Creating Effective Marine Reserves
Systematizing the Steps Needed for Success

By The Clawless Lobsters

Fabio Castagnino, Roxanne Diaz, Denise Garcia, Sarah Salem, Camila Vargas

Faculty Advisor
Steve Gaines

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Authors

Fabio Castagnino
Roxanne Diaz
Denise Garcia
Sarah Salem
Camila Vargas

Faculty Advisor
Steve Gaines

Client
Fundación Claudia y Roberto Hernández
Claudia Madrazo
Marilu Bosoms

PhD Mentor
Julia Lawson

External Advisors
Gavin McDonald
Inés Lopez

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As authors of this Group Project report, we archive this report on the Bren School's website such that the results of our research are available for all to read. Our signatures on the document signify our joint responsibility to fulfill the archiving standards set by the Bren School of Environmental Science & Management.

Fabio Castagnino

Roxanne Diaz

Denise Garcia

Sarah Salem

Camila Vargas

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The Group Project is required of all students in the Master of Environmental Science and Management (MESM) Program. The project is a year-long activity in which small groups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. This Group Project Final Report is authored by MESM students and has been reviewed and approved by:

Dr. Steve Gaines

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Abstract

Global threats such as pollution, overfishing, habitat destruction, and climate change are having major impacts on marine ecosystems. To mitigate these threats, marine resource managers are employing conservation and fishery management tools to help keep certain areas or fisheries safe from anthropogenic damage. Marine reserves have been increasingly proposed as an effective tool to address fisheries and conservation goals as they prohibit the take or catch of species of concern. Multiple initiatives on establishing marine reserves have emerged around the world, each one with a wide range of designs, experiences, and outcomes.

We developed a manual to systematize the process of creating no-take marine reserves. To create the manual, we analyzed the Quintana Roo, Mexico efforts to establish marine reserves, or fish refuges as coined in the Mexican law, analyzed and synthesized scientific literature including reports, guidelines, and toolkits that provided valuable information on the process of creating these areas.

The content of this manual has been translated into a web-based hub. This hub is intended to make this information and process accessible to institutions or organizations that want to develop marine reserves. We believe that developing a user-friendly hub that integrates scientific information with case studies is a valuable instrument and will contribute to developing more effective marine reserves.

In this report, we describe our process of developing the manual and the web-based hub.

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Abbreviations

AFAM	Adaptive Fisheries Assessment and Management
BC	Banco Chinchorro Cooperative
CO	Cozumel Cooperative
CONANP	Comisión Nacional de Áreas Naturales Protegidas National Commission of Natural Protected Areas
CONAPESCA	Comisión Nacional de Pesca y Acuicultura National Commission of Aquaculture and Fisheries
FLAGS	Fisheries Landscape Assessment and Global Setting
FR	Fish Refuge
INAPESCA	Instituto Nacional de Pesca National Fisheries Institute
INVEST	Integrated Valuation of Ecosystem Services and Tradeoffs
IUCN	International Union for Conservation of Nature
JM	Jose María Azcorram Cooperative
KKA	Kanan Kay Alliance
LA	Langosteros del Caribe Cooperative
MAREA	Marine Reserve Evaluation Application
MARET	Marine Reserve Evaluation
MPA	Marine Protected Area
MPA-MEAT	Marine Protected Area Management Effectiveness Assessment Tool
MR	Marine Reserve
NGO	Non-Governmental Organization
QR	Quintana Roo
RBBC	Reserva de la Biosfera de Banco Chinchorro Banco Chinchorro Biosphere Reserve
RBSK	Reserva de la Biosfera de Sian Ka'an Sian Ka'an Biosphere Reserve
SAGARPA	Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food
SCPP	Sociedad Cooperativa de Producción Pesquera Cooperative Association for Fishery Production
SEMARNAT	Secretaría de Medio Ambiente y Recursos Naturales Secretariat of the Environment and Natural Resources
TURF	Territorial User Rights for Fishing
UN	United Nations
VC	Vigia Chico Cooperative

Executive summary

Overfishing, habitat destruction, and degradation pose major threats to marine ecosystems around the world, and the services they provide to humans. To address these problems, a series of management strategies and tools have been designed and implemented, applying different approaches and focusing on a combination of goals. Marine Reserves (MR) are among the most important management tools applied globally and largely contribute to conserving biodiversity and ecosystem services. Marine reserves, also called fish refuges in Mexico, are expanses of ocean closed to the extraction of a target species or group of target species. The effective design and regulations of marine reserves depend on their fisheries and conservation goals. There is an array of information focused on the process of implementing marine reserves around the world. This includes best practices and design principles, which could help guide the process of implementation new reserves.

In Mexico, more than 30 fish refuges (FR), have been created in the last decade in the Baja California Peninsula, the Gulf of California and on the Caribbean coast. Within Mexico, MRs are created using a bottom-up approach and serve as a fishery management tool for community-based management of marine resources. Although the process for creating a FR is enacted by the Mexican law, where specific guidelines are provided, the goals, design strategies and principles, and process of every FR within each host-community has been highly variable. In many cases, communities require external assistance and technical expertise from facilitators (e.g. Non-Governmental Organizations, funders, environmental institutions) to carry out the process of design and officially implement a FR (facilitators are individuals and or groups that take the lead in creating and implementing FRs).

In our thesis project, we analyzed and learned from the FR process in Quintana Roo State of Mexico (QR). We developed system maps to analyze stakeholders' involvement and relationship with each other based on a multi-stakeholder initiative called the Kanan Kay Alliance (Alliance). We also surveyed fishers, NGOs, and funders that work together in the Alliance to understand their perceptions on FRs. In addition, through our literature analysis, we identified that establishing a FR or MR entails four phases: Engagement, Creation, Implementation and Learning & Enhancement. The manual describes the strategies that will help to implement more efficient and successful MRs. This is done through the acknowledgment and integration of four components: ecological, governance, social and economic.

In the face of swift adoption and expansion of FRs across Mexico, the need for systematization and compilation of the processes and results arises. Our project focuses on integrating the best practices from around the world with those in QR to develop a hub of information including a streamlined, efficient procedure that FR facilitators can easily access and use.

We recognize that there are ample information and tools available to improve design and help incorporate local and scientific knowledge. Systematizing existing information and tools by integrating them into an easily accessed platform will contribute to creating more effective MRs. Thus, based on literature and the case study in QR, we developed a manual titled: “Guidelines for Creating Effective Marine Reserves.” It synthesizes some of the positive experiences, knowledge, and available tools to implement successful MRs. This information is currently being used to build a web-based hub that allows facilitators to get easy access to the content.

Background and Significance

Worldwide context

Overfishing and deterioration of key habitats are one of the major threats for marine conservation and fishery production worldwide (Pauly et al. 2005; Halpern et al. 2008, Pandolfi et al. 2011). This issue creates a major impact on food security, livelihoods, biodiversity, and the long-term sustainability of marine resources (Convention on Biological Diversity, 2004; Watson et al. 2014). Thus, closing off areas of the ocean to prohibit extraction and use has been developing as a viable option to increase marine populations and improve ecosystem functions (Uribe et al. 2010; Gaines et al. 2010; Green et al. 2014).

In recent decades, marine protected areas (MPAs), including marine reserves, have received increasing attention from the scientific community (Web of Science citation report, 2017), policy makers, and high level international bodies (e.g. Convention on Biodiversity's Aichi Targets, U.N. Oceans Conference Voluntary Commitments) as a fundamental tool to achieve biodiversity and sustainable goals (Pendleton et al. 2017).

Within the MPA spectrum, marine reserves are areas where the capture of one or more target species is prohibited (IUCN-Ia Reserve types; IUCN 2017). They are an effective way to increase stocks and positively affect adjacent fishing grounds (Lester and Halpern 2008; Lester et al. 2009), while preserving biodiversity and meeting other conservation objectives (Worm et al. 2006; Lester et al. 2009). Despite the popularity of marine reserves as a management tool and the increase of information and experiences in design and implementation, the process of creation of these areas is complicated due to intersecting social, economic, ecological, fishery, and political dimensions (McCay and Jones, 2011; Gelcich et al. 2013).

Mexico Case Study

In Mexico, a regulation passed in 2014 (NOM-049-SAG/PESC 2014), allows fishers to request legal recognition of marine reserves, under the name of fish refuge zones (FRs). Since 2014, more than 30 FRs have been established within the Pacific, Gulf of California, and Caribbean coasts of Mexico. The National Commission of Aquaculture and Fisheries (CONAPESCA), based on technical opinion of the National Fisheries Institute (INAPESCA), can establish FRs based on dimensions and temporal period requested by fishers. This report focuses on the experience of establishing FRs in the State of Quintana Roo (QR).

In this region, the Caribbean spiny lobster (*Panulirus argus*) are the main economically important commercial species for artisanal fishers. This species is widely spread across the western central Atlantic Ocean inhabiting rocky reefs, coral reefs, and seagrass beds down to a depth of 90 meters (Butler et al. 2011). Spiny lobsters are fished both commercially

and recreationally and are thought to be fully or overexploited (Cochrane and Chakalall, 2001). Other fishery target species include the Queen Conch (*Strombus gigas*), sharks, and a variety of finfish mainly harvested during the closed season of lobster. Currently there are approximated 2,000 fishermen in Quintana Roo and approximately 4% of territorial waters are fully protected from fishing –a small percentage in comparison to all federal waters.

In QR, fishing co-operatives are holders of fishing concessions along the barrier reef and within protected areas (Velez et al 2014). Fishing co-operatives and their respective concessions are integral to the development of the fishing industry in that area (Velez et al. 2014; Sosa-Cordero, 2011). Currently, there are 11 spiny lobster concessions that cover 33% of the State's territorial waters (Moreno et al. 2016). Co-operatives subdivide approximately 40% of their fishing concession areas among members via individual fishing rights. They have strict internal regulations for respecting each other's fishing rights and violations are sanctioned. Most co-operatives adhere to similar rules and limited-entry mechanisms (Velez et al. 2014).

Motivated by the overfishing and threats to the Mesoamerican reef, invested stakeholders aim to provide effective solutions that would allow the recovery of artisanal fisheries while promoting resilience of coastal communities and protecting the coral reef ecosystems (Moreno et al. 2016). To address this problem, key regional representatives of fishing cooperatives, NGOs, academia, foundations, and government came together to define a common strategy that maximizes the limited resources and capacities available in the region (Moreno et al 2016). This process led to the creation of the Kanan Kay Alliance (in spanish Alianza Kanan Kay), a voluntary multi-stakeholder collaborative network with the common objective of establishing an effective network of fish refuges in QR, Mexico. The Alliance have worked with fishing co-operatives to identify and prioritize conservation areas. Through bottom-up collaborative effort, fishers and NGO members agreed on specified FR placement and boundaries. Then they conducted technical justificatory studies in accordance with the regulation and submitted their proposal to the government. Currently, there are 17 fish refuges in this region. Some of them valid for six years and subject to a renewal process thereafter, while others are permanent.

Significance

The design and implementation of MRs aim to protect and conserve marine biodiversity, habitat, vulnerable species, livelihoods of local communities (e.g. tourism), and build resilience against climate change (Convention on Biological Diversity, 2004; Crawford et al. 2006; Watson et al. 2014). However, the process of creating, establishing, and implementing them is complex and lacks efficiency.

In Mexico, there is a legal recognition for the creation of MRs (or FRs), which allows the community to ask for legitimate protection of marine resources. In this area, NGOs are key actors and facilitators in assisting fishing co-operatives to implement new tools and

approaches in fisheries management (Espinosa-Romero et al. 2014). The development of the Alliance has facilitated communication among the fishers and fishery management agencies, integrating local and scientific knowledge to improve performance of small-scale fisheries (Karr et al. 2017). After 8 years of working together, small-scale fishers and NGOs in QR, realized the need to systematize the process, learn from their experiences, and share it with other coastal communities in Mexico, and if possible, other countries.

In summary, marine reserves have been increasingly implemented worldwide to improve fishing stocks and achieve conservation goals. With more than hundreds of experiences worldwide, there are also a wide range of views, designs, and practices (Pendleton et al 2017). Even within Mexico, experiences and outcomes have been different and diverse.

Our project focuses on integrating the best practices from around the world with those in QR to develop a hub for a streamlined and efficient procedure that MR facilitators can easily access and use. Systematizing this information and tools and integrating them into an easily accessed platform can contribute to creating more effective MRs.

Project objectives

The main objective of this project is to systematize the process of creating effective MRs by producing a web-based hub containing the necessary information, tools, and procedures to create MRs.
To achieve this goal, we define several specific objectives:

1. Assess the fish refuge process and status in Quintana Roo, Mexico.
2. Analyze and synthesize current marine reserves creation and implementation strategies worldwide.
3. Compile list of available tools than can inform and provide a scientific insight to the process of creating, implementing, and evaluating marine reserves.
4. Develop a web-based hub with the necessary information to create effective marine reserves.

In this report, we present the methods, results, and discussion developed to achieve these objectives.

Methods

Mexico Case Study

The Kanan Kay Alliance: Structure and process of creating fish refuges

In the summer of 2017, we visited QR to analyze and evaluate the process and status of FRs in the area. While there, we met with different members of the KKA including fishing co-operatives, funders, and NGOs. We conducted interviews with several members within the KKA and fishing co-operatives. We documented and transcribed this process into a series of systemization maps that addressed the biological, governance, and capacity building processes the KKA underwent to create FRs. In addition, we developed a systemization map of all stakeholders involved in the KKA, reflecting level of involvement in establishing FRs and relationships among members. Finally, we developed a systems map outlining the Mexican legal system related to the creation of FRs incorporating the ecological and social approach the KKA has adopted.

Surveys

We developed and conducted perception-based surveys with the aim of understanding how different stakeholders (fishers, NGOs, funders) of the Alliance perceive the process and benefits of fish refuges in the Sian Ka'an Biosphere Reserve and the Banco Chinchorro Biosphere Reserve.

Fishers survey

The participating fishing co-operatives in the implementation of FRs in QR are the Sociedad Cooperativa de Producción Pesquera (SCPP) José María Azcorra, SCPP Banco Chinchorro, SCPP Langosteros del Caribe, SCPP Andres Quintana Roo, SCPP Cozumel, and SCPP Pescadores de Tulum.

We interviewed 38 fishers from five different co-operatives within the QR area (Figure 1). The co-operatives included were Banco Chinchorro and Langosteros del Caribe, from the Banco Chinchorro Biosphere Reserve and Cozumel, Jose Maria Azcorra, and Vigia Chico, from the Sian Ka'an Biosphere Reserve. We interviewed fishers based on a set of 34 questions on the perceptions of FR impacts (Appendix A). Twenty-two questions were asked on a grading scale of -10 (extremely negative impact) to 10 (extremely positive impact) with 0 as a neutral or indifference point. We also included 12 open-ended questions about fishers' objectives, and benefits and costs associated with a FR. A subset of the 34 questions were analyzed. For unanswered questions, the data point was replaced with the means of available observations for that question in the statistical analyses.

Figure 1. Map of Quintana Roo showing the fishing cooperatives that where part of our survey. The four yellow dots indicate the relative locations of fish refuges of each of the five cooperatives.

We conducted a set of single-sample t-tests to assess the general perceptions of fishers on the impacts of FRs and the Alliance, with a 95% confidence level. Additionally, we ran a set of multiple regression analyses using FR design features and governance characteristics as predictive variables, and fishers' perceptions on the impacts of FRs and the Alliance, with a 95% confidence level. Within the predictive variables, we included the age of the FR, the total area covered by the FR within the fishing concession, and the FR average size inside a concession. We also considered the identity of the co-operatives, the age of the co-operatives, and the Biosphere Reserve in which the FR is located as governance-related proxies. Finally, to identify if there were significant differences across co-operatives for the selected indicators, we performed a series of Kruskal-Wallis tests, at 95% confidence level.

NGOs and Funders Survey

We created a web-based survey to gather the perceptions of 14 NGOs and four funders of the Alliance on their involvement and impact in the creation and implementation of FRs in the Quintana Roo area. We asked a set of 17 open-ended questions and 18 questions

based on a grading scale of -10 (extremely negative impact) to 10 (extremely positive impact) with 0 as a neutral or indifference point (Appendix B and C, respectively). A subset of questions was analyzed.

To assess the general perceptions of NGOs and funders on the impacts of FRs and the Alliance, we applied a set of two-tailed t-tests for one sample (of each type of organization separately) including the answers or the organizations of each group. We tested if the means of the whole sample for each question were significantly different than zero, with a 95% confidence level.

Literature review

We conducted an extensive analysis of primary literature including reviewing over 100 scientific papers, governmental reports, NGO and funder reports, books, and other framework guidelines used in other countries. We then synthesized best practices, design principles, and challenges to create a set of phases detailing the process of implementing MRs, either a single or a network (Figure 2). We compiled this information and phasic process into a physical manual that describes a set of guidelines and case studies about the process of creating marine reserves. This manual will be translated into a user-friendly web-based hub that facilitators can access to implement marine reserves.

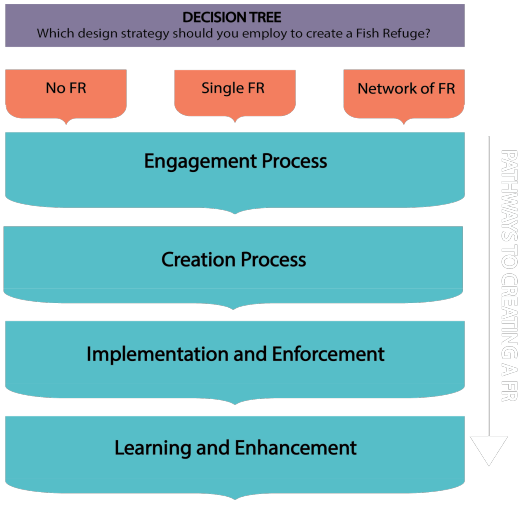


Figure 2. Overview of the process involved in creating marine reserves/Fish Refuges as described in the manual

Applicable tools

There are existing tools that can help facilitators achieve marine reserves objectives. Some tools were created by previous thesis projects from the Bren School of Environmental Science and Management as well as from the Sustainable Fisheries Group-a partnership between Marine Science Institute and the Bren School of Environmental Science and Management at the University of California Santa Barbara (Sustainable Fisheries Group, 2016). Since Mexico shares the Mesoamerican Reef system with other countries, we looked into similar FR initiatives and discovered other tools used to design these areas under different management scenarios. Thus, these tools form the basis of the toolkit component of the manual.

For each tool, corresponding published literature, manuals, websites, and reports were reviewed to have a better understanding of its intent and use. We developed a series of categories to help standardize the information. This includes a tool name, developer, what can the tool do, how is it useful for designing and/or implementing marine reserves, what data are needed, and where it can be accessed. We synthesized six toolkits (Figure 9) and incorporated them into the manual. These toolkits can be used at various stages throughout the marine reserve process and targets, at varying degrees, the ecological, economic, governance, and social components of these zones.

We also adapted a model to analyze cost and benefits of a hypothetical FR in QR, Mexico from a fishery perspective. Currently, the model is in its preliminary phase, therefore we included the methodology and preliminary results as an appendix of this report (Appendix D).

Web-based hub

In order to translate the information provided in the manual to the web-based hub we are using the Wix platform. This web interface provides a user-friendly platform that work well with other software that have been utilized in the project, this includes R Studio and Adobe Suite 2018. The digital graphics made in the manual are designed using Adobe Suite, which has many of the same features found in Wix. Additionally, a Wix website can be easily maintained by our client post production, allowing the web hub to be maintained in the future. Within the website, there is a R Studio Shiny App that has been developed to make the users experience of the Decision Tree, simpler and faster. Based on the input user's response the app provides a specific output that eventually leads the user to a final design output. The web hub is designed to synthesize the information from the manual and provide the user with a streamlined experience when creating a marine reserve.

Results

Mexico case study

Systematization Maps

Kanan Kay Alliance structure

In order to understand the Alliance, we constructed a systematic map reflecting all the stakeholders involved in the process of creating a FR. We identified NGOs, philanthropies, government agencies, fishing cooperatives, universities, and other external parties and how they connect with each other. This exercise allowed us understand the high number of stakeholders involved in the process of creating fish refuges together with the complexity of the situation and the different connections and communication channels within all the actors. The systematization map contains private information from the Alliance so it is not displayed in this report.

Process of creating a FR based on the Alliances experience

Through an extensive in-depth analysis of the procedures and local, state, and national legal systems, we developed a second map to outline the Alliance's process of establishing FRs in the QR region (Figure 4). The figure below outlines the process for the creation and placement of a FR that incorporates the local knowledge of fishers and baseline data from underwater surveys of target species. This information along with coordinates of areas are compiled into a technical justificatory report that is submitted to the Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food (in Spanish Secretaria de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación, SAGARPA) via the CONAPESCA with technical recommendations from INAPESCA. CONAPESCA regulates fishing while INAPESCA directs and coordinates scientific investigation (http://en.presidencia.gob.mx/cabinet/).

It is important to note that a FR specifically aims to improve the status of exploited species within a fishing concession and inside or outside natural protected areas. Thus, there is a legal distinction between this new fishery management law and that of traditional no-take areas in Mexico's natural protected areas system such as nucleus zones in biosphere reserves. The FRs studied in this report are within concessions and natural protected areas. Thus, CONAPESCA has the discretion to solicit advice from the CONANP, an arm of the Secretariat of the Environment and Natural Resources (Secretaría del Medio Ambiente y Recursos Naturales, SEMARNAT) and is responsible for natural protected areas. However, such request of advice is not mandated by law and is discretionary (Gobierno de Mexico, 2017). Through this process, local fishing co-operatives have legal authority from the Mexican government to propose, designate, and implement fish refuges under the new regulation, "NOM 049."

Finally, the Alliance aims to address the social structures within each of the co-operatives and provide capacity-building opportunities to fishers to better facilitate the fish refuge process. Through this engagement process, the Alliance hopes to create healthy

relationships with fishers and provide learning opportunities via workshops to better equip them to manage their fish refuges, strengthen interior social and governance structure, and feel ownership of the fish refuges within their concessions—lending to effective and successful fish refuges.

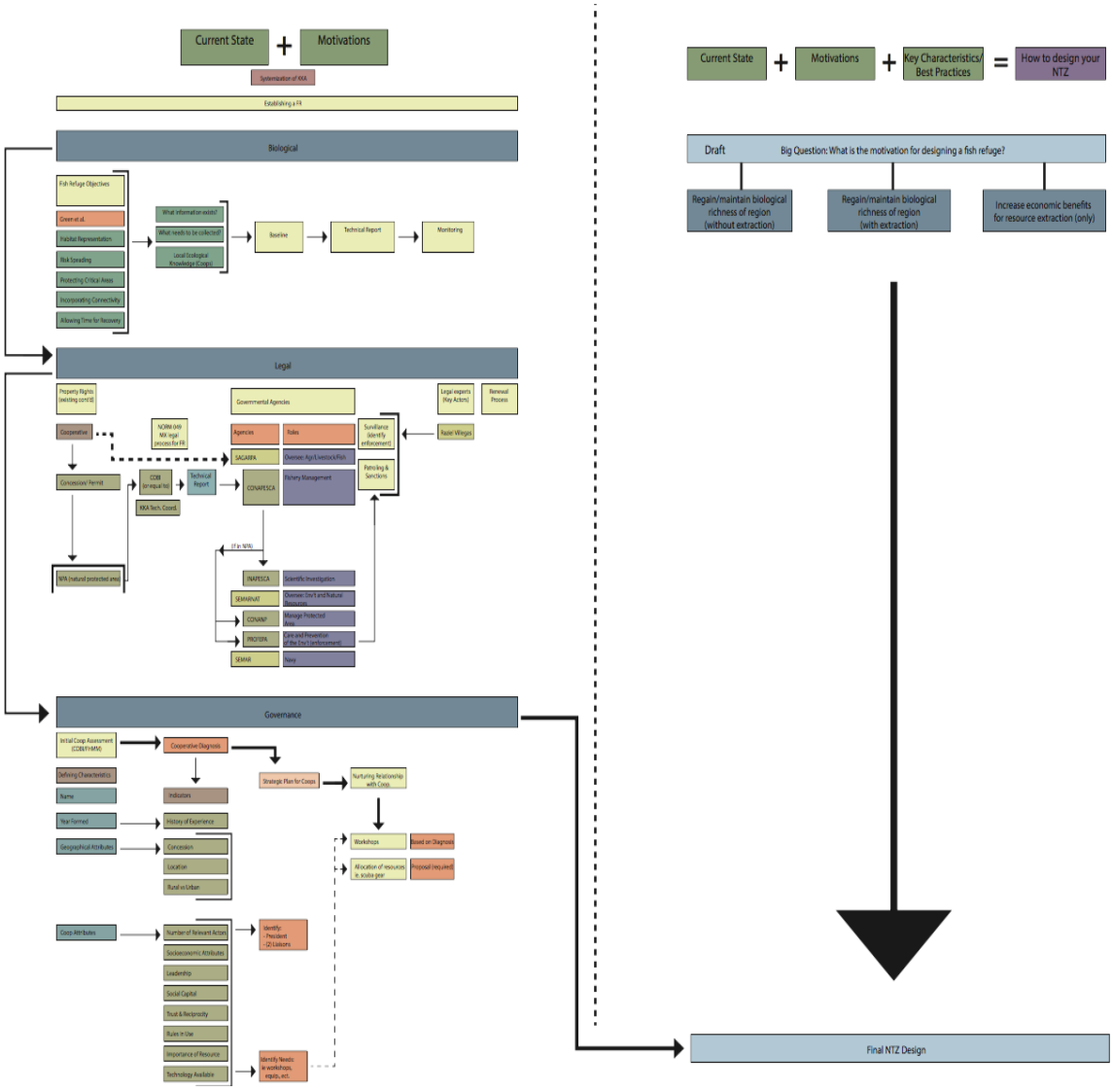


Figure 3. Mega map outlining the Alliances current process to create and implement a fish refuge in the Quintana Roo region.

Survey Results

Here, we present the main results obtained from the perception-based surveys of the fishers, funders, and NGOs.

Fishers' Survey

From surveyed local fishers' perspectives, FRs had a mainly positive impact on most of the assessed aspects. In general, the series of t-test showed that FRs have a significantly positive impact on fishers' livelihoods (Table 1). They also showed that the benefits of being part of the Alliance are higher than the costs. Regarding ecological impacts of FRs, the fishers perceived them as strongly positive (Table 2). However, slight differences in grade were shown when questioned about the impacts of a FR on social and economic structures. In this sense, we understand that the FRs brought consistent ecological benefits to communities, but their social and economic benefits showed to be more variable. However, the performed models failed to identify clear drivers for these differences at the whole-sample scale.

Table 1. Results of two-tailed t-tests performed for selected general indicators. Overall impact: how the FR has had an impact over the fisher's livelihood in general. General perception: the overall fisher's perception of the FR. Cost-benefit: how much the benefits overcome the costs, either of having a FR established, or of being part of the Alliance. Tests were performed over the whole sample of surveyed fishers. Significant p-values are represented as follows: (***) =p<0.001; (**) = p<0.01; (*)=p<0.05.

Indicator	Mean	t	Df	p
Overall impact	2.94	4.94	37	***
General perception	6.98	13.71	37	***
Cost-benefit of the Alliance	4.09	4.77	37	***
Cost-benefit FR	6.74	12.17	37	***

Table 2. Results of two-tailed t-tests performed for selected ecological indicators. Overall ecosystem: how the FR has impacted the local ecosystem. Fish abundance: how the FR has impacted the abundance of fish in the surveyed fisher's concession. Ecosystem health: impact of FR over the health of the local ecosystem. Tests were performed over the whole sample of surveyed fishers. Significant p-values are represented as follows: (***) =p<0.001; (**) =p<0.01; (*) =p<0.05.

Indicator	Mean	t	Df	p
Overall ecosystem	7.78	18.29	37	***
Fish abundance	7.19	13.55	37	***
Ecosystem health	6.46	10.04	37	***

Table 3. Results of two-tailed t-tests performed for selected social indicators. Overall co-operatives functioning: how the process of creating and implementing a FR has influenced the co-operatives functioning. Leadership: how the process of creating and implementing a FR has influenced the leadership inside the co-operatives. Members trust: in how the process of creating and implementing a FR has had an impact on the co-operatives members trust. Internal governing: how the process of creating and implementing a FR has influenced the co-operatives' internal governing. Tests were performed over the whole sample of surveyed fishers. Significant p-values are represented as follows: (***)=p<0.001; (**)=p<0.01; (*)=p<0.05.

Indicator	Mean	t	df	p
Overall co-operatives functioning	5.33	8.15	37	***
Leadership	3.19	4.02	37	***
Members trust	2.78	3.33	37	***
Internal governing	0.66	1.37	37	0.178

The impacts of FRs on social aspects were almost all significantly positive. However, FRs did not have a significantly positive impact on the co-operatives internal governing (Table 3). Furthermore, the perceived economic impacts of FRs on co-operatives were significantly positive, although the more specific impacts on income and co-operatives financial situations showed smaller means (Table 4). The costs generated by the creation of the FR itself includes a reduction in the fishing ground. The benefits derived from successful implementation include increased catch outside the closed areas due to spillover. Economic strategies to overcome the most important costs and enhance the benefits create motivation for the users to enforce the FR. The FR located in the Banco Chinchorro Biosphere Reserve is the biggest in area, across the whole region. Due to its size, we expect it to produce higher costs at the beginning, in comparison with other smaller FRs. In the long term, however, it would be expected to produce bigger ecological or fisheries benefits for the community. As the FR has been in place for a short time before this survey was conducted, this idea could not be evaluated yet, but remains as one of the hypothetical sources for the observed inconsistency. Finally, the surveys also showed that the fishers perceive the role of the Alliance as consistently positive in the process of creating and implementing FRs (Table 5).

Table 4. Results of two-tailed t-tests performed for selected economic indicators. Overall economy: how the FR has impacted the overall economy of the fishers and their communities. Fishing (catch): how the FR has impacted the fishing (catch) in the concession where it is located. Income: how the FR has impacted the fisher's income. Co-operatives finances: how the FR has impacted the co-operatives financial situation. Tests were performed over the whole sample of surveyed fishers. Significant p-values are represented as follows: (***)=p<0.001; (**)=p<0.01; (*)=p<0.05.

Indicator	Mean	t	df	p
Overall economy	4.17	6.51	37	***
Fishing (catch)	3.52	4.76	37	***
Income	1.78	2.71	37	**
Co-operatives finances	1.91	3.04	37	*

Table 5. Results of two-tailed t-tests performed for selected indicators of the importance and influence of the Alliance over co-operatives and the process of creating and implementing FR. Technical studies: to what extent the Alliance was important in building the technical studies required for the creation of the FR. Fishers inclusion: to what extent the Alliance included the surveyed fisher in the location selection for the FR. FR facilitation: to what extent the Alliance has facilitated the process of creating and implementing a FR. Monitoring preparation: to what extent the fisher feels prepared by the Alliance to perform the FR monitoring. Tests were performed over the whole sample of surveyed fishers. Significant p-values are represented as follows: (***)=p<0.001; (**)=p<0.01; (*)=p<0.05.

Indicator	Mean	t	df	p
Technical studies	3.60	4.91	37	***
Fishers inclusion	6.70	11.94	37	***
FR facilitation	5.33	7.29	37	***
Monitoring preparation	7.57	14.88	37	***

On the other hand, the series of multiple regression analysis performed showed that none of the selected possible drivers of positive impacts significantly predicted the answers. However, when co-operatives were compared based on these answers, some statistically significant differences were shown. The co-operatives Banco Chinchorro and Vigia Chico had significant differences, as the first showed consistently positive perceived impacts of FR over livelihoods, whereas the second was closer to neutral (Figure 5).

The co-operative that showed the lowest overall impact on livelihood and well-being was Vigia Chico. While one of the reasons for that may be the short time that their FR has been in place, that co-operative has also not been consistent in the long-term process of creating the FR and interaction with the Alliance. In fact, the co-operative broke away from the Alliance after initiating the process of proposing the FR and resumed the process two years later. It is likely that these differences and inconsistencies could have affected the extent in which they could have benefited from the FR. All these considerations, however, stand as hypotheses to be further assessed, but lay outside of the scope of the present project.

Although Banco Chinchorro and Langosteros del Caribe share a common FR, they differ in how the FR has impacted their livelihoods. While none of the previously assessed drivers successfully explain this difference, interviews with stakeholders closely working with these cooperatives suggest the results may be due to cultural differences that influence the answers to the surveys, rather than different underlying realities. Langosteros is a much younger co-operative, with younger members who are more conscious and critical of the impacts of the FR in their area. This observation highlights the importance of understanding the community's particular experience, not only in the process of creation of a FR but in the long term.

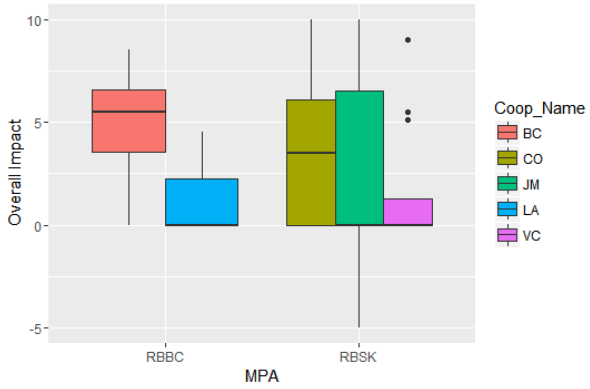


Figure 4. Overall perceived impacts of FR over fishers' livelihoods, grouped by co-operatives. BC=Banco Chinchorro; CO=Cozumel; JM=Jose Maria Azcorra; LA=Langosteros del Caribe; VC=Vigia Chico. The x-axis groups the co-operatives by the marine protected area in which they are located. RBBC=Banco Chinchorro Biosphere Reserve; RBSK=Sian Ka'an Biosphere Reserve. Kruskal-Wallis paired test showed that Banco Chinchorro and Vigia Chico had a statistically significant difference ($p<0.05$).

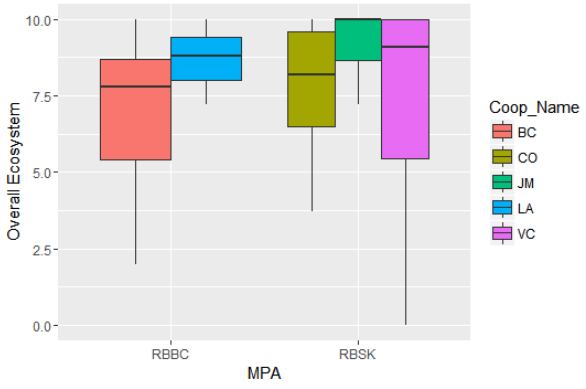


Figure 5. Overall perceived impacts of FR over the local ecosystem, grouped by co-operatives. BC=Banco Chinchorro; CO=Cozumel; JM=Jose Maria Azcorra; LA=Langosteros del Caribe; VC=Vigia Chico. The x-axis groups the co-operatives by the marine protected area in which they are located. RBBC=Banco Chinchorro Biosphere Reserve; RBSK=Sian RBSK=Sian Ka'an Biosphere Reserve. Kruskal-Wallis paired test showed that Banco Chinchorro and Jose Maria Azcorra had a statistically significant difference ($p<0.05$).

Perceptions of overall ecological impacts of implemented FRs were strongly positive across all co-operatives, however, results showed a significant difference between Banco Chinchorro and Jose Maria Azcorra (Figure 6). Cozumel and Jose Maria Azcorra showed a statistically significant difference when compared to Langosteros del Caribe and Vigia Chico on their perceptions on how FRs affect overall functioning of the co-operative (Figure 7), with the former two having higher positive perceived impacts, and the latter two having answers closer to neutral. Moreover, perceptions of economic impacts of FRs showed statistically significant differences between Cozumel (higher positive impacts) and both co-operatives from Banco Chinchorro (closer to neutral) (Figure 8).

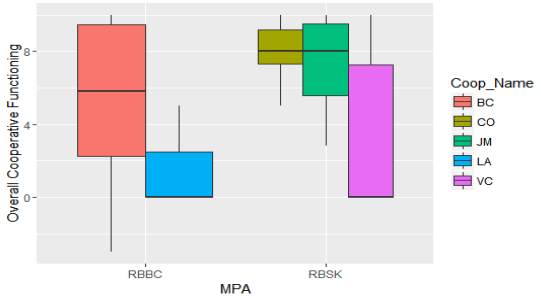


Figure 6. Overall perceived impacts of FR over how the co-operative functions, grouped by co-operative. BC=Banco Chinchorro; CO=Cozumel; JM=Jose Maria Azcorra; LA=Langosteros del Caribe; VC=Vigia Chico. The x-axis groups the co-operatives by the marine protected area in which they are located. RBBC=Banco Chinchorro Biosphere Reserve; RBSK=Sian RBSK=Sian Ka'an Biosphere Reserve. Kruskal-Wallis paired test showed that Cozumel and Jose Maria Azcorra had a statistically significant difference with Langosteros del Caribe and Vigia Chico ($p<0.05$).

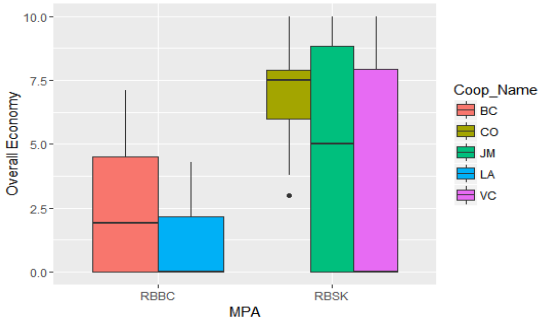


Figure 7. Overall perceived impacts of FR over local economy, grouped by co-operative. BC=Banco Chinchorro; CO=Cozumel; JM=Jose Maria Azcorra; LA=Langosteros del Caribe; VC=Vigia Chico. The x-axis groups the co-operatives by the marine protected area in which they are located. RBBC=Banco Chinchorro Biosphere Reserve; RBSK=Sian Ka'an Biosphere Reserve. Kruskal-Wallis paired test showed that Cozumel had a statistically significant difference with Banco Chinchorro and Langosteros del Caribe ($p<0.05$).

NGOs and Funders' Survey

The surveyed NGOs and funders also perceived similar highly positive impacts on ecosystem health but more inconsistent social and economic impacts. NGOs seem to have positive economic perceptions (access to funding) from FRs, as FR creation and implementation has increased funding in the Quintana Roo area for this process. NGOs and funders both had a significantly positive perception of FRs (Tables 6 and 9), and there was a consensus about the positive overall impacts of FR and the Alliance on Mexico's Mesoamerican Reef System (Tables 7 and 10). Perceptions of NGOs included significantly positive impacts on species diversity and fish abundance (Table 7). The impact of FRs and the Alliance on multi-stakeholder relations was significantly positive in the case of NGOs (Table 8) but not in the case of funders (Table 10).

Table 6. Results of two-tailed t-tests performed for selected general indicators based on NGO answers. General perception: the general perception of FR by the organization. Alliance effectiveness: how effective was the Alliance in reaching its own goals. Alliance enhancement of FR creation: to what extent the Alliance enhanced the process of creating and implementing FR. Cost-benefit Alliance & FR: to what extent the benefits of creating FR and being part of the Alliance overcome its costs. Tests were performed over the whole sample of surveyed fishers. Significant p-values are represented as follows: (***) =p<0.001; (**) =p<0.01; (*) =p<0.05.

Indicator	Mean	t	df	P
General Perception	8	13.61	10	***
Alliance Effectiveness	6.75	11.66	11	***
Alliance Enhancement of FR Creation	7.58	13.29	11	***
Cost-Benefit Alliance & FR	4.33	2.39	11	*

Table 7. Results of two-tailed t-tests performed for selected ecological indicators based on NGO answers. Overall ecosystem: the overall impact of the FR in the ecosystem. Species diversity: to what extent the FR helped increase species diversity within the area. Fish abundance: to what extent the FR helped to increase fish abundance within the area. Tests were performed over the whole sample of surveyed fishers. Significant p-values are represented as follows: (***) =p<0.001; (**) =p<0.01; (*) =p<0.05.

Indicator	Mean	t	df	P
Overall ecosystem	6.3	11.27	9	***
Species diversity	5.55	7.72	10	***
Fish abundance	6.18	7.88	10	***

Table 8. Results of two-tailed t-tests performed for selected socio-economic indicators based on NGOs' answers. Overall social relations: composed of the average of the scores for how the process of creating the FR and the participation in the Alliance impacted the organization's relationships with government agencies, cooperatives and other members of the alliance. Organization's objectives: to what extend the process of creating the FR and the participation in the Alliance influenced the objectives of the organization. Access to funding: how the process of creating the FR and the participation in the Alliance impacted the organization's access to funding. Tests were performed over the whole sample of surveyed fishers. Significant p-values are represented as follows: (***) =p<0.001; (**) =p<0.01; (*) =p<0.05.

Indicator	Mean	t	df	P
Overall social relations	5.57	7.80	10	***
Organization's objectives	4.91	5.40	10	***
Access to funding	2.42	2.48	11	*

While access to funding slightly increased due to the creation of FRs and their participation in the Alliance (Table 8), these two components influenced funders to direct more resources to QR, but they did not significantly impact the funders' yearly budget (Table 10). This is consistent with the general idea that the Alliance, and specifically, the creation of FR across the state of Quintana Roo, has motivated the direction of important resources to the area. This effect would have been difficult to be sensed by funders, as many of them are international organizations whose resources do not come from economic activities performed in the area. From the perspective of both groups of organizations, the Alliance was effective, enhanced the process of creating FR, and helped them reach their objectives (Tables 6 and 9). Finally, the surveyed organizations stated that the benefits overcome the costs of participating in the creation of FRs and being part of the Alliance (Tables 6 and 9).

Table 9. Results of two-tailed t-tests performed for selected general indicators based on Funders' answers. General perception: the general perception of FR by the organization. Alliance effectiveness: how effective was the Alliance in reaching its own goals. Cost-benefit Alliance & FR: to what extent the benefits of creating FR and being part of the Alliance overcome its costs. Alliance helped organization goals: to what extent the Alliance helped the organization reach its own goals. Tests were performed over the whole sample of surveyed fishers. Significant p-values are represented as follows: (***) =p<0.001; (**) =p<0.01; (*) =p<0.05.

Indicator	Mean	t	df	P
General perception	9.5	19	3	***
Cost-benefit Alliance & FR	9.33	14	2	**
Alliance Effectiveness	7	17.15	3	***
Alliance helped organization goals	8.25	8	3	**

Table 10. Results of two-tailed t-tests performed for overall ecological and selected socio-economic indicators based on Funders' answers. Overall ecosystem: the overall impact of the FR in the ecosystem. Overall social relations: composed of the average of the scores for how the process of creating the FR and the participation in the Alliance impacted the organization's relationships with government agencies, cooperatives and other members of the alliance. Yearly budget: to what extent the organization involvement in the creation of the FR and its participation in the Alliance has impacted its yearly budget. Funding to Quintana Roo area: to what extent the organization involvement in the creation of the FR and its participation in the Alliance has impacted the amount of funds that the organization directs to the Quintana Roo Area. Tests were performed over the whole sample of surveyed fishers. Significant p-values are represented as follows: (***) =p<0.001; (**) =p<0.01; (*) =p<0.05.

Indicator	Mean	t	df	P
Overall ecosystem	6.66	7.56	2	*
Overall social relations	6.33	1.99	2	0.185
Yearly budget	1.33	1	2	0.423
Funding to Quintana Roo area	7.67	5.28	2	*

Integrating literature review and the Quintana Roo case study: The Manual

The literature review enhanced our understanding of what MRs can and cannot achieve, along with describing successful characteristics and methods for implementing marine reserves. With this and the lessons learned in QR, we developed a manual to implement effective marine reserves (Appendix E). Here we outline the structure and key characteristics of the manual.

The manual contains the following:

- **Decision Tree:** The user of this manual will first encounter a series of questions with yes or no answers to evaluate if marine reserves are the proper approach according to the biology of the target species. The decision tree has three possible outcomes: Single Marine Reserve, Network of Marine reserves and No Marine Reserves.
- **No Marine Reserves:** In many cases, marine reserves are not the necessary tool to protect the target species. This section outlines different management approaches that can help improve the sustainability of the target species.
- **Single Marine Reserves:** This section describes the necessary approach to develop one marine reserve.
- **Network of Marine Reserves:** A possible outcome of the decision tree that involves connectivity and protection of different habitats relevant for the target species.
- **Compilation of Tools:** Different available tools that can help reinforce the process of creating, implementing, and evaluating marine reserves are described, pointing out the necessary data for their use.

We systematized this process into four phases:

1. Engagement

This is the first approach to engage local communities. This phase focuses on understanding the local needs (economic and ecological), aspirations, organization/structure, and well-being being of the community. It aims to establish a trusting relationship with the community and to develop a clear view of the opportunities and challenges they face. If these user-groups and communities show strong social structure, their participation and involvement in the marine reserve planning and decision-making process can increase the likelihood of its success (Grantham et al., 2013; FAO, 2011; Halpern et al., 2013; Dyer & McGoodwin, 1994). By making inclusion a formal objective, it may lead to compromises in marine reserve design but ultimately provide a more sustainable conservation plan (Halpern et al., 2013).

2. Creation

This is creating the full design and legal development of the MR as prescribed by engaged stakeholders and community members or resource users. This phase may require compromises in the science of the MR design but should still provide benefits. The scientific design process should be complemented by user local knowledge of the area and productive habitats.

3. Implementation

During this phase, the defined and agreed marine management strategy is applied. This phase requires monitoring and enforcement of marine reserves as well as periodic evaluation of target species and habitat. In this phase, application of the financial strategies is paramount to overcome the short-term costs.

4. Learning and Enhancement

This includes the learned experiences from the three phases described above to adapt the management strategy to achieve more benefits. It also includes sharing information with other groups associated with a marine reserve to learn what is working and what is not and how to enhance benefits.

Furthermore, within each of the phases we addressed four main components: biological, governance, social, and economic.

Ecological Component

Scientific analysis on the status and biology of the target ecosystem and/or species will help determine the size, location, duration, and connectivity of marine reserves that are critical to their effectiveness. Target species for marine reserve conservation include key fisheries species, species with important ecological functions such as herbivores and indicator species, and rare and threatened species (King & Beazley, 2005). Dependent upon how far these focal species move or which life history stage will be protected, stakeholders must determine how big a marine reserve should be, how many, or if marine reserves can provide adequate protection for conservation at all.

Governance Component

In this report, governance is the process by which laws, systems, and institutions surrounding marine reserves are developed and enforced to attain marine resource management across all scales of government, organizations, and users (Jones et al. 2013) (Gallacher et al. 2016). In small-scale fisheries, governance has many forms, and has evolved from state control, to co-management, to community-based management, property rights and more recently, an integrated approach to governance (Basurto et al., 2017). Growing external forces like the dependence of locals on marine resources and increase demand in the global fish market, lead users to develop a wide range of incentive mechanisms to govern the resources. According to Jones et al. (2013), these incentives include better communication and knowledge sharing, economic, participative and legal incentives including political will, surveillance and enforcement. This same logic can be applied to where it is used as a tool for achieving conservation and/or fisheries benefits.

Social Component

Each coastal community is different, and their leadership and organization structures will influence the success of a marine reserves (FAO, 2011). There are several key social science frameworks that help identify these characteristics and inform how best to integrate them for marine reserves success as marine reserves directly and indirectly impact coastal resource users and/or associated fishing communities (Christie et al., 2003).

If these user-groups and communities show strong social structure, their participation and involvement in the marine reserves planning and decision-making process can increase the likelihood of its success (Dyer & McGoodwin, 1994; FAO, 2011; Grantham et al., 2013; Halpern et al., 2013). By making inclusion a formal objective, it may lead to compromises in marine reserves design but ultimately provide a more sustainable conservation plan (Halpern et al., 2013).

Economic Component

Economic incentives drive important behavioral changes in the fisheries sector and including incentives in the marine reserve process is crucial for marine reserve to succeed in achieving conservation and fishery management goals (Hilborn et al., 2005; Gonzalez et al., 2006; Costello et al., 2010). Marine reserve facilitators should provide these incentives to communities to create and implement successful marine reserves. Incentives include: (1) financing the creation of the marine reserves, (2) reducing costs attributable to marine reserves, and (3) enhancing the benefits they provide – in the short and long term. By incorporating a financial plan, facilitators improve fisher livelihoods, effectively reduce the risk of low to no enforcement and surveillance by local communities/cooperatives and help create effective marine reserves (Gelcich & Donlan, 2015; Hamel et al., 2017).

Available tools for improving marine reserves

For almost any combination of marine reserve phase and component, there are existing tools that can help facilitators achieve desired objectives (Figure 9, Table 11). The selected list of tools presented here are specific to achieving and/or evaluating marine conservation and fisheries management goals, developed by experts in the field. Some applications are transversal through the different phases and touch on one or more components that help determine target species, size, location, and monitoring. If facilitators who are designing and implementing marine reserves know beforehand of the type of data needed, available tools, and expected outcome, this can enhance the establishment of more effective and efficient areas.

Figure 8. Application of tools for each phase and component of the manual. For each phase and component there exists tools such as Adaptive Fisheries Assessment and Management Toolkit (AFAM) (2nd row), TURFReserve Toolkit (2nd row), Marine Reserve Evaluation Application (MAREA) (3rd row), MPA Management Effectiveness Assessment Tool (MPA MEAT) (4th row), Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) (5th row) and Marxan.

Tool	Developer	How is it helpful?	Marine Reserve Phase
1. Adaptive Fisheries Assessment and Management (AFAM) Toolkit	Sustainable Fisheries Group	Estimate how fishery is doing and help implement and adjust fisheries management measures (McDonald et al. 2018).	Engagement, Creation
2. TURF-Reserve Toolkit	Sustainable Fisheries Group/Fish Forever	Decision support tool that incorporates species and habitat information to create TURF-Reserve design options. A model then analyzes and weight tradeoffs regarding fishery abundance, harvest and fisher profits (Oyandel et al. 2015).	Engagement, Creation, Implementation
3. Marine Reserve Evaluation Application (MAREA-TurfEffect Tool)	Villasenor et al. 2017	Uses a framework that evaluates effectiveness of no-take reserves by considering biophysical, socioeconomic and governance indicators (Villasenor-Derbez et al 2018).	Implementation , Learning & Enhancement
4. MPA Management Effectiveness Assessment Tool (MPA MEAT)	National Coral Triangle Initiative Coordinating Committee. 2011	This tool assesses governance in terms of enforcement, implementation, and maintenance. It was developed for the Philippines marine protected areas and uses scoring and certain threshold governance processes that help evaluate management effectiveness	Engagement, Creation, Learning & Enhancement

		outputs and outcomes (National Coral Triangle Initiative Coordinating Committee, 2011).	
5. Integrated Valuation of Ecosystem Services and Tradeoffs (INVEST)	Natural Capital	INVEST is an open-source software model used to map and value ecosystems goods and services. The model assesses tradeoffs with alternative management choices and identify areas where investment in natural environment can enhance human development and conservation (Sharp et al. 2016).	Engagement, Creation, Implementation, Learning & Enhancement
6. Marxan	Marxan Conservation Solutions	Marxan is a decision-support tool for systematic conservation planning (Ardron et al. 2010). This tool identifies areas that achieve conservation goals at minimal costs and meet spatial requirements while including data on ecological processes, threats and conditions. Marxan is able to produce various options to meet socio-economic and conservation objectives.	Engagement, Creation, Implementation, Learning & Enhancement

Table 11. Description of available tool kit. Details each tool's developer, its usefulness and suggested phase in the marine reserve process.

We further explore each tool and provide recommendation for its use.

Adaptive Fisheries Assessment and Management (AFAM) Toolkit

The AFAM tool is an eight-step cycle that estimates status of fishery, recommends fisheries management measures, evaluates the measures, and makes adjustments accordingly (McDonald et al. 2018). This tool has been applied at Fish Forever site like Belize. The steps include:

- Step 1 - Determine Assessment and Management Tier.
- Step 2 - Determine Appropriate Fisheries Management Controls.
- Step 3 - Select Performance Indicators, Reference Points, and Assessment methods.
- Step 4 - Define Harvest Control Rules.
- Step 5 - Perform Assessment Methods using HTML based dashboard.
- Step 6 - Interpret Assessment Results
- Step 7 - Adjust Fisheries Management controls using Defined Harvest Control Rules.
- Step 8 - Complete your Fishery Management Plan.

Why is it useful?

Although the AFAM Toolkit focusses on assessing and managing fisheries, Step 3 of the AFAM process can help facilitators determine the status or condition of the fisheries of interest. Selecting Assessment Methods is very resourceful because the facilitator can choose an appropriate method from suggested options to assess status of stock. This step provides a variety of models to conduct assessment based on performance indicators such as fishing mortality, spawning potential ratio, trends over time, biomass ratio, and density ratio.

The assessment methods include:

- Catch curve model
- Mean length
- Bounded mean length mortality estimator
- Length-based spawning potential ratio
- Froese sustainability indicators
- Trend analyses
- Mean weight
- Coral-reef thresholds
- Fished: unfished density ratio
- No-take zone catch curve

Facilitators can take advantage of these models to estimate fishing mortality of fisheries or trends over time if limited data like landings is available.

Required Data

To use Step 3 and corresponding models, minimum data required includes qualitative characterization of the fishery (including local history, gear types, target species, fishing locations, fishing seasons), TURF and Reserve size and location (if applicable), list or prioritized species for management, list or prioritized goals for management, and estimated vulnerability of prioritized target species. Recommended data include landings, effort, and CPUE of key target species; length composition data of key target species; fished: unfished density ratio and coral reef thresholds; household survey data on community's knowledge, attitude, interpersonal communication and practices relating to fisheries management; household survey data on the impact fisheries management is having on the community; information on violations to the NTZ and violations of TURF regulations; and qualitative information on the community's preparedness for implementing fisheries management and what barriers that may need to be removed.

Recommendation

Use AFAM toolkit to decide on appropriate assessment methods based on existing data and to explore the status of fish stocks. Evaluating the condition of the fisheries can help facilitators and users determine if a marine reserve is the appropriate management option. This can be used in the Creation Phase to address ecological component.

TURF-Reserve Toolkit

This toolkit has been used at Fish Forever sites to develop TURF-Reserves. The tool helps stakeholders evaluate different design options by assessing the performance of the designs based on ecological and socioeconomic information (Oyandel et al. 2015). TURF-Reserve Toolkit is comprised of the following tools:

- Fisheries Landscape Assessment and Global Setting
- Turf-Reserve Design Survey
- Marine Reserve Evaluation Tool (MaRET)
- Turf-Reserve Tool

Fisheries Landscape Assessment and Global Setting (FLAGS)

This tool helps users identify threats, goals, and priorities. It sets objectives for reserves; assesses risk to the ecosystem; and prioritizes species and habitat for protection and management. Although this tool targets establishing the reserves for Turf-Reserves, it can help facilitators of marine reserves choose target species and goals based on stakeholder involvement.

Why is it useful?
FLAGS is useful in cases where facilitators do not have enough background information of the communities and users. It provides an opportunity to engage the community in setting respective goals for target species taking into consideration the local information.

Required Data
Data needed for this tool includes stakeholder participation for local knowledge on species, habitat, and threats.

Recommendation
Use FLAGS in communities where minimal information exists on marine resources and users want to engage in management. This tool is appropriate during the Engagement phase to help identify goals and priorities of community members. Outputs of FLAGS can better inform the Creation phase.

Turf-Reserve Design Survey:

This tool is a research- and survey-based resource assessment from the perspective of local users. It integrates local knowledge with scientific technical expertise to provide guidance in designing the TURF-Reserve. It gathers information on coastal environment, resources, and people via interviews, community-drawn maps, diagrams, habitat assessments, