); **Figure 2A**, **Table S1**]. The extent to which these reserves have produced measurable ecological benefits remains unclear; some have reported enhanced resilience to environmental variation (Micheli et al., 2012) or increases in fin-fish biomass (Quintana et al., 2021), while others found little to no effect on density of targeted species (Villaseñor-Derbez et al., 2019).

While area protected in these reserves may seem small relative to other Mexican marine reserves such as Revillagigedo (representing 98.4% of Mexico's total no-take area coverage), we must emphasize that these have all been implemented through truly participatory and community-based processes, which maximize community buy-in and long-term commitment (Gelcich et al., 2008; Costello and Kaffine, 2010). In fact, all but one of the communities continue to foster their reserves by actively monitoring and enforcing them (Isla Magdalena decided to re-open their reserve five years after its implementation claiming economic hardship). Future conservation interventions should strive to replicate this participatory process, ensuring fishers and community members are not only consulted, but directly involved in the process of designing, establishing, and monitoring the reserves.

3.2 Human Capital

Collaboration between COBI personnel and community members was undoubtedly necessary to achieving this level of conservation, but has also resulted in mutual enrichment and capacity building. The ecological monitoring program has trained 133 community members (120 males, 13 females) as PADI Open Water Divers and Scientific Divers. The program initially engaged fishers, but has also expanded to include other community members since 2013, particularly women who expressed interest in being part of, and eventually leading, the ecological monitoring programs of the reserves [**Figure 2C**; Torre et al. (2019); Solano et al. (2021)]. Some community members have gone on to obtain certification as PADI Dive Masters and also offer dive tours in their reserves and adjacent waters, providing potential alternative livelihoods.

Community members now independently perform ecological and oceanographic monitoring of their reserves and *own* the data they generate. With the exception of some oceanographic monitoring data, fishers do not yet independently analyze it and often rely on external collaborations in order to maximize its value (Fulton et al., 2019) – this highlights the potential for further investment in human capital. Yet, this has motivated the younger population to become advocates for the cause (Espinoza-Tenorio et al., 2021). In cases where Mexican fishers have been involved in the ecological monitoring of marine reserves, participants have also reported personal growth in areas ranging from environmental awareness to public-speaking skills (Quintana et al., 2020), which has anecdotally enhanced their negotiating power with seafood buyers and policy-makers.

TABLE 1 | Long-term ecological monitoring has ancillary benefits.

Topic	Reference
Citizen science	Fulton et al. (2019)
Climate change and marine reserve design	Álvarez-Romero et al. (2018)
Detection of invasive species - *Sargassum filicinum*	Riosmena-Rodríguez et al. (2012)
Environmental variation and ecosystem resilience	Micheli et al. (2012)
Genetic diversity and connectivity	Munguía-Vega et al. (2015)
Range extension - *Holacanthus clarionensis, Stegastes leucorus, Stegastes acapulcoensis*	Hernández-Velasco et al. (2016)
Trophic ecology of endangered marine mammals	Arias-Del-Razo et al. (2019)
Women's role in small-scale fisheries	Solano et al. (2021)

The ecological monitoring data was collected to evaluate the effectiveness of marine reserves, but has been used in a plethora of other studies that continue to advance our knowledge and understanding of the natural world. This table shows some examples.

Two decades of citizen science and community-based monitoring programs have produced a vast network of expert scientific divers that are eager to contribute to conservation and transfer their knowledge. They are passionate conservationists that can become important allies by incentivizing others to join the movement. But more importantly, they will be the first to remind us that policy interventions have real-world implications that affect human lives. Future programs should leverage this vast human capital and incorporate their expertise on future conservation efforts.

3.3 Production of Knowledge

The first years of the conservation program focused on socializing with coastal communities, identifying *their* needs, and designing interventions. In 2001, COBI and the communities implemented ecological monitoring programs designed to provide the necessary data to evaluate the effectiveness of the marine reserves, answering questions like: "Has biomass gone up?" or "How has species richness changed?". The monitoring protocols were then adapted and standardized in 2006. Since then, more than 11,900 invertebrate and fish transects have been conducted, covering an area of 717,600 m^2 across 59 monitoring sites (**Figure 2B**). This massive monitoring effort has produced a valuable data set with more than half a million records for 268 invertebrate and fish species. This long-term record of species richness, abundance, and geographic distributions provides an important ecological baseline for three important marine ecosystems in Mexico: kelp forests, rocky reefs, and coral reefs.

Monitoring is one of the most valuable scientific undertakings (Giron-Nava et al., 2017). Not only does data allow us to answer the questions we set forth to understand when collecting them, but they also allows us to look back in time and ask new questions. These data have been useful to perform policy-evaluation studies to test for the performance of marine reserves Ferraro and Pattanayak (2006); Villaseñor-Derbez et al. (2019). However, they have also been used to answer other questions that advance our understanding of the natural world, inform management, or contribute data for risk-evaluation at the IUCN. The community-based conservation program resulted in the publication of 14 book chapters, 36 outreach articles, and 98 peer-reviewed publications. Only 37% of these peer-reviewed publications have been led by COBI personnel, highlighting the highly collaborative nature of the program (Lopez-Olmedo et al., 2019).

The bulk of the papers have a regional focus, with most of them studying the Gulf of California (n = 50). But the Pacific coastline of the Baja California Peninsula (N = 19) and the Mexican Caribbean (n = 9) have also been covered. Other studies reported results at the national (n = 15) or global (n = 4) level. Studies leveraging data from the marine reserve program have been crucial in identifying and documenting range extensions for multiple fish species, studying the effect of environmental variation on marine communities, or detecting invasive species (**Table 1** provides some examples). While these data will continue to be useful to evaluate the reserves, they can also serve as a baseline for the ecological status of the three main ecosystems and continue to support our understanding of the natural environment.

