Chapter 7
From Fishing Fish to Fishing Data: The Role of Artisanal Fishers in Conservation and Resource Management in Mexico

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Abstract Although, the involvement of artisanal fishing communities in conservation and management is now commonplace, their participation rarely goes beyond providing local and traditional knowledge to visiting scientists and managers. Communities are often excluded from ongoing monitoring, evaluation, and decision-making, even though these measures can have tremendous impacts on their livelihoods. For the past 17 years, we have designed, tested, and implemented a community-based monitoring model in three key marine ecosystems in Mexico: the kelp forests of Pacific Baja California, the rocky reefs of the Gulf of California, and the coral reefs of the Mesoamerican Reef System. This model is intended to engage local fishers in data collection by fulfilling two principal objectives: (1) to achieve science-based conservation and management decisions and (2) to improve livelihoods through access to knowledge and temporary employment. To achieve these

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goals, over 400 artisanal fishers and community members have participated in a nationwide marine reserve program. Of these, 222 fishers, including 30 women, have been trained to conduct an underwater visual census using SCUBA gear, and, to date, over 12,000 transects have been completed. Independent scientists periodically evaluate the training process and standards, and the data contribute to international monitoring efforts. This successful model is now being adopted by both civil society and government for use in different parts of Mexico and neighbouring countries. Empowering community members to collect scientific data creates responsibility, pride, and a deeper understanding of the ecosystem in which they live and work, providing both social and ecological benefits to the community and marine ecosystem.

Keywords Citizen science · Local and Traditional Knowledge (LTK) · Community participation · Small-scale fisheries

7.1 Introduction

Given growing concerns about declining environmental conditions in marine habitats in the face of climate change, the impacts of increasing fishing pressure on commercial stocks, and the impacts on the livelihoods of artisanal fishers operating in the coastal waters of developing countries, measures are being undertaken by researchers, governments, and civil society to involve fishers in improving fisheries and coastal zone management. Fishers are often highly aware of subtle changes in the environment in which they operate and thus can provide important information to scientists and managers. Fishers' local and traditional ecological knowledge (LTK) has been recognized as an important resource for marine conservation initiatives worldwide (Schafer and Reis 2008; Butler et al. 2012). For a review of this literature, see Thornton and Maciejewski-Scheer (2012).

Berkes et al. (1995) list five ways in which traditional ecological knowledge (TEK) is relevant to fishers and fishing: (1) TEK is known to offer biological and ecological insights, (2) some TEK systems provide models for sustainable resource management, (3) TEK is relevant for protected areas and conservation education, (4) the use of TEK is often crucial for development planning, and (5) TEK may be used in environmental assessment.

In the vast majority of cases, LTK that is documented by researchers has been orientated towards species-specific studies. Few genuinely collaborative studies, in which fishers have been able to address conservation and management issues, have been documented in the literature (Thornton and Maciejewski-Scheer 2012). Despite this shortcoming, strong arguments can be made that the inclusion of local communities in conservation programs can strengthen conservation projects and create environmental and social benefits (Drew 2005).

Fishers' LTK should not be considered a panacea to the threats that coastal oceans face. However, incorporating LTK into co-management arrangements allows the interchange of knowledge between fishers, scientists, civil society organizations (CSOs), and governmental agencies. There are numerous benefits to the use of LTK. Favourable conditions are created for the advancement of mutually beneficial arrangements; fishers can potentially maintain their stock levels (Roberts et al. 2001; Russ and Alcala 2004; Cudney-Bueno et al. 2009a; White 2009); scientists can use LTK to test hypotheses and generate recommendations (Ballantine 2014); conservationists can maintain biodiversity (Groves et al. 2002); and the government can balance both environmental and social development goals (Thomas et al. 2014).

7.1.1 Marine Reserves as Fisheries Management Tools

Bottom-up resource management, in which communities are directly involved in managing the resources they exploit, has been gaining ground over the past decade, as human-environment interactions have become recognized as a key part of the now popular ecosystem-based management approach (Pikitch et al. 2004). The importance of combining LTK and community-led resource management is increasingly recognized (Thornton and Maciejewski-Scheer 2012), but this integration requires a cautious, participatory, and transparent approach in order to establish successful conservation measures. Worldwide, one of the most popular conservation tools of this kind is the establishment of community marine reserves, particularly in developing countries (Russ and Alcala 2003).

Marine reserves are not the only conservation solution, and other strategies must be employed in order to achieve widespread benefits, including direct benefits to fisheries (Hilborn 2016). However, in many cases, marine reserves have provided benefits to both ecosystems (Roberts and Hawkins 2000; Williamson et al. 2004; Aburto-Oropeza et al. 2011) and fisheries (Roberts et al. 2001; Gell and Roberts 2002). Hence, experts have recommended increasing the area that is fully protected from fishing to preserve fish stocks for future generations (Marine Conservation Institute 2013). Similarly, local management action has been highlighted as a key component of future ocean conservation to counter the threat of climate change (Micheli et al. 2012; Kennedy et al. 2013).

While fishers are generally aware of the benefits that marine reserves can provide, they are often reluctant to set aside parts of their fishing grounds for several reasons. These include (1) marine reserve creation that concentrates fishing in a smaller open area (Charles and Wilson 2009); (2) a lack of clear property rights (e.g. fishing concessions) in the water (Costello and Kaffine 2010); (3) a lack of surveillance and enforcement by authorities, resulting in illegal fishing practices (Cudney-Bueno et al. 2009b; Velez et al. 2014); (4) benefits that are often not felt in the short term (Russ and Alcala 2004; Ovando et al. 2016); (5) a lack of adequate compensa-

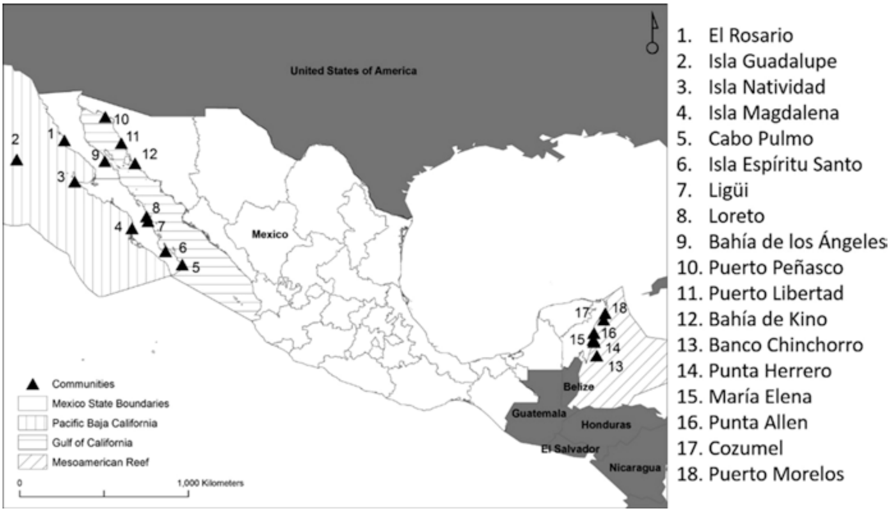

Fig. 7.1 The three marine priority ecoregions and 18 communities in Mexico where fishers have participated in collaborative research to implement fishery management tools

tion (Ovando et al. 2016); and (6) a lack of leadership to guide the community through changes (Cudney-Bueno et al. 2009b).

This chapter describes the key features of a model that demonstrates how the involvement of small-scale fishers in community-inclusive processes to establish marine reserves[1] leads to successful outcomes in marine conservation and fisheries management. The model is a successful program that has been implemented in three marine priority areas of Mexico. It shows how to overcome or reduce the aforementioned issues (Fig. 7.1). Through collaborative research, this model involves fishers in science-based decision-making processes. Its implementation has resulted in the training of 222 fishers in underwater visual census techniques. Data have been generated to further our understanding of Mexico's marine ecosystems and provide evidence to support new conservation and fisheries management tools for over 620,000 hectares of coastal ocean.

7.1.2 Citizen Science

Conservation and research organizations around the world are incorporating an increasing amount of non-expert, trained observers – sometimes called 'citizen scientists' or 'volunteers' – to support a variety of biological and environmental

[1] In this chapter, 'marine reserve' refers to an area completely closed to extractive activity, also commonly referred to as a no-take zone.

monitoring needs. Participants in citizen science initiatives receive project-specific training and engage in scientific research. Citizen science has its roots in the early days of the conservation movement. The National Audubon Society's Christmas Bird Count began in 1900 as an alternative to the traditional Christmas shoot, a program that continues to this day, with tens of thousands of observers counting over 63 million birds in North America in 2014. Data collected have contributed to over 350 scientific publications (Silvertown 2009). Other common uses for citizen science include mapping invasive species, restoration, monitoring climate change and species distribution changes, and biological monitoring (Thornton and Maciejeski-Sheer 2012).

In the marine realm, the boom in recreational SCUBA diving towards the end of the twentieth century allowed organizations such as REEF (founded 1990) and Reef Check (founded 1996) to achieve worldwide popularity in volunteer-led underwater visual census monitoring. These organizations have particularly focused on heavily fished and indicator species in their citizen monitoring programs. In these programs, volunteer divers undertake training courses in simple but robust methodologies before collecting data to contribute to marine science initiatives. Subsequently, more complex methodologies were developed to allow volunteers with a background in marine science or sufficient training and experience in the field to collect more detailed data. Examples of these methodologies include the Atlantic Gulf Rapid Reef Assessment (AGRRA), Mesoamerican Barrier Reef Synoptic Monitoring Program, and the Global Coral Reef Monitoring Network.

Since these programs began, the use of volunteers to collect scientific data in the coastal zone has become commonplace in many countries, including Australia (Hassell et al. 2013), Belize (Mumby et al. 1995), Fiji (Leopold et al. 2009), Indonesia (Harding et al. 2000), New Zealand (Fletcher and Shortis 2001), the Philippines (Beger 2002), Tanzania (Darwall and Dulvy 1996), the USA (Schmitt and Sullivan 1996; Pattengill-Semmens and Semmens 2003; Shuman et al. 2011), and the Wider Caribbean Region (Ward-Paige et al. 2010). In the developed world, participants in marine citizen science programs generally participate as a hobby, focusing on areas of high-perceived value such as coral reefs and popular SCUBA dive sites. In developing countries, it is more common for the resource users themselves to participate, as the project objectives are more local in focus and aligned for the benefit of the community.

The advantages of involving volunteers in data collection are clear. Using volunteers to collect part, or all, of the scientific data required for monitoring reduces costs, allows long-term regular monitoring rather than one-off investigations, and raises awareness amongst marine resource users. While concerns have been raised over the quality of the data collected by non-professionals, it is generally accepted that a well-trained volunteer conducting an appropriate methodology can collect reliable data (Mumby et al. 1995; Darwall and Dulvy 1996; Harding et al. 2000; Hassell et al. 2013; Fulton et al. 2013; Forrester et al. 2015). In addition, the process can help build trust and facilitate the involvement of resource users in conservation practices.

7.2 Implementing a Community-Based Monitoring Model

7.2.1 Involving Mexican Fishers in Data Collection

The management of Latin American small-scale fisheries is notoriously complex (Salas et al. 2007). Fisheries are often multi-specific, poorly regulated, labour-intensive, and data-poor. Mexican small-scale fisheries are no different, with 102,807 registered boats (CONAPESCA 2009) supporting at least 308,421 fishers, based on an average of 3 fishers per boat (Moreno-Baéz et al. 2012). The sector fishes along the length of Mexico's extensive 9330 km coastline, which is the 13th longest in the world.

Comunidad y Biodiversidad (COBI), a Mexico marine conservation CSO, was founded in 1999 with a mission to develop effective participatory approaches for fisheries management and marine biodiversity conservation (Espinosa-Romero et al. 2014). The organization's multidisciplinary team operates along four national strategies: (1) capacity building to strengthen skills of local leaders and fishing organizations for achieving sustainable fisheries, (2) implementation of international standards for sustainable fishing, (3) implementation of marine reserves for fishery and ecosystem recovery, and (4) collective action for the development of formal institutional arrangements to promote sustainable fishing. This chapter discusses Mexican fishers' involvement in a national marine reserve program which implicitly incorporates the four strategies supported by COBI. This section discusses the participatory process implemented in the program, the products generated, and the implications of the program.

Fishers from 18 communities around Mexico took part in the program (Fig. 7.1). These fishers target a mix of small-scale fisheries including both high value (lobster, abalone) and low value (mixed finfish) species. Fishers operate from small fibreglass or wooden boats (7–9 m in length), but fishing gear is varied, including lobster pots, hook and line, SCUBA, hookah, and free diving. Relatively few fishers regularly use nets. In Pacific Baja California and the Mesoamerican Reef, concessions are common for some high-valued benthic species such as lobster and abalone. These are only allocated to cooperatives, and exclusive access to the resource is granted through a fishing permit. Fishing permits to common access areas, for finfish and other species, are assigned to cooperatives and individual fishers alike.

Fully protected marine reserves (or no-take zones) have been established in many developing countries with the aim of maintaining or promoting marine biodiversity and protecting heavily fished stocks. In Mexico, three management tools are available to completely protect areas from fishing: voluntary community reserves[2],

[2] Voluntary community reserves are areas set aside by fishers for the recuperation of target species based on traditional knowledge and fishery interests.

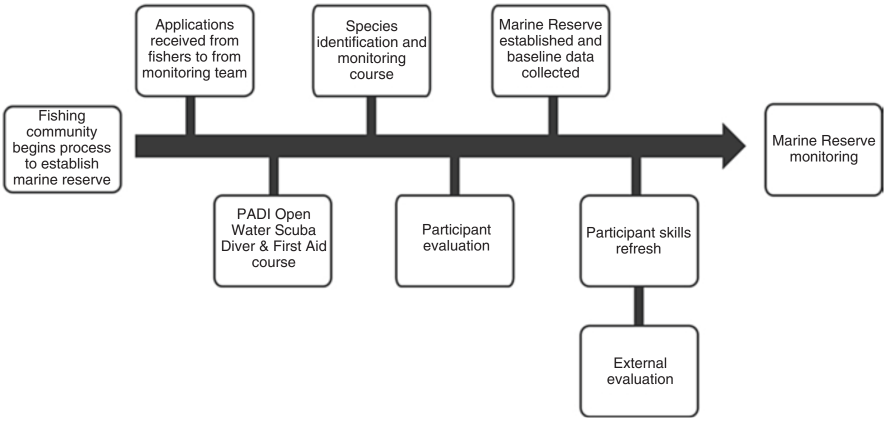

Fig. 7.2 Process to establish a community-led marine monitoring team

core zones of federal protected areas[3], and fish refuges[4]. During the process of marine reserve creation (Fig. 7.2), which was monitored by the fishers in the case study, introductory workshops were held in each community in which stakeholders discussed the biological and fisheries benefits (and risks) of setting aside areas for marine reserves. As the process advanced, fishers were invited to apply for the opportunity to participate in the biological monitoring team, a community group supported by biologists that evaluates the effectiveness of the sites closed to fishing. The selection criteria for fishers were based on their status and standing in the fishing organization and/or community (reputation for following social and legal norms, relationships with other fishers) as well as other factors such as physical condition (based on internationally recognized SCUBA diving medical standards) and literacy.

The fishers were trained in a variety of monitoring techniques, including underwater visual census with SCUBA, surface snorkel surveys, installation and use of oceanographic equipment, and the identification and capture of invasive species. During data collection, fishers were offered a stipend to compensate for the forgone fishing days. This was estimated by taking the mean of the difference between a good and bad day's fishing. In cases where socioeconomic data for the fishery exist, this can be calculated precisely. If no such data exist, estimates were made within the monitoring team and a suitable level for the stipend was agreed upon.

[3] Core zones of federal protected areas defined by the General Law of Ecology and Environmental Protection (LGEEPA in Spanish) are areas where the principal objective is long-term ecosystem preservation.

[4] Fish refuges (or *refugios pesqueros* in Spanish), a term used by the General Law of Sustainable Fishing and Aquaculture (LGPAS in Spanish), are no-fishing areas established in federal waters that preserve and contribute to the development of fishing resources, with a particular focus on reproduction, recruitment, and growth. They can be either temporary, permanent, species specific, or completely closed.

During the program, 222 fishers were trained to conduct underwater visual censuses in the kelp forests of the Baja California Peninsula, the rocky reefs of the Gulf of California, and the coral reefs of the Mesoamerican Reef System. While each environment requires specific protocols, fishers followed a standardized training program to ensure accuracy, precision, and confidence in the data generated. Fishers received an internationally recognized SCUBA certification from the Professional Association of Diving Instructors (PADI) and first aid training before undertaking an intensive course in species identification and underwater visual census techniques. Methodologies were selected that are both internationally recognized and locally appropriate (based on habitat type) in order to contribute to other regional datasets. In Baja California, the Reef Check methodology (Freiwald et al. 2013) was used; in the Gulf of California, an adapted version of the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) protocol (PISCO 2016); and in the Mesoamerican Reef, an adapted version of the Atlantic Gulf Rapid Reef Assessment (Lang et al. 2010).

