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Integrating Science-Based Co-management, Partnerships, Participatory Processes and Stewardship Incentives to Improve the Performance of Small-Scale Fisheries

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Small scale fisheries are critically important for the provision of food security, livelihoods, and economic development for billions of people. Yet, most of these fisheries appear to not be achieving either fisheries or conservation goals, with respect to creating healthier oceans that support more fish, feed more people and improve livelihoods. Research and practical experience have elucidated many insights into how to improve the performance of small-scale fisheries. Here, we present lessons learned from five case studies of small-scale fisheries in Cuba, Mexico, the Philippines, and Belize. The major lessons that arise from these cases are: (1) participatory processes empower fishers, increase compliance, and support integration of local and scientific knowledge; (2) partnership across sectors improves communication and community buy-in; (3) scientific analysis can lead fishery reform and be directly applicable to co-management structures. These case studies suggest that a fully integrated approach that implements a participatory process to generate a scientific basis for fishery management (e.g., data collection, analysis, design) and to design management measures among stakeholders will increase the probability that small-scale fisheries will implement science-based management and improve their performance.

Keywords: fishery management, science-based, rights-based management, sustainability, adaptive management, data-limited fisheries

INTRODUCTION

Small-scale fisheries are critically important globally for supporting local economies, poverty alleviation, and food security (Berkes et al., 2001; FAO, 2012). A recent analysis (Costello et al., 2012) suggests that fisheries that collect data, use the data to assess stock status against management targets, and employ effective governance regimes to achieve these targets perform relatively well with respect to management objectives. Small-scale fisheries, many of which are lacking a formal data collect system to guide management and which lack strong governance (Salas et al., 2007; Purcell and Pomeroy, 2015), appear to be underperforming with respect to conservation, the amount of food they can produce, the amount of money they can generate, and the quality of the livelihoods they can support (Costello et al., 2012).

Many factors related to successful small-scale fisheries management have been elucidated in the literature and through practical experience, including strong leadership (Gutiérrez et al., 2011), co-management (Gelcich et al., 2010; Cinner et al., 2013), secure catch or marine tenure privileges (Ovando et al., 2013), and scientific assessment of fishery status (Worm and Branch, 2012). Both the pathways and tools employed in fishery reform vary, but there is a growing consensus that the integration of effective fisheries governance and science-based management is crucial for success (Worm and Branch, 2012). For example, strong leadership and co-management with high social capital may not result in sustainable yields if scientific information on the true status of target stocks and the level of fishing mortality is not available due to the lack of monitoring and rampant illegal fishing (Hauck and Kroese, 2006; van Sittert et al., 2006; Spiller et al., 2016). To ensure good and sustainable yields, credible assessments of stock status should be integrated into a management regime that promulgates management measures on the basis of scientific assessment and monitoring, such as the Adaptive Fisheries Assessment and Management framework (Fujita et al., 2017; McDonald et al., 2017).

Because factors external to the harvest sector can drive overfishing or fishery stewardship, other strategies can and should be integrated with science and governance to improve fishery performance with respect to conservation, social, and economic goals. For example, seafood certification systems such as Fair Trade USA and the Marine Stewardship Council programs provide standards, information, training, and (in the case of Fair Trade USA) price premiums to facilitate and incentivize better performance (Gutiérrez et al., 2016). Such programs also provide better market access, in particular access to buyers committed to sourcing sustainable seafood, as do Fishery Improvement Projects (FIPs) (Bush and Oosterveer, 2015; Sampson et al., 2015). Ideally, science-based management, good fisheries governance, and demand-side strategies that reward good fishery performance are combined to generate strong incentives for continued improvement throughout a fishery's supply chain. Market access tied to outcome-based performance benchmarks could be used as a powerful driver for fishery improvement (Sampson et al., 2015), which should include the implementation of science-based harvest controls embedded within a good governance system that incentivizes high compliance.

The importance of integrating good governance with science-based management is also supported by case studies and experience in large scale fisheries (Costello et al., 2008; Grimm et al., 2012) and by a growing number of case studies of small-scale fisheries reform. Here, we examine five case studies of small-scale fisheries in Cuba, Mexico, the Philippines, and Belize to show lessons for how to integrate science-based management with good fisheries governance (**Table 1**).