Citizen science is a topic rapidly gaining traction in the marine conservation realm. Two decades of interfacing with community members have shown that fisher's participation as citizen scientists increases the likelihood of attaining conservation goals (Fulton et al., 2018) and can produce vasts amounts of knowledge (Fulton et al., 2019). Future programs should leverage the existing data and knowledge, and continue to support the community participation.

3.4 Digital Capital

The permeation of digital technology into fisheries and conservation became evident over the last decade. This brought the development of shared digital infrastructure for intervention planning, evaluation, and peer-to-peer communication. For example, the CostApp (innovacionazul.shinyapps.io/AppCosteo/) is a web-based tool that allows managers to estimate the operational costs of conservation interventions, ensuring that programs have sufficient funds to succeed. On the management side, the Marine Reserve Evaluation App was developed to standardize the evaluation of marine reserves by leveraging the already-existing monitoring data described above (Villaseñor-Derbez et al., 2018). And finally, platforms like PescaData (pescadata.org) offer an integrated peer-to-peer environment designed to meet the needs of community members. As of 2022, PescaData has more than 1,200 subscribers from 56 fishing organizations in 12 countries.

Together, these apps provide a common platform where community members can interact with one another, and where they can collaborate with managers to design and evaluate conservation interventions. Future efforts should leverage these and other similar resources to design and evaluate interventions, and continue to embrace and enable the technological revolution taking place in the oceans.

4 PARALLEL AND COMPLIMENTARY EFFORTS

The collaborative efforts between COBI and many different fishing communities have not been the only successes advancing community-based conservation over the past two decades. The movement has benefited from the inertia of a number of different groups which must also be noted. Other actors include government offices, non-profit organizations, and academic institutions. Their successes have been documented elsewhere, but it is worth recognizing some of the most notable ones. Here, we briefly recount five particularly important efforts that have resulted in significant advances in legislation, action, data access and transparency, and science communication in Mexico. We cannot causally attribute the success of the reserves to the existence of these parallel efforts, nor can we say that these initiatives sprouted into action due to the reserves. However, we can safely say that they all contribute to the foundation on which to continue to build the marine conservation movement over the next decade.

- Perhaps one of the most transformative actions was the development of the normative framework that defines the implementation process of a Fish Refuge—the institution that allows community-based marine reserves to gain legal recognition. While many groups were involved [see Espinosa-Romero et al. (2014)], this was largely made possible by CONAPESCA (the regulatory office governing fisheries and aquaculture in Mexico). While some hurdles for scaling and accelerating the implementation of Fish Refuges remain, the agency's vision and willingness to adapt effectively revolutionized the way marine conservation with the fishing communities was carried out. This resulted in the empowerment of fishing communities and allowed them to show their commitment to sustainable fisheries and marine conservation.
- Many organizations have been involved in the implementation of community-based marine reserves. But perhaps one of the most notable ones is Sociedad de Historia Natural Niparajá. This non-profit organization was a key factor in pushing for regulatory changes but they also collaborated with fishers along the Gulf of California to implement a network of partial no-take zones under the Fish Refuge designation. This program also generated vasts amounts of ecological, socioeconomic, and fishery data through their respective monitoring programs and marked the beginning of long-term collaborations along the Gulf of California coast.
- "Data is power" is an often-heard phrase used by fishers who *own* the data they collect. Two notable efforts around data availability are worth mentioning. "Metadatos Marinos de México" (Mexican Marine Metadata) set out to generate a database of marine metadata, an inventory of what is available thanks to the arduous data-gathering programs by NGOs and academics, as well as publicly-available data (Palacios-Abrantes et al., 2019). The second, "Pescando datos" (fishing for data) seeks to promote access to administrative data sets, particularly those relating to financial data on fisheries and conservation. Not only have they successfully lobbied the Mexican government into making large amounts of data publicly available, but they also curate them and make them more readily available on their online platform.
- Finally, the Kanan Kay Alliance (alianzakanankay.org) is a model of multisectoral collaboration (fishing organizations, government, civil society, and academia) that created 17 Fish Refuges in the Mexican Caribbean (Moreno et al., 2017). This decade-long collaborative approach centered around the co-creation of common goals and objectives has proven to be a durable and scalable model for collaboration with the fisheries sector.

5 ACTIONABLE RECOMMENDATIONS

- Innovate, but do not ignore the past. Use the existing data, insights, knowledge and human capital.
- Design and evaluate policy interventions, and promote the use of experiments and randomized control trials Ferraro and Pattanayak (2006). Marine conservation should not be exempted from providing evidence of effectiveness (Sutherland et al., 2004). Interventions must be designed to allow for explicit program evaluation of their stated goals by leveraging state-of-the-art causal identification methods, which provide robust measures of the effect of policy interventions (Burgess et al., 2018).
- Incentivize data collection. Long-term monitoring can allow us to uncover new patterns in data, reveal nonlinear relationships, and improve a model's predictability of a system (Giron-Nava et al., 2017). Future efforts should support ongoing and new monitoring programs, particularly those that enable the use of causal identification strategies to evaluate the effects of policy interventions (Fox et al., 2017).
- But more importantly, "do no harm" (Torre and Fernández Rivera-Melo, 2018). Continue to involve local communities to ensure policy outcomes are met and avoid the implementation of paper parks at the expense of fisher's livelihoods.

AUTHOR CONTRIBUTIONS

JV-D: conceived the manuscript, analyzed the data and wrote the first draft. IA-C Procured the data and edited the manuscript. AH-V collected data and edited the manuscript. JT and SF conceived the manuscript, procured funding, and edited the manuscript. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2022.893104/full#supplementary-material

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