The training courses were divided into three parts: (1) classroom theory sessions, (2) in-water species identification, and (3) monitoring practice. Theory sessions provided participants with in-depth information about ecosystem-based monitoring, marine reserves, and an overview of the importance of monitoring. Focus was subsequently turned to the specific fish and invertebrate species common in the area, as well as detailed information about the types of benthic cover and other information relevant to the local marine reserves. Common names for species can vary greatly from one community to the next. Although common names were often used initially, fishers were strongly encouraged to use scientific names as soon as possible to reduce errors in data collection and facilitate collaboration with scientists and fishers from other areas. In-water species identification began when fishers demonstrated mastery of the theory. In dive groups with low fisher to trainer ratios (ideally 1:1), fishers learned to identify fishes and their estimate sizes correctly. Size estimation, which is key for biomass calculations, was evaluated using a line of plastic fish for each of which the observer estimates the size to the nearest centimetre from a distance of 2–3 m. After each practice session, trainers reviewed and gave feedback on the fishers' performances during the dive.

Monitoring protocol training included land-based practice in which transect dimensions and speed were demonstrated, while the fishers familiarized themselves with the monitoring equipment (fibreglass tape measures, underwater tables with waterproof paper, quadrants, PVC measuring poles). This was followed by in-water practice in which fishers laid practice transects accompanied by the trainer and demonstrated safe diving practices. Training was complete when the trainer was confident that each fisher was able to collect accurate data for each species group (fish, invertebrates, and benthic cover). Fishers were provided with waterproof species ID guides to assist with the learning process, and many began to use the guides outside of survey periods to identify catches and species seen during their fishing trips. In many cases, the competitive nature of fishers provided unexpected benefits. The daily challenge between participants ranged from 'who caught the most today?' to 'who knows the scientific name of her/his catch?'

When monitoring teams were established to collect data in newly established marine reserves, baseline data had to be collected before the reserve was formally closed to fishing. Subsequent surveys were completed at suitable intervals to detect ecological changes. Intervals vary on a case-by-case basis depending on the objectives and target species of the reserve. The monitoring program must be adapted to reflect the recovery rate of the target species (Abesamis et al. 2014). Before each subsequent survey, fishers underwent a 2-day refresher course and evaluation to ensure that their proficiency had not dropped. Periodically, visiting scientists were consulted to provide an objective external assessment of fishers' activities. The scientists evaluated the fishers on their ability to correctly apply the methodology and correctly identify and estimate the size of marine organisms. Recommendations were also provided by the scientists on how to improve the training process and diver performance during surveys.

Fishers' participation in citizen science during the program was not restricted to transect SCUBA surveys in community marine reserves. Fishers along the Mexican portion of the Mesoamerican Reef have also conducted surveys and control measures for the invasive lionfish (*Pterois volitans*) population, monitored megafauna (shark, ray, and turtle), and identified fish spawning aggregation sites for key commercial species such as groupers (Serranidae) and snappers (Lutjanidae). The contribution of fishers' LTK to the search for fish spawning aggregations has been extensively documented (Hamilton et al. 2011; Heyman 2011). However, in the Sian Ka'an Biosphere Reserve, the fishers successfully petitioned the government to create a fish refuge on a Nassau grouper (*Epinephelus striatus*) spawning site (Secretaria de Gobernación 2013), the first visually verified fish spawning aggregation site to be closed to fishing in the Mexican Caribbean. Fishers continue to survey the site during spawning season.

In the Pacific island community of Isla Natividad, two marine reserves were established in 2006 to protect dwindling abalone stocks from over-exploitation. Approximately 8% (200 hectares) of the cooperative's fishing ground was included in the marine reserves, with fishers selecting the sites based on past productivity and the estimated opportunity cost of the lost fishing grounds. In 2009, fishers observed an unusually high mortality of benthic invertebrates, mostly likely caused by a hypoxic event linked to changes in the California current (Micheli et al. 2012). In collaboration with the fishing cooperative, scientists used oceanographic instruments to monitor both hypoxic events and temperature fluctuations. This biological and oceanographic monitoring program, established in 2006, continues to give a unique perspective of the impact of changes in large-scale ocean processes on local marine biodiversity. While abalone density inside the reserves declined during the hypoxic events, declines were greater outside the reserves. Additionally, the larger size and higher density of abalone inside the reserves led to increased post-mortality recruitment, not only inside the reserves but also in adjacent areas (Micheli et al. 2012).

7.2.2 Outputs and Products of Collaborative Research

Fishers who took part in the community-led monitoring programs described herein are active participants in the evaluation of their resources and help to generate information that can be used in science-based decision-making for local- and regional-level management. To date, community partners have contributed to over 60 projects including undergraduate and Masters' theses, PhD dissertations, book chapters, conference proceedings, and articles focusing on biogeography, biodiversity, bioeconomics, and fisheries. Table 7.1 summarizes the products of the collaborative research program, and some of the most important contributions to both the scientific literature and fisheries management are discussed below.

The success of any conservation or fisheries management tool depends heavily on community acceptance, implying that active stakeholder participation is key to ensuring local buy-in to the project (Espinosa-Romero et al. 2014; Ruiz-Frau et al. 2015). In this case, the marine reserves were designed with data collected by the fishers themselves. Each reserve has specific objectives, primarily fishery recuperation or ecosystem protection. Examples of reserves with the goal of fishery recuperation are those of the blue (*Haliotis fulgens*) and yellow (*H. corrugata*) abalone fishery of Isla Natividad and the lobster (*Panulirus argus*) and grouper (*Epinephelus striatus*) fisheries of Quintana Roo (Secretaria de Gobernación 2013). Reserves created to protect and restore ecosystems include the core zone of the Isla San Pedro Mártir Biosphere Reserve (Secretaria de Gobernación 2002) and the coral reefs of María Elena, Sian Ka'an Biosphere Reserve (Secretaria de Gobernación 2012).

All area-based management tools (core zones of federal protected areas, fish refuges, and community reserves) allow both principal objectives to be reached and can be effective tools to mitigate the negative effects of climate change on marine ecosystems and livelihoods in coastal communities (Micheli et al. 2012).

Information generated by fishers has been used to create recommendations for the management of the pen shell (*Atrina tuberculosa*; temporary closures, marine reserves; Moreno et al. 2005) and swimming crab (*Callinectes* spp.; marine reserves, fishery effort monitoring, fishing gear improvements; Torre et al. 2004) fisheries of Bahia de Kino, Sonora (Cisneros-Mata et al. 2011a, b), and the development of a management plan for aquarium fish fisheries (Secretaría de Medio Ambiente y Recursos Naturales 2012). The data collected and management tools put in place have also allowed fishers to gain access to permits through the use of the data to calculate quotas. These fisheries include the clam (*Megapitaria squalida*, *M. aurantiaca*) fishery in Puerto Libertad and the aquarium fish and invertebrate fishery in Ligüi, Baja California Sur. Range extensions for species have been detected in these cases. In the Gulf of California, four species of the genus *Scarus* (Gonzalez-Cuellar et al. 2013) and Limbaugh's damselfish (*Chromis limbaughi*), a highly sought-after fish in the aquarium trade (Martínez-Torres et al. 2014), were detected. In Baja California, as water temperatures rise with climate change, tropical species have also been detected (Hernández-Velasco et al. 2016). Additional reports have included invasive species (*Sargassum filicinum*) by Riosmena et al. (2012) and

Table 7.1 Products generated through collaborative research

Product	Relevance/focus	References
Journal articles, book chapters, and proceedings	Benefits of marine reserves	Micheli et al. (2012), Rossetto et al. (2013), Munguia-Vega et al. (2015a), Rossetto et al. (2015), and Villaseñor-Derbez et al. (2015)
	Community participation in marine conservation	Fulton et al. (2013, 2014) and Heyman et al. (2014)
	Ecosystem services	Suarez-Castillo et al. (2014)
	Species range extensions	Gonzalez-Cuellar et al. (2013), Martínez-Torres et al. (2014), Fernández-Rivera Melo et al. (2015b), and Hernández-Velasco et al. (2016)
	Interdisciplinary research	Munguía-Vega et al. (2015b)
	Species distribution	Riosmena-Rodríguez et al. (2012) and Fernández-Rivera Melo et al. (2015a)
	Fisheries management, economics, and sustainability	Reyes-Bonilla et al. (2009), Moreno-Baez et al. (2012), Micheli et al. (2014), and Germain et al. (2015)
	Genetics and connectivity	Greenley et al. (2012) and Munguía-Vega et al. (2014)
Theses	Critical habitats	Moreno-Dávila (2013) and Suárez-Castillo (2014)
	Population dynamics	Rossetto (2012)
	Fishery impacts	Hernandez-Velasco (2010)
	Species distribution	Gonzalez-Cuellar (2012) and Precoma de la Mora (2015)
	Optimization of monitoring protocols	Fernández-Rivera Melo (2015)
	Co-management and marine reserves	Revollo-Fernández (2012) and Germain (2014)
Communication articles	Community participation and co-management	Fernández-Rivera Melo et al. (2013, 2014), Hernández-Velasco et al. (2015), and Fernández-Rivera Melo et al. (2015c)
	Women in citizen science	Hernandez-Velasco & Vazquez-Vera (2013)
Technical reports	Coral reef health	Healthy Reefs Initiative (2012) and Kramer et al. (2015)
	Stock assessments and fishery information	Torre et al. (2004), Moreno et al. (2005), and Cisneros-Mata et al. (2011a, b)
	Threatened species	Mercier et al. (2013)
	Ecosystem services	Lucas et al. (2012)
	Ecosystem modelling	Ainsworth et al. (2011)
	Seafood eco-certification	Marine Stewardship Council (2012) and Monterey Bay Aquarium Sea Food Watch (2014)
Management plans	Ornamental fish management plan	Secretaria de Medio Ambiente y Recursos Naturales (2012)
Biological monitoring protocols		Fernández-Rivera Melo et al. (2012)
Protected area creation	Marine protected areas	Secretaria de Gobernación (2002)
	No-take zones	Secretaria de Gobernación (2012)
		Secretaria de Gobernación (2013)

albinism in brown sea cucumber (*Isostichopus fuscus*) by Fernández-Rivera Melo et al. (2015a). These official reports have been the result of having more trained eyes in the water than was previously possible, which has allowed for more effective, data-driven decisions to be made on species management and capture.

7.2.3 Gender Equality in Conservation

The stereotypical fishing camp brings to mind a group of weathered men working their nets, traps, and lines, with little interest in resource conservation. Mexico, which currently ranks 71st out of 187 countries on the United Nations Development Program Gender Inequality Index (UNDP-HDR 2015), has, like most countries, a largely male-dominated fishery. The fishing cooperative, *Mujeres del Golfo*, is a leading example for other female fishers and women in coastal communities along the Baja California Peninsula. The cooperative, dedicated to catching and commercializing ornamental fish for the aquarium trade, was founded and is currently run by women from the community of Ligüi, Baja California Sur. In 2007, after a member of the cooperative took part in a species identification and monitoring workshop with male fishers, a group of her colleagues quickly followed, and the cooperative began monitoring their own resources to ensure sustainable catches. This project inspired other women, now totalling 30 from 6 communities in Baja California, to request and take part in SCUBA diving training and monitoring courses.

In Isla Natividad, Baja California Sur, 14 women have collaborated in research projects that take place on the island with a variety of different organizations. The women currently organize their own research trips, conduct underwater visual censuses, enter the data into databases, and send it directly to both national and international researchers. The advantages of working with women's groups such as those mentioned here are numerous. From a purely logistical point of view, the women are available to take part in research projects year-round, unaffected by the state of the fishery which, during peak times, can affect male fishers' willingness to participate. However, the social benefits are much greater in the long-term. Gender barriers are being broken down in what are traditionally some of the more conservative communities in the country.

7.2.4 Measuring Confidence in the Data

During the training process and before each monitoring session, fishers passed through a series of evaluations to ensure the accuracy and precision of the data collected. Species identification was tested using a combination of slideshow exams and in-water 1:1 dives with a trainer. Size estimation accuracy was evaluated by having fishers visually estimate the size of objects underwater.

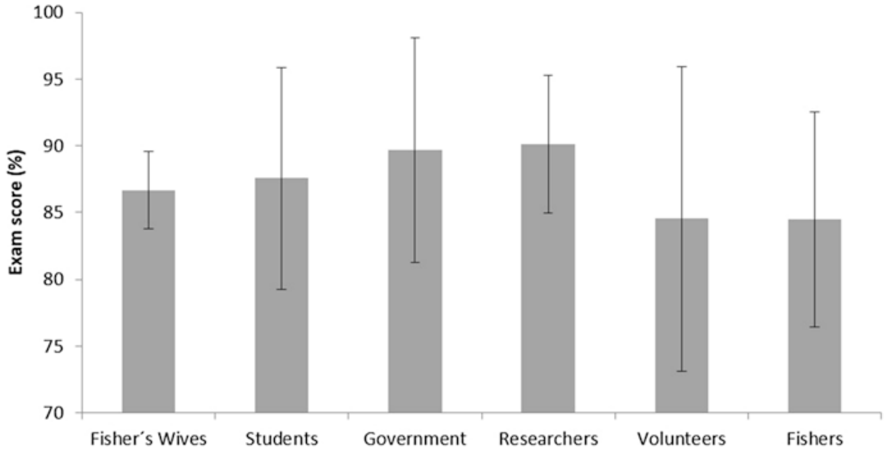

Fig. 7.3 Classroom species ID exam scores (%) for participants of different backgrounds with standard deviation

Classroom exam scores for fishers were compared with other participants who have also taken the monitoring course, including volunteers, students, fishers' wives, researchers, and members of government agencies (Fig. 7.3). To detect possible differences between the scores, one-way analysis of variance (ANOVA, $\alpha = 0.05$; Zar 2010) was conducted. Taking into account the two principles for parametric analysis (normality and homoscedasticity), corresponding a priori tests were carried out, Bartlett's Chi-Square (Zar 2010). The analysis did not show significant differences between the participants ($F_{(5,90)} = 1.107$, $p = 0.362$).

In-water species identifications skills were evaluated by comparing data collected by trainers with those of the fishers taken on the same transect line. Coral and benthic data were evaluated by both divers, who registered data along a leaded rope that remained stationary on the seafloor (unlike a fibreglass tape which may sway with the surge), and allowed the same point to be registered by both divers. Fish data were collected by the trainer simultaneously, who swam above the fisher during the transect. The measure of similarity in the results was calculated using the Bray-Curtis measure (Smith 2002):

$$\mathrm{BC}_{ij} = \frac{\Sigma\left[p_{ik} - p_{jk}\right]}{\Sigma\left[p_{ik} + p_{jk}\right]}$$

Equation 7.6.1 Calculation of the Bray-Curtis measure.

where p_{ik} and p_{jk} represent the proportions of individuals in census i and j, respectively, which belong to species k. The index ranges from 0, where there are no species in common, to 1.0, where the distribution of species is identical. The data,

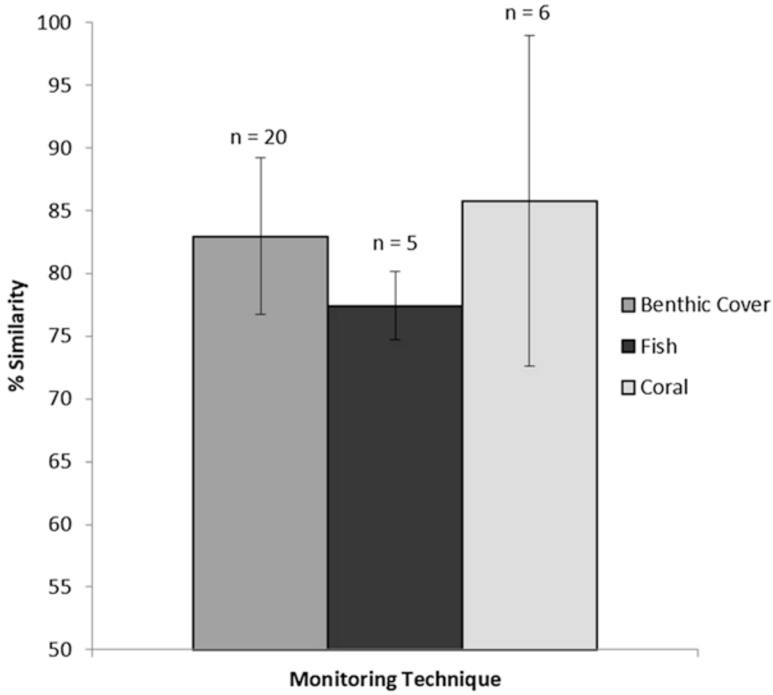

Fig. 7.4 Bray-Curtis similarity measure for species identification between fishers and trainer during in-water tests

expressed as a similarity percentage (Fig. 7.4), suggest that fishers can successfully identify coral and benthic cover accurately (85.7% and 82.9% similar to the instructor, respectively).

Fish identification accuracy was slightly lower (77.4% similar), although more variation is expected due to the differing viewpoints of the two observers on the simultaneous transect. All three techniques compare favourably to other studies on volunteer divers using similar methodologies. Mumby et al. (1995) found that volunteer divers in Belize could correctly identify coral 52–70% of the time and benthic cover 70–90% of the time. Similarly, Harding et al. (2000) found volunteer diver fish data to be 75.3% similar to that of instructors after 1 week's training, rising to 78.5% after 4 weeks.

Preliminary analysis of the fish data reported in this study suggests that the error incurred is a result of underrepresentation of smaller fishes, such as those of the family Labridae. Analyses of this type provide trainers with the necessary information to focus further training and improve performance.

Considering that fishers target many of these species on a daily basis, it comes as no surprise that identification of commercial species is highly accurate. During training, attention was focused more on non-commercial species, including those of

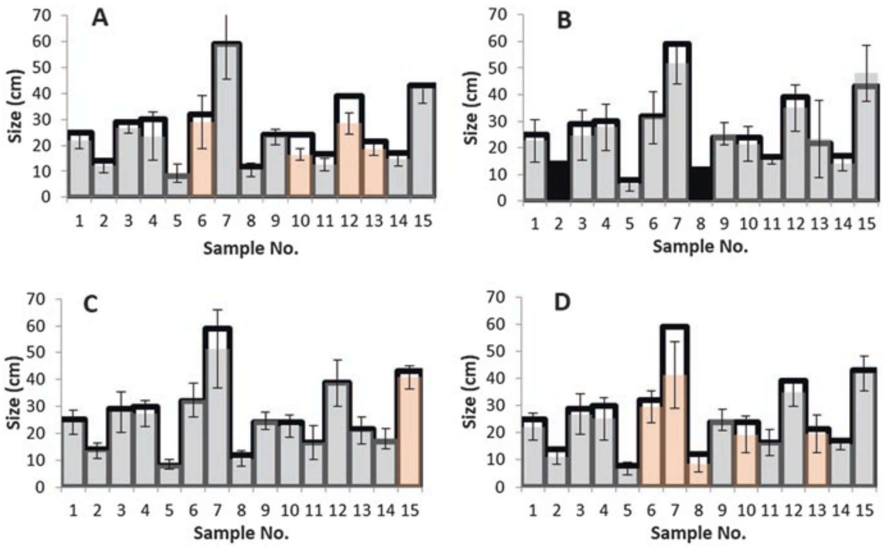

Fig. 7.5 Results of underwater size estimation exercises using plastic fish. Thick black line represents the true size of each plastic fish (n = 15), and the coloured shading represents the averaged estimates of each group (**a**, **b**, **c**, **d**) with standard deviation. Grey shading represents estimations within the correct size category, red shading represents an underestimated size, and a black column represents no data. (**a**) Fishers from the Cozumel Fishing Cooperative, Maria Elena, Sian Ka'an, March 2015, n = 6; (**b**) fishers from Banco Chinchorro, June 2013, n = 3; (**c**) students on a university training course, July 2014, n = 14; and (**d**) volunteer divers (principally biologists) taking part in AGRRA workshop, April 2013, n = 7

high importance to ecosystem health that fishers may have previously ignored. It has been noted that, particularly for cryptic commercial species (organisms that are not easily visible) such as octopus, lobster, and some shellfish, fishers are considerably more reliable than biologists in registering the species present. For example, during abalone censuses in Isla Natividad, abalone fishers found abalone much more quickly than researchers, and similar results have been seen with lobster in the Mesoamerican Reef. In general, we saw that fishers have a heightened awareness for their target species, which can prove beneficial during surveys.

Size estimation accuracy, which is critical for biomass calculation, is also consistent amongst fishers and volunteer observers. The size of the plastic fish was estimated underwater by each observer as mentioned above. Postdive, the plastic fish were measured, and sizes were compared to the observers' estimates. Group average size estimations by fishers (Fig. 7.5, A and B) and volunteer divers taking part in reef monitoring training workshops (C and D) were registered. Non-fisher groups consisted principally of biology students or biologists working in CSOs. The results showed that fishers can estimate size underwater as effectively as volunteer divers, even when the majority of the volunteer divers are biologists. We can also see that, amongst all observers, underestimation is more common than overestimation with individual data, again calling for personalized training to be undertaken to improve estimation accuracy for those individuals that need it.

7.3 Discussion and Conclusion

It is important to highlight that, while the fishers engaged in this program are participants in a citizen science program, the program differs somewhat from the conventional sense: with the establishment of marine reserves, the fishers are investing in their future. This is unlike the Audubon Society's Bird Surveys or REEF, where data are collected by volunteers in their free time and used by the host organization to monitor general population health and large-scale changes in species distribution. In the case studies discussed in this chapter, the fishers collect the data at a very local level, and, while scientists provide technical support and make management suggestions, the fishers are the ones who decide whether to implement them based on the data collected. The fishers also keep the data for their own use.

Successful implementation of the recommendations is often due to increased trust in the data and concerns over the long-term sustainability for their fisheries. Unfortunately, it is common for scientists to visit communities and collect data without providing feedback to the community, causing fishers to fear that these data will be used against them in top-down management measures, such as the closure of fishing grounds, rather than for their benefit and in a clear, transparent process in which they have a voice. The result is that they can be less likely to participate or share important information that could be mutually beneficial for both fishers and scientists alike.

In the case of marine reserves where members of affected communities collect the data themselves, there can be no quibble amongst fishers regarding their reliability. Additionally, data generated in the marine reserves has been seen to provoke one of two reactions: (1) if no recovery of marine biodiversity is seen, fishers feel the need to redouble their conservation efforts, given that they have a vested personal interest in the area and are responsible for the data collected; and (2) if improvements in the marine biodiversity are seen, great pride is felt within the community without the suspicion that the data are not representative or trustworthy. To date, we have not seen a negative reaction to the reserves that have shown slow or little recovery. The adaptive management options available also help to curtail this possibility. The most commonly used framework for these marine reserves is the voluntary community scheme or the 'fish refuge' scheme governed by Mexican Fisheries Law. Both frameworks allow reserves to be moved or modified, if necessary.

The importance of data collected by non-professionals is well documented, and, despite some criticism, the majority of studies comparing the validity of data collected by volunteers and experts using suitable methodologies have been favourable (Schmitt and Sullivan 1996; Hassell et al. 2013). Fewer studies have evaluated the ability of small-scale fishers from developing countries to collect accurate data, although Beger (2002) and Uychiaoco et al. (2005) found more variation in data collected by the fishers than what was collected by trainers. However, in the second study, training time was limited due to financial restrictions and the capacity of the monitoring team.

In the case of this program, fishers are financially compensated with a small stipend for the time they commit to the monitoring program, thus avoiding conflicts between taking part in the monitoring program and supporting their families. In this study, we observed that fishers can conduct visual censuses and estimate sizes with the same accuracy as trained volunteer divers, as reported by Mumby et al. (1995) and Harding et al. (2000). Similarly, test results suggest that fishers can identify species as successfully as groups with stronger formal educational backgrounds, although, as expected, professional researchers did score considerably higher. The range of evaluations conducted with the fishers in this study are necessary to ensure the validity of the data collected, and confidence in the resulting data is not only high amongst fishers but also government agencies and visiting scientists. The importance of a suitable methodology cannot be overemphasized.

Most of our community partners have completed only basic education, and while literacy is a requirement for joining the monitoring team, individual literacy abilities can vary. The methodology, data sheets, and databases should take this into account to ensure that minimal errors occur during data collection and entry into the databases. Frequent follow-up with the community is also important. Data analysis is performed off-site by CSO staff or researchers, and, as such, data must be given back to the fishers as soon as possible.

This chapter demonstrates how the involvement of small-scale fishers in the implementation of conservation measures in three ecoregions of Mexico – kelp forests, coral reefs, and rocky reefs – has been achieved through a participatory process. The model used in this chapter has been adopted for use by organizations in other areas, both in Mexico and neighbouring countries. These findings suggest that it is a very effective community empowerment tool, given that involving community members in the scientific process creates responsibility, pride, and a deeper understanding of the ecosystem in which they live and work. In this way, the empowerment of fishers allows them to make more effective, participatory management decisions for their fisheries to ensure the long-term success of fisheries and fishers' livelihoods.

The program shows the importance of participative processes, including training, follow-up, and returning data back to those involved in monitoring. Work needs to be done to ensure the long-term sustainability, expansion, and replication of such programs for the benefit of resource conservation, the sustainability of fisheries, and the viability of fishing communities.

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References

Abesamis RA, Green AL, Russ GR, Jadloc CRL (2014) The intrinsic vulnerability to fishing of coral reef fishes and their differential recovery in fishery closures. Rev Fish Biol Fish 24(4):1033–1063

Aburto-Oropeza O, Erisman B, Galland GR, Mascareñas-Osorio I, Sala E, Ezcura E (2011) Large recovery of fish biomass in a no-take marine reserve. PLoS One 6(8):e23601. https://doi.org/10.1371/journal.pone.0023601

Ainsworth CH, Kaplan IC, Levin PS, Cudney-Bueno R, Fulton EA, Mangel M, Turk-Boyer M, Torre-Cosio J, Pares-Sierra A, Morzaria-Luna H (2011) Atlantis model development for the Northern Gulf of California. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-110

Ballantine B (2014) Fifty years on: lessons from marine reserves in New Zealand and principles for a worldwide network. Biol Conserv 176:297–307

Beger M (2002) Fish and benthic monitoring at Danjugan Island Marine Reserve and Sanctuaries, Negros Occidental, Philippines: training local fisherfolk to monitor their reefs using SCUBA. Rufford Small Grants Foundation, London

Berkes F, Folke C, Gadgil M (1995) Traditional ecological knowledge, biodiversity, resilience and sustainability. In: Perrings CA (ed) Biodiversity conservation. Kluwer Academic Publishers, Dordrecht, pp 281–299

Butler JRA, Tawake A, Skewes T, McGrath V (2012) Integrating traditional ecological knowledge and fisheries management in the Torres Strait, Australia: the catalytic role of turtles and dugong as cultural keystone species. Ecol Soc 17(4):34. https://doi.org/10.5751/ES-05165-170,434

Charles A, Wilson L (2009) Human dimensions of marine protected areas. ICES J Mar Sci: J Conseil 66(1):6–15

Cisneros-Mata MA, Ulloa R, Laurencez-Reyes V, Rojo M, Meza A, Torre J, Andrews K (2011a) Evaluación de un banco de callo de hacha liso (Atrina oldroydii) en Bahía de Kino, Sonora en marzo de 2011 (Technical Report). Instituto Nacional de Pesca, Guaymas

Cisneros-Mata MA, Ulloa R, Laurencez-Reyes V, Rojo M, Meza A, Torre J, Andrews K (2011b) Evaluación de un banco de callo de árbol en El Desemboque, Sonora en marzo/abril de 2011 (Technical Report). Instituto Nacional de Pesca, Guaymas

Comisión Nacional de Pesca y Acuacultura (2009) Anuario estadístico de pesca y acuacultura. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación, Mazatlán

Costello C, Kaffine DT (2010) Marine protected areas in spatial property-rights fisheries. Aust J Agric Resour Econ 54(3):321–341

Cudney-Bueno R, Lavín MF, Marinone SG, Raimondi PT, Shaw WW (2009a) Rapid effects of marine reserves via larval dispersal. PLoS One 4(1):e4140. https://doi.org/10.1371/journal.pone.0004140

Cudney-Bueno R, Bourillón L, Sáenz-Arroyo A, Torre-Cosío J, Turk-Boyer P, Shaw WW (2009b) Governance and effects of marine reserves in the Gulf of California, Mexico. Ocean Coast Manag 52(3):207–218

Darwall WR, Dulvy NK (1996) An evaluation of the suitability of non-specialist volunteer researchers for coral reef fish surveys. Mafia Island, Tanzania—a case study. Biol Conserv 78(3):223–231

Drew J (2005) Use of traditional ecological knowledge in marine conservation. Conserv Biol 19:1286–1293

Espinosa-Romero MJ, Rodríguez LF, Weaver AH, Villanueva-Aznar C, Torre J (2014) The changing role of NGOs in Mexican small-scale fisheries: from environmental conservation to multi-scale governance. Mar Policy 50:290–299

Fernández-Rivera Melo FJ (2015) Análisis de los métodos de monitoreo empleados para evaluar el estado de las áreas naturales protegidas marinas en el Golfo de California. Master's thesis, Universidad Autónoma de Baja California Sur, Mexico

Fernández-Rivera Melo FJ, Hernández-Velasco A, Luna M, Lejbowicz A, Sáenz-Arroyo A (2012) Protocolo de Monitoreo para reservas marinas del Golfo de California (Programa Península de Baja California). Comunidad y Biodiversidad A.C., La Paz BCS

Fernández-Rivera Melo FJ, Reyes-Bonilla H, Sánchez-Alcántara I (2013) Un ejemplo de co-manejo pesquero en el Golfo de California: Caso de estudio cooperativa pesquera 'Mujeres del Golfo'. El Sudcaliforniano, p 6

Fernández-Rivera Melo FJ, Suarez-Castillo A, Hernández-Velasco A, Fulton S, Cuevas-Zimbron E, Torre-Cosio J (2014) Ciencia ciudadana: ¿Qué es?, ¿Cómo participan las comunidades? El Sudcaliforniano, p 11

Fernández-Rivera Melo FJ, Reyes-Bonilla H, Cantú A, Urías J (2015a) First record of albinism in the brown sea cucumber *Isostichopus fuscus* in the Gulf of California, Mexico. Mar Biodivers Rec 8:14. https://doi.org/10.1017/S1755267214001353

Fernández-Rivera Melo FJ, Reyes-Bonilla H, Campos-Dávila L, Balart EF (2015b) Range extension of *Lutjanus inermis* (Peters, 1896) (Perciformes: Lutjanidae) to the central region of the Gulf of California, Mexico. J Appl Ichthyol 31(3):541–543

Fernández-Rivera Melo FJ, Hernández-Velasco A, Suarez-Castillo A, Rojo M, Weaver AH, Walther-Mendoza M, Padilla R (2015c) Monitoreo submarino comunitario en el Golfo de California: un ejemplo de como las comunidades costeras participan en el manejo y conservación de sus recursos naturales. El Sudcaliforniano, p 3

Fletcher D, Shortis M (2001) A comparison of the precision and accuracy of estimates of reef-fish lengths determined visually by divers with estimates produced by a stereo-video system. Fish Sci 99(1):63–71

Forrester G, Baily P, Conetta D, Forrester L, Kintzing E, Jarecki L (2015) Comparing monitoring data collected by volunteers and professionals shows that citizen scientists can detect long-term change on coral reefs. J Nat Conserv 24:1–9

Freiwald J, Wisniewski C, Wehrenberg M, Shuman CS, Dawson C (2013) Reef check California instruction manual: a guide to rocky reef monitoring, 7th edn. Reef Check Foundation, Pacific Palisades

Fulton S, Caamal J, Ribot C, Lucas B, Garcia C, Bourillon L, Flores E (2013) Coral reef monitoring with fishers' participation in Quintana Roo, Mexico: building social capital to preserve marine ecosystems. In: Proceedings of the Gulf and Caribbean Fisheries Institute 2013, Corpus Christi, Texas, USA, November 4–8, 2013, pp 353–359

Fulton S, Bourillón L, Ribot C, Caamal J, García C, Flores E, Heyman W, Olivares M (2014) Fishermen investing in a network of fish refuges (no-take zones) in Quintana Roo, Mexico. In: McConney P, Medeiros RP, Pena M (eds) Enhancing stewardship in small-scale fisheries: practices and perspectives. Centre for Resource Management and Environmental Studies & Too Big to Ignore, Barbados, pp 138–144

Gell FR, Roberts CM (2002) The fishery effects of marine reserves and fishery closures. WWF-US, Washington

Germain N (2014) Factibilidad de la pesquería de ornato y co-manejo sostenible en áreas costeras e insulares. Doctoral thesis, Universidad Autónoma de Baja California Sur, Mexico

Germain N, Hartmann HJ, Fernández-Rivera Melo FJ, Reyes-Bonilla H (2015) Ornamental reef fish fisheries: new indicators of sustainability and human development at a coastal community level. Ocean Coast Manag 104:136–149

Gonzalez-Cuellar OT (2012) Estructura comunitaria y zonación geográfica de peces en arrecifes rocosos del norte del Golfo de California. Bachelors' thesis, Universidad Autónoma de baja California Sur, Mexico

Gonzalez-Cuellar OT, Reyes-Bonilla H, Fourriere M, Rojo M, Hernandez-Velasco A, Sanchez-Alcántara I, Pfister T (2013) Range extensions of four species of parrotfishes (Scaridae) in the northern Gulf of California, Mexico. Cybium 37:223–226

Greenley AP, Muguia-Vega A, Saenz-Arroyo A, Micheli F (2012) New tetranucleotide microsatellite loci in pink abalone (*Haliotis corrugata*) isolated via 454 pyrosequencing. Conserv Genet Resour 4(2):265–268

Groves CR, Jensen DB, Valutis LL, Redford KH, Shaffer ML, Scott JM, Baumgartner JV, Higgins JV, Beck MW, Anderson MG (2002) Planning for biodiversity conservation: putting conservation science into practice. Bioscience 52(6):499–512

Hamilton RJ, Potuku T, Montambault JR (2011) Community-based conservation results in the recovery of reef fish spawning aggregations in the Coral Triangle. Biol Conserv 144(6):1850–1858

Harding S, Lowery C, Oakley S (2000) Comparison between complex and simple reef survey techniques using volunteers: is the effort justified? In: Proceedings of the 9th international coral reef symposium. International Coral Reef Society, Bali, October 23–27, 2000, pp 883–889

Hassell NS, Williamson DH, Evans RD, Russ GR (2013) Reliability of non-expert observer estimates of the magnitude of marine reserve effects. Coast Manag 41:361–380

Healthy Reefs Initiative (2012) Report card for the Mesoamerican Reef. Healthy Reefs Initiative, Belize City

Hernández-Velasco JA (2010) Efecto de la pesca artesanal en la estructura comunitaria de peces de arrecife rocoso del noreste del Golfo de California, México. Bachelors' thesis, Universidad Autónoma de Baja California Sur, Mexico

Hernández-Velasco A, Vásquez-Vera L (2013) Pioneras del buceo comunitario en la Península de Baja California. Espacio Profundo Digit 123:33–39

Hernández-Velasco A, Villaseñor JC, Torre J, Suarez-Castillo A, Espinoza A (2015) Un bosque bajo el agua Isla Natividad. Espacio Profundo Digit 136:28–33

Hernández-Velasco A, Fernández-Rivera-Melo FJ, Melo-Merino SM, Villaseñor-Derbez JC (2016) Occurrence of *Holacanthus clarionensis* (Pomacanthidae), *Stegastes leucorus*, and *Stegastes acapulcoensis* (Pomacentridae) at Magdalena Bay, BCS, Mexico. Mar Biodivers Rec 9(1):49. https://doi.org/10.1186/s41200-016-0062-1

Heyman WD (2011) Elements for building a participatory, ecosystem-based marine reserve network. Prof Geogr 63(4):475–488

Heyman WD, Olivares M, Fulton S, Bourillón L, Caamal J, Ribot C, Kobara S (2014) Prediction and verification of reef fish spawning aggregation sites in Quintana Roo, Mexico. In: McConney P, Medeiros RP, Pena M (eds) Enhancing stewardship in small--scale fisheries: practices and perspectives. Centre for Resource Management and Environmental Studies & Too Big to Ignore, Barbados, pp 73–81

Hilborn R (2016) Policy: marine biodiversity needs more than protection. Nature 535(7611): 224–226

Kennedy EV, Perry CT, Halloran PR, Iglesias-Prieto R, Schönberg CH, Wisshak M, Form AU, Carricart-Ganivet JP, Fine M, Eakin CM, Mumby PJ (2013) Avoiding coral reef functional collapse requires local and global action. Curr Biol 23(10):912–918

Kramer P, McField M, Álvarez-Filip L, Drysdale I, Rueda-Flores M, Giro A, Pott R (2015) 2015 Report card for the Mesoamerican Reef. Healthy Reefs Initiative, Miami

Lang J, Marks KW, Kramer PA, Kramer R, Ginsburg RN (2010) Atlantic Gulf rapid reef assessment protocol version 5.4. http://www.agrra.org/. Accessed 19 Aug 2016

Leopold M, Cakacaka A, Meo S, Sikolia J, Lecchini D (2009) Evaluation of the effectiveness of three underwater reef fish monitoring methods in Fiji. Biodivers Conserv 18(13):3367–3382
Lucas B, Lau W, Rolón E (2012) Feasibility study for a marine payment for ecosystem services in the Mesoamerican Reef of Mexico (Final Report). Comunidad y Biodiversidad. A.C., Puerto Morelos
Marine Conservation Institute (2013) Global ocean refuge system. https://globaloceanrefuge.org. Accessed 19 Aug 2016
Marine Stewardship Council (2012) MSC Public Certification Report for Sian Ka'an and Banco Chinchorro Biosphere Reserves Spiny Lobster fishery. MRAG Americas Inc., St. Petersburg
Martínez-Torres M, Reyes-Bonilla H, Fernández-Rivera Melo FJ, Sánchez-Alcántara I, González-Cuellar OT, Morales-Portillo CD (2014) Range extension of the blue and yellow damselfish *Chromis limbaughi* (Pomacentridae) to the northern Gulf of California, Mexico. Mar Biodivers Rec 7. https://doi.org/10.1017/S1755267214000281
Mercier A, Hamel J-F, Toral-Granda T-G, Alvarado JJ, Paola Ortiz E, Benavides M (2013) *Isostichopus fuscus*. The IUCN red list of threatened species 2013. https://doi.org/10.2305/IUCN.UK.2013-1.RLTS.T180373A1621878.en
Micheli F, Sáenz-Arroyo A, Greenley A, Vazquez L, Espinoza Montes JA, Rossetto M, De Leo GA (2012) Evidence that marine reserves enhance resilience to climatic impacts. PLoS One 7(7):e40832. https://doi.org/10.1371/journal.pone.0040832
Micheli F, Butner C, De Leo G, Martone RG, Shester G (2014) A risk-based framework for assessing the cumulative impact of multiple fisheries. Biol Conserv 176:224–235
Monterey Bay Aquarium Sea Food Watch (2014) California Yellowtail. http://www.seafoodwatch.org/-/m/sfw/pdf/reports/mba_seafoodwatch_mexicocayellowtailreport.pdf. Accessed 14 May 2015
Moreno C, Torre J, Bourillón L, Durazo M, Weaver AH, Barraza R, Castro R (2005) Estudio y evaluación de la pesquería de callo de hacha (Atrina tuberculosa) en la Región de Bahía de Kino, Sonora y recomendaciones para su manejo (Internal Report). Comunidad y Biodiversidad, A.C., Guaymas
Moreno-Báez M, Cudney-Bueno R, Orr BJ, Shaw WW, Pfister T, Torre-Cosio T, Loaiza R, Rojo M (2012) Integrating the spatial and temporal dimension of fishing activities for management in the Northern Gulf of California, Mexico. Ocean Coast Manag 55:111–127
Moreno-Davila BB (2013) Taxonomía y biogeografía de ascidias (Tunicata: Ascidiacea) asociados a mantos de rodolitos y bosques de sargazo en el noroeste del Pacífico Mexicano. Master's thesis, Universidad Autónoma de Baja California Sur, Mexico
Mumby PJ, Harborne AR, Raines PS, Ridley JM (1995) A critical assessment of data derived from Coral Cay conservation volunteers. Bull Mar Sci 56(3):737–751
Munguia-Vega A, Jackson A, Marinone SG, Erisman B, Moreno-Baez M, Girón-Nava A, Pfister T, Aburto-Oropeza O, Torre J (2014) Asymmetric connectivity of spawning aggregations of a commercially important marine fish using a multi-disciplinary approach. PeerJ 2:e511. https://doi.org/10.7717/peerj.511
Munguía-Vega A, Sáenz-Arroyo A, Greenley AP, Espinoza-Montes JA, Palumbi SR, Rossetto M, Micheli F (2015a) Marine reserves help preserve genetic diversity after impacts derived from climate variability: lessons from the pink abalone in Baja California. Glob Ecol Conserv 4:264–276
Munguía-Vega A, Torre J, Turk-Boyer P, Marinone SG, Lavín MF, Pfister T, Shaw W, Danemann G, Raimondi P, Castillo-Lopez A, Cinti A, Duberstein JN, Moreno-Báez M, Rojo M, Soria G, Sánchez-Velasco L, Morzaria-Luna HM, Bourillón L, Rowell K, Cudney-Bueno R (2015b) PANGAS: an interdisciplinary ecosystem-based research framework for small-scale fisheries in the Northern Gulf of California. J Southwest 57:337–390
Ovando D, Dougherty D, Wilson JR (2016) Market and design solutions to the short-term economic impacts of marine reserves. Fish Fish 17:939–954
Pattengill-Semmens CV, Semmens BX (2003) Conservation and management applications of the Reef Volunteer Fish Monitoring Program. Environ Monit Assess 81(1–3):43–50

Pikitch EK, Santora EA, Babcock A, Bakun A, Bonfil R, Conover DO, Dayton P, Doukakis P, Fluharty D, Heheman B, Houde ED, Link J, Livingston PA, Mangel M, McAllister MK, Pope J, Sainsbury K (2004) Ecosystem-based fishery management. Science 305:346–347
PISCO (Partnership for Interdisciplinary Studies of Coastal Oceans) (2016) Partnership for interdisciplinary studies of coastal oceans. http://www.piscoweb.org. Accessed 20 Feb 2016
Precoma de la Mora M (2015) Distribución potencial de peces de importancia comercial en el norte del Golfo de California, México: influencia del cambio climático sobre las principales áreas de pesca de la zona. Master's thesis, Centro de Investigación Científica y de Educación Superior de Ensenada. Ensenada, Baja California, Mexico.
Revollo-Fernández DA (2012) Eficiencia técnica, social y económica de la pesquería de abulón bajo un esquema de gestión por medio de reservas marinas: el caso de Isla Natividad, Baja California, México. Doctoral thesis, Universidad Nacional Autónoma de México, México, D.F
Reyes-Bonilla H, Herrero-Perezrul MD, Fernández-Rivera Melo FJ (2009) Aspectos económicos de los recursos pesqueros no tradicionales residentes en zonas arrecifales del Golfo de California. In: Urciaga-Garcia J, Beltrán-Morales LF, Lluch-Belda D (eds) Recursos marinos y servicios ambientales en el desarrollo regional. Instituto Politécnico Nacional. Centro Interdisciplinario de Ciencias Marinas, La Paz, pp 245–264
Riosmena-Rodríguez R, Boo GH, López-Vivas JM, Hernández-Velasco A, Sáenz-Arroyo A, Boo SM (2012) The invasive seaweed *Sargassum filicinum* (Fucales, Phaeophyceae) is on the move along the Mexican Pacific coastline. Bot Mar 55(5):547–551
Roberts CM, Hawkins JP (2000) Fully-protected marine reserves: a guide. WWF Endangered Seas Campaign and University of York, Washington, DC & York, UK
Roberts CM, Bohnsack JA, Gell F, Hawkins JP, Goodridge R (2001) Effects of marine reserves on adjacent fisheries. Science 294(5548):1920–1923
Rossetto M (2012) Population dynamics and resilience of green abalone *Haliotis fulgens* in Isla Natividad. Doctoral thesis, UniversitàdegliStudi di Parma. Dipartimento di Scienze Ambientali, Italy
Rossetto M, Leo GAD, Greenley A, Vazquez L, Saenz-Arroyo A, Montes JAE, Micheli F (2013) Reproductive potential can predict recruitment rates in abalone. J Shellfish Res 32(1):161–169
Rossetto M, Micheli F, Saenz-Arroyo A, Montes JAE, De Leo GA (2015) No-take marine reserves can enhance population persistence and support the fishery of abalone. Can J Fish Aquat Sci 72(10):1503–1517
Ruiz-Frau A, Possingham HP, Edward-Jones G, Klein CJ, Segan D, Kaiser MJ (2015) A multidisciplinary approach in the design of marine protected areas: integration of science and stakeholder based methods. Ocean Coast Manag 103:86–93
Russ GR, Alcala AC (2003) Marine reserves: rates and patterns of recovery and decline of predatory fish, 1983–2000. Ecol Appl 13(6):1553–1565
Russ GR, Alcala AC (2004) Marine reserves: long-term protection is required for full recovery of predatory fish populations. Oecologia 138(4):622–627
Salas S, Chuenpagdee R, Seijo JC, Charles A (2007) Challenges in the assessment and management of small-scale fisheries in Latin America and the Caribbean. Fish Res 87(1):5–16
Schafer AG, Reis EG (2008) Artisanal fishing areas and traditional ecological knowledge: the case study of the artisanal fisheries of the Patos Lagoon estuary (Brazil). Mar Policy 32(3):283–292
Schmitt EF, Sullivan KM (1996) Analysis of a volunteer method for collecting fish presence and abundance data in the Florida Keys. Bull Mar Sci 59(2):404–416
Secretaria de Gobernación (2002) Decreto por el que se declara área natural protegida con la categoría de reserva de la biosfera, la región denominada Isla San Pedro Mártir, ubicada en el Golfo de California, frente a las costas del Municipio de Hermosillo, Estado de Sonora, con una superficie total de 30,165-23-76.165 hectáreas. Gobierno de Mexico, Mexico, D.F
Secretaria de Gobernación (2012) Acuerdo por el que se establece una red de zonas de refugio pesquero en aguas marinas de jurisdicción federal en el área de Sian Ka'an, dentro de la Bahía Espíritu Santo en el estado de Quintana Roo. Diario Oficial de la Federación. México. Gobierno de Mexico, Mexico, D.F

Secretaria de Gobernación (2013) Acuerdo por el que se establece una red de zonas de refugio pesquero en aguas marinas de jurisdicción federal en las áreas de Banco Chichorro y Punta Herrero en el estado de Quintana Roo. Diario Oficial de la Federación. México. Gobierno de Mexico, Mexico, D.F

Secretaria de Medio Ambiente y Recursos Naturales (2012) Plan de manejo tipo para peces marinos de ornato. Gobierno de Mexico, México, D.F. http://www.semarnat.gob.mx/archivosanteriores/temas/gestionambiental/vidasilvestre/Documents/Planes%20de%20Manejo/PM%20Peces%20Ornato%2031%20octubre%202012.pdf. Accessed 19 Aug 2016

Shuman CS, Dawson C, Wisniewski C, Wehrenberg M, Freiwald J (2011) Reef check California instruction manual: a guide to rocky reef monitoring, 6th edn. Reef Check Foundation, Pacific Palisades

Silvertown J (2009) A new dawn for citizen science. Trends Ecol Evol 24(9):467–471

Smith EP (2002) Ecological statistics. In: El-Shaarawi AH, Piegorsch WW (eds) Encyclopedia of environmetrics. John Wiley and Sons, Ltd., Chichester, pp 589–602

Suárez-Castillo A (2014) Bosques de Sargassum en el Golfo de California: estrategias para su conservación y manejo. Doctoral thesis, Universidad Autónoma de Baja California Sur, Mexico

Suarez-Castillo AN, Torre-Cosío J, Rojo-Amaya M, Fernández-Rivera Melo FJ, Talamantes C, Figueroa-Carranza AL, Mariano-Meléndez E, Urciaga-García J, Cabrera A, Sáenz-Arroyo A, Aburto-Oropeza O, Riosmena-Rodríguez R (2014) Valoración económica de los servicios ecosistémicos de los bosques de sargassum en el Golfo de California, Mexico. En: Urciaga J (ed) Desarrollo regional en Baja California Sur: una perspectiva de los servicios ecosistémicos, Universidad Autónoma de Baja California Sur, La Paz, pp 79–111

Thomas HL, Macsharry B, Morgan L, Kingston N, Moffitt R, Stanwell-Smith D, Wood L (2014) Evaluating official marine protected area coverage for Aichi Target 11: appraising the data and methods that define our progress. Aquat Conserv Mar Freshwat Ecosyst 24(S2):8–23

Thornton TF, Maciejeski-Sheer A (2012) Collaborative engagement of local and traditional knowledge and science in marine environments: a review. Ecol Soc 17(3):8. https://doi.org/10.5751/ES-04714-170,308

Torre J, Bourillón L, Weaver AH (2004) La pesquería de la jaiba verde (*Callinectes bellicosus*) en la región de Bahía de Kino y Canal de Infiernillo entre 1998 y 2002 (Informe Interno) Comunidad y Biodiversidad, A.C, Guaymas

UNDP-HDR (2015) Gender inequality index. http://hdr.undp.org/en/composite/GII. Accessed 19 Aug 2016

Uychiaoco AJ, Arceo HO, Green SJ, Margarita T, Gaite PA, Aliño PM (2005) Monitoring and evaluation of reef protected areas by local fishers in the Philippines: tightening the adaptive management cycle. Biodivers Conserv 14(11):2775–2794

Velez M, Adlerstein S, Wondolleck J (2014) Fishers' perceptions, facilitating factors and challenges of community-based no-take zones in the Sian Ka'an Biosphere Reserve, Quintana Roo, Mexico. Mar Policy 45:171–181

Villaseñor-Derbez JC, Hernández-Velasco A, Erauskin M, Fulton S, Cota-Nieto JJ, Torre-Cosio J, Herzka-Llona S, Aburto-Oropeza O (2015) Effects of short-term marine reserves on grouper and bass populations. DataMares. Interactive Resource. https://doi.org/10.13022/M33K52

Ward-Paige CA, Mora C, Lotze HK, Pattengill-Semmens C, McClenachan L, Arias-Castro E, Myers RA (2010) Large-scale absence of sharks on reefs in the Greater-Caribbean: a footprint of human pressures. PLoS One 5(8):e11968. https://doi.org/10.1371/journal.pone.0011968

White C (2009) Density dependence and the economic efficacy of marine reserves. Theor Ecol 2(3):127–138

Williamson DH, Russ GR, Ayling AM (2004) No-take marine reserves increase abundance and biomass of reef fish on inshore fringing reefs of the Great Barrier Reef. Environ Conserv 31(2):149–159

Zar JH (2010) Biostatistical analysis. Pearson Education. Inc., Englewood Cliffs

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