CASE STUDIES

Multispecies Fishery, Cuba

The coastal and marine ecosystems of Cuba support rich biodiversity and a variety of fisheries (Kritzer et al., 2014). Lobster and shrimp fisheries important for exports have been monitored and managed based on scientific stock assessments for over 30 years (Alfonso et al., 2004; Puga et al., 2005, 2013; González-Yáñez et al., 2006; Formoso, 2007; Alzugaray and Puga, 2012; Giménez Hurtado et al., 2012). Cuba is now focusing on the assessment and management of nearshore finfish fisheries due to their importance for maintaining coastal ecosystem integrity, local livelihoods, food security, and many other ecosystem services such as nature-based tourism. Overfishing appears to be worsening and, though information about the health of most fish populations is sparse, scientists estimate that up to 60% of ecologically and commercially important fish species are overfished, threatening fishing communities, food security and biodiversity (Valle et al., 2011).

In 2012, the Cuban government initiated a community-based fisheries management project, *Sostenibilidad de las Pesquerías* (SOS Pesca). SOS Pesca is an international collaboration that targets two fishing communities (Playa Florida and Guyabal; **Figure 1A**) to demonstrate how marine protected areas and community-based fisheries management can work together to improve livelihoods, end overfishing and protect habitats. Scientists, managers and fishers worked collaboratively to complete a Productivity and Susceptibility Analysis (Puga et al., in press) of marine fisheries, using available life history data and expert knowledge to identify which fish stocks are most vulnerable to overfishing and should be priorities for management. Concurrently, diverse stakeholders from the communities, industry, NGOs and the government collaborated to enacted new community-based monitoring programs, proposed a fishery management plan to include catch limits and season closures for priority species (including current and future commercial targets and ecologically important species) and finalized a National Plan of Action for the Conservation and Management of Sharks. This experience suggests that scientific analysis, even when data are limited, can help initiate and guide a strategy for fishery improvement which included the management of priority species based on their vulnerability to overfishing and value to the nation. These scientific management activities are embedded within a more collaborative approach to management that is based on a partnership between scientists,

TABLE 1 | Fishery characterization of Multispecies Fishery, Cuba; Curvina Fishery of the Upper Gulf of California, Mexico; Multispecies Finfish Fishery of El Corredor San Cosme-Punta Coyote, Mexico; Nearshore Multispecies Fisheries, Philippines; and the Lobster and Conch Fisheries, Belize.

Case study	Country	Region	Fishery	Stakeholders	Years of stakeholder involvement	Data	Management	Management efforts
Multispecies Fishery, Cuba	Cuba	Entire country	Multispecies Finfish Lobsters Shrimp Sharks/Rays	Fishers Cooperatives Government NGOs (local and international)	5	Fishery Dependent (~1960–current) Fishery Independent (variable by target)	Size Limits (some finfish, 2015) Gear and Season Limits NPOA	In Progress Implementation of size limits, regional fishing restrictions, and fishery management plans
Curvina Fishery of the Upper Gulf of California, Mexico	Mexico	Upper Gulf of California	Single species Gulf curvina (Cynoscion othonopterus)	Fishers Processors Government (local and state) NGOs (local and international)	7	Fishery Dependent (1970–current) Fishery Independent (2011–current)	Gear , season, and size restrictions (2007) Species specific fishing permits TAC (2012) Fishing Restricted for Conservation of Vaquita	On Hold Fishery minimized to protect the local population of Vaquita
Multispecies Finfish Fishery of El Corredor San Cosme-Punta Coyote, Mexico	Mexico	Lower Gulf of California	Multispecies Finfish	Fishers Cooperatives Government NGOs (local and international)	10	Fishery Dependent (2009–current) Fishery Independent (2009–current)	Assess current status of commercial targets Updating data collection to fill in data gaps Collaborating with the government in reassessment of no-take areas	In Progress Fisher management no-take reserves, data collection, and enforcement
Nearshore Multispecies Fisheries, Philippines	Philippines	In all three of the major regions in the Philippines-Luzon, Visayas, and Mindanao	Multispecies Demersal fish Small-pelagic fish Crustaceans	Fishers Government (local) NGOs (local and international)	2	Fishery Dependent (2014–current) Fishery Independent (2011–current)	Assess current status of commercial targets Insituting data collections across all TURF+Reserves Assessment of no-take areas	In Progress TURF+Reserves being scaled across the country, institution of fishery dependent data collection and local management plans
Lobster and Conch Fisheries, Belize	Belize	Entire country	Single species Lobster Conch	Fishers Cooperatives Government NGOs (local and international)	5	Fishery Dependent (1950s–current) Fishery Independent (1996–current)	Gear, season, and size restrictions Species specific fishing permits TAC	In Progress Manage Access scaled to the entire country, national Fishery Management Plans for both lobstr and conch

fishery managers, fishers, community members and NGOs. Efforts are now underway to scale the success of this model for collaboration between managers, scientists, fishers and communities through participatory process and capacity-building, which increased environmental consciousness at the community-level and in turn spurred local action to make fisheries more sustainable and to protect resources to other sites across Cuba.

Curvina Fishery of the Upper Gulf of California, Mexico

The Gulf curvina (*Cynoscion othonopterus*) fishery is a small-scale fishery in the Upper Gulf of California, Mexico (**Figure 1B**). Fishing occurs primarily within the Upper Gulf of California and Colorado River Delta Biosphere Reserve. The curvina fishery has become one of the most important fisheries sustaining remote communities in these regions, both socially and economically. Gulf curvina are synchronous, multiple batch spawners (Gherard et al., 2013). The entire spawning stock of adult curvina migrates into the spawning aggregation grounds from late February through early June, making it highly vulnerable to overfishing (Erisman et al., 2012, 2014). Another aggregating fish, the *Totoaba macdonaldi*, was severely overfished in this region during the 1950s (Barrera Guevara, 1990; IUCN, 2010) resulting in the closure of the fishery in 1974 (Cisneros-Mata et al., 1995; Lercari and Chávez, 2007).

Subsequently, the Gulf curvina fishery developed—in the absence of any scientific assessments or fishery governance—into an intense race for fish and supply gluts resulting in price collapses and high discard levels. Fishery monitoring initiated in 1997 generated data streams that were used to conduct data-limited assessments of stock status. These assessments suggested that the stock contained a low proportion of older, highly fecund individuals (Erisman et al., 2014) and other indications that the stock was experiencing high levels of fishing mortality, creating a relatively high risk of overfishing and stock collapse (Erisman et al., 2012).

In 2011, the Mexican National Fisheries Commission, based on a stock assessment and other analyses conducted by the Mexican National Fisheries Institute, established an annual Total Allowable Catch (TAC) limiting the amount of curvina landed to about half of recent levels. This application of science to management could have resulted in economic hardship and conflict, but instead served as a catalyst for participatory work with upper Gulf communities to improve fisheries governance in order to reduce the economic impacts of the TAC. Community-based systems analysis (Cap Log, 2014) was used to develop common understandings of the dynamics driving overfishing, supply gluts, and price collapses. These efforts resulted in a highly participatory system (i.e., a new governance system), with shares of the TAC allocated to each fishing permit. Agreements were signed in 2012 between the cooperatives and major curvina buyers that set minimum prices in return for commitments to stabilize the supply of fish. These governance improvements resulted in dramatically reduced discards and high compliance with the TAC, while simultaneously keeping prices high resulting in economic benefits to fishermen (Cap Log, 2014). As part of the transition to catch shares, a technical group composed of scientists, NGOs and government authorities, as well as a multi-stakeholder committee were established to identify research priorities to improve science, inform management decisions and provide a space for management discussions among interested parties. During this transition a community catch accounting program was set up with the support of government and NGOs (Espinosa-Romero et al., 2014). This program has increased stewardship and trust in the fisheries management. The curvina fishery is now managed with a science-based TAC and other regulations embedded within a catch shares governance system with associated accountability measures (i.e., permits, seasonal closure, size limits, gillnet mesh size, and designated landing sites).

Multispecies Finfish Fishery of El Corredor San Cosme-Punta Coyote, Mexico

The El Corredor San Cosme-Punta Coyote region in Baja California Sur, Mexico, includes a remote archipelago that lies between La Paz and Loreto; it includes 12 small fishing communities (**Figure 2A**). The NGO Niparaja worked with fishermen in El Corredor to collect data on the distribution and abundance of target species. As a result of the co-production of knowledge about the potential effects of increased fishing effort and mortality on these populations, and subsequent impacts on livelihoods and food security, fishermen asked the Mexican government to establish a network of fishing refugia, which was completed in 2012. Three key drivers of success were identified. First, the government, fishers and Niparaja developed a common understanding of the problems and steps for marine resource security. Second, to overcome limited data availability, Niparaja worked with fishermen and the fishing community to both elicit empirical local knowledge through siting surveys in the development of the fishing refugia network and the implementation of scientific monitoring programs to collect fishery independent and dependent data. The data generated from these programs were used to conduct data-limited stock assessments showing that most of the six target species were being fished at unsustainable levels (Mateo, 2012; Niparaja, 2012). Finally, sufficient social capital and trust was built among the government, fishers and Niparaja to overcome poor governance and lack of capacity to implement and assess management actions. Partnerships between the government, fishers and NGOs were initiated and formed through the continual leadership from Niparaja to promote compliance with refugia regulations, resulting in a form of co-management which included enforcement and decision-making committees. Organizing at both the community and fishery cooperatives enabled participation in different processes related to local production and increasing economic incentives to comply with the refugia regulations (Ostrom, 2009; Niparaja, 2012; Ovando et al., 2013). The next step will be to use the scientific basis for fisheries management generated through collaborative research with fishermen to articulate management targets and limits that will be embedded in the

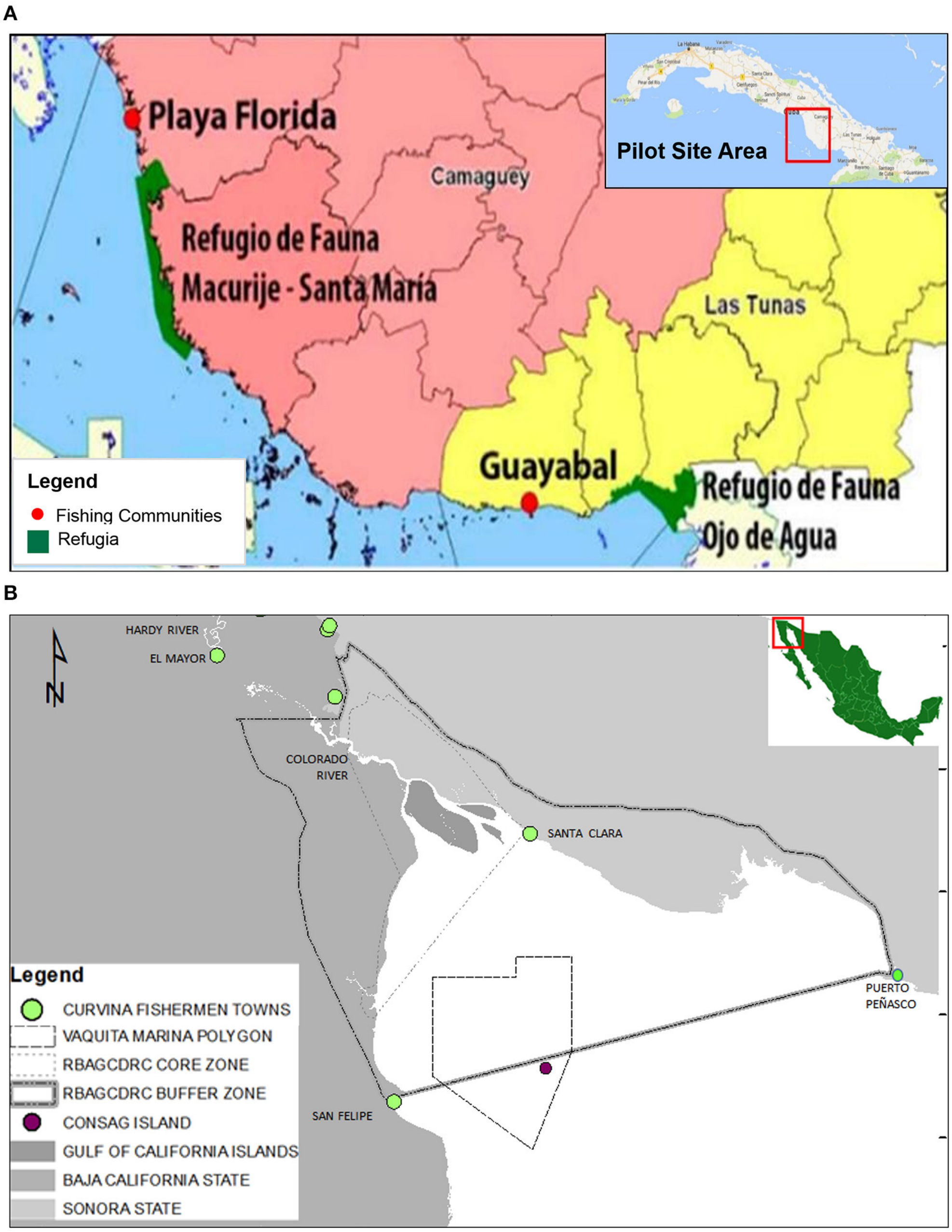

FIGURE 1 | Maps of the regions presented in the case studies for **(A)** Cuba multispecies and **(B)** Gulf of California Curvina fishery.

emerging co-management governance system. It is expected that high levels of social capital generated thus far coupled with co-management and accountability measures will result in good compliance with science based limits on fishing mortality.

Nearshore Multispecies Fisheries, Philippines

Improving the management of small-scale fisheries has become a major focus in the Philippines. The Philippines is among the top 15 nations in global marine fisheries capture production (FAO, 2014), and many Filipinos depend on fish products for both food and livelihood. The average Filipinos derives an estimated 43% of their animal protein diet from fish and fish products (FAO, 2001), and over 1.6 million Filipinos were employed in fisheries-related occupations based on 2011 data (BFAR, 2011). Historically, fisheries management is the responsibility of the government, both national and municipal. But the participation of local management units has increased, decentralizing the management of nearshore fisheries to municipalities and

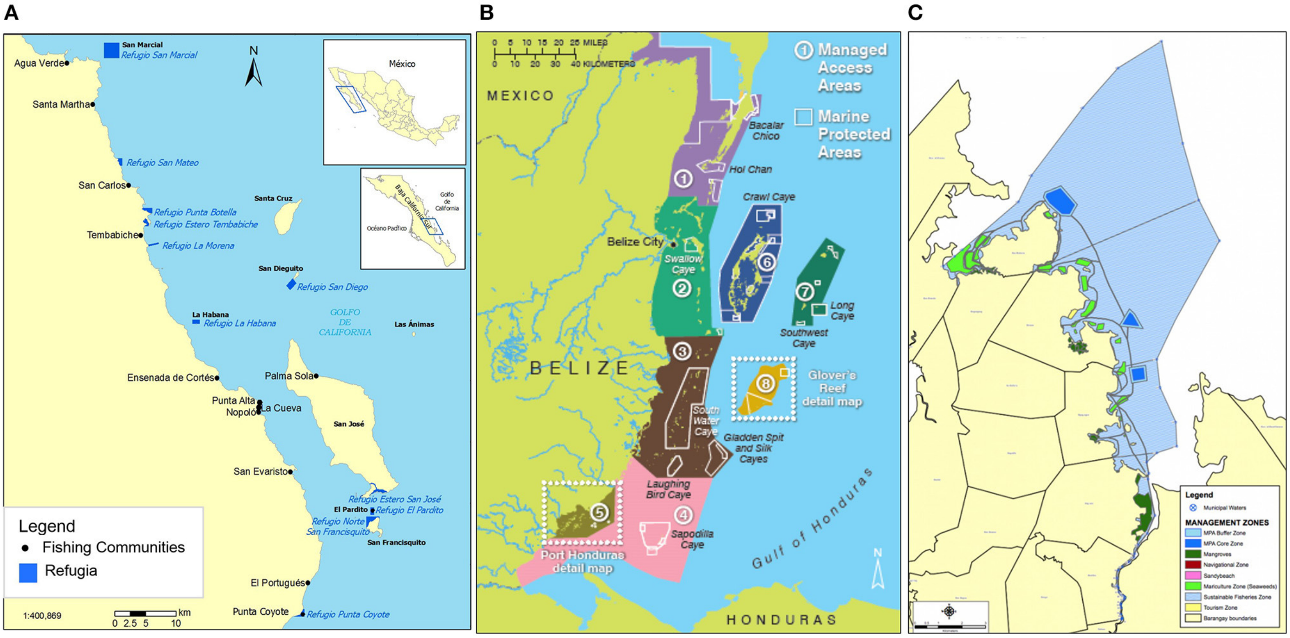

FIGURE 2 | Maps of the regions presented in the case studies for **(A)** El Corredor multispecies finfish and **(B)** Belize conch and lobster (Fujita et al. 2017) and **(C)** the Philippines multispecies fisheries.

local fishing communities (Pomeroy, 1995; Alcala and Russ, 2006). Information on stock status is limited, but research suggests 10 of 13 fishing grounds are overfished and that catch-per-unit effort is erratic or has dramatically declined in many of these fisheries (Green et al., 2003), indicating stock decline and economic underperformance (Muallil et al., 2014).

To reverse these trends, an initial four prototype sites started in 2013, expanding in 2017 to 19 sites in the Philippines combined science-based fishery management with an existing governance structure (co-management) enhanced with Territorial Use Rights for Fishing (TURFs) and with no-take marine reserves located within the TURF, creating a TURFs+Reserves system (locally known as the Managed Access Areas + Sanctuaries system). In exchange for secure access privileges to the TURF and exclusive access to the spillover from the reserve which often associated with higher catch rates and lower fishing costs (Buxton et al., 2014; Lester et al., 2017), these fishermen bear the responsibility for conservation. Specific responsibilities include data collection, participation in fishery management, patrolling, and reporting violations. Together communities and the government across the 19 sites have developed a system for rights, rewards and responsibilities to align fisheries governance with desired outcomes. These sites are part of an effort to develop a network of TURF+Reserves both within municipal waters (0–15 km) and between adjoining municipalities (**Figure 2B**). These communities have engaged in participatory design processes that have produced detailed plans for TURF+Reserves which have recently been approved by the relevant authorities. They have also collected fisheries data, and are now embarking on efforts to use data-limited analytical methods to assess fish stock status, articulate targets and limits for harvest management, and implement harvest-control measures. Efforts to improve fishery governance through the development of co-management and TURFs preceded the collection and analysis of scientific data at these sites, largely to avoid fears of catch restrictions and opposition prior to the development of motivation and institutional capacity to manage fisheries sustainably. Social marketing and behavior change techniques based on Rare's Pride methodology (Rare, 2017) of partnering with local organizations were used successfully to build awareness and motivation, while participatory processes and trainings were used to build buy-in, harness local knowledge, and build the capacity to scientifically assess and manage stocks. A strong platform for marine resource stewardship was created as a result of decades of investment and efforts aimed at building up the capacity of communities to manage marine resources, with a focus on the implementation of marine protected areas (Pollnac, 1994; Alcala and Russ, 2006). Increasing concern with the status of fisheries important for food security, livelihood, and economic development outside of the MPAs prompted a more recent round of initiatives centering on restoring these fisheries, including social marketing efforts, community-based fishery management (influenced by traditional marine tenure systems such as Indonesia's sasi system—Novaczek et al., 2001), and the enactment of new legislation requiring the science-based fishery management. These efforts are anticipated to result in better long-term social, biological, ecological, and economic outcomes (Costello et al., 2008; White and Costello, 2011; Lester et al., 2017).

Lobster and Conch Fisheries, Belize

The Central American nation of Belize has been innovating a range of stakeholder-centered solutions to integrate fisheries governance and science-based management. In 2009, the Government of Belize initiated efforts to improve fisheries governance in order to address trends of rising fishing effort and declining catch of lobster and conch, the two most valuable export species (Government of Belize, 2009). In 2011, the Belize Fisheries Department established two pilot sites (Glover's Reef and Port Honduras Marine Reserves, which are multi-use Marine Protected Areas) to study the effects of TURF (or Managed Access Areas in Belize) as a management tool. The pilot Managed Access Areas with several management zones (e.g., no-take and general use with Managed Access to fishing) were expected to result in reduction of fishing effort through the restriction of fishing licenses and allow for fish recovery within the no-take areas and into the attached areas from spillover into to the Managed Access Areas (Uchida et al., 2012; Lester et al., 2017; **Figure 2C**).

Improvements in lobster and conch population status have been observed in these pilot sites (Babcock et al., 2015). The success of these pilot areas in increasing catches, reducing fishing effort, and increasing catch reporting and compliance with regulations led to the scaling of Managed Access Areas to the rest of Belize's fishing grounds in 2016 (Government of Belize, 2015; Fujita et al., 2017). Participatory and behavior change processes were used to engage about 2000 of Belize's 2700 fishermen in the design of the national Managed Access system, led by a team that included fishermen, government officials, and NGOs. Elected Managed Access committees for each of Belize's eight TURFs determine who is eligible for Managed Access licenses in each area (Fujita et al., 2017).

Recognizing that a combination of fisheries governance, scientific assessment and science-based fishing mortality control are the next step to prevent overfishing or stock collapse, the government initiated an effort to develop an adaptive management framework (AMF) for its conch and lobster fisheries that is designed for data-limited circumstances (Fujita et al., 2017). It uses fishery-dependent (catch) and fishery-independent (underwater visual censuses) data to set harvest controls and adjusts them every year as new data are collected and analyzed and compared with fishery performance indicators and reference values. Data collection and monitoring is being structured and standardized through a Spatial Monitoring and Reporting Tool (SMART) that is deployed throughout Belize. The use of the AMF and SMART has strengthened collaboration among scientists, government and fishermen in Belize. A training and education program for managers and fishermen in the AMF and SMART systems is building capacity and improving the data collection and analysis processes. AMF and SMART are being integrated into Belize's fisheries management system to ensure that the Managed Access governance system coupled with science based adaptive management results in good fishery outcomes.

LESSONS LEARNED

How can the performance of small-scale fisheries be improved across a variety of contexts? Based on these case studies, the solution often includes: participatory processes; partnerships across agencies and sectors (government, NGOs, stakeholders); and scientific analysis directly applicable to co-management structures. Participatory processes are important for supplementing scientific knowledge with local knowledge and generating buy-in, as seen in each of the case studies. Each of the five case studies utilized participatory processes to engage participants in decision making, goal setting, scientific data-collection and ultimately implementation of measures aimed at improving fishery performance.

In addition, successful implementation of fishery management is associated with the formation of partnerships across agencies and sectors (governments, NGOs, stakeholders) early in the process—with frequent communication across agencies and sectors. The clearest examples described here of well-developed partnerships among stakeholders and sectors are in Cuba and the El Corredor fishery in Baja Sur, California. In Cuba, the community-based fisheries management project SOS Pesca utilized communication, goal setting and interests of fishing communities and the government to introduce alternative fishing management options. Similarly, the El Corredor fishery used the partnership developed between NGOs and fishers, and NGOs and the government to facilitate communication and the development of common goals by all the stakeholders, resulting in newly developed Marine Protected Areas/Refugia and fishing zones for sustainable fishery management.

The third major lesson learned from the case studies is that scientific data collection and analysis must be embedded within policies that bring science to action (e.g., Belize's adaptive management framework). Each of the case studies either developed new systems for data collection and analysis or made better use of existing data streams, using the best available science to assess fishery performance relative to science-based targets and limits. Fishery sustainability, in part, depends on this scientific enterprise, but even the best stock assessments, targets, and limits cannot result in sustainability without good fishery governance and compliance.

Additionally, the prevalence of policy or management system that generates stewardship incentives, also promote users to comply with science-based regulations. Although the case studies examined here vary in context, all of them made use of the participatory processes to build buy-in, harness local knowledge, build the capacity to scientifically assess and manage stocks, and to design and implement management and governance systems that could generate stewardship incentives. The integration of these elements appears to be important for improving management outcomes in these small scale fisheries (Pollnac, 1994; Pomeroy, 1995; Lester et al., 2017).

CONCLUSIONS

Small-scale fisheries occur in many different governance and data contexts. By elucidating attributes of successful small-scale fishery reform efforts and mainstreaming this dialogue, we can begin to understand what conditions result in success. Embedding science-based fisheries management within governance systems that create incentives aligned with management objectives, such as strengthened traditional tenure systems, co-management systems, and well-designed rights-based systems has the potential for dramatically improving the performance of small-scale fisheries, just as it has for large-scale fisheries (Costello et al., 2008; Cinner et al., 2012).

AUTHOR CONTRIBUTIONS

KK, RF, and JK conceived the study, organized the case studies, and processed the lessons learned. KK, RF, JK contributed to the organization of information for each case study and wrote the manuscript. RC, LE, JRF, MG, PG, JM, and BW contributed to the Belize case study. JF, RO, LR, HL, AS, and CV contributed to the Curvina case study. OG, AW, TP, and SR contributed to the El Corredor case study. JG, EL, and RM contributed to the Philippines case study. VM and DW contributed to the Cuba case study. All authors wrote the manuscript and gave final approval of the version to be published and agree to be accountable for all aspects of the work.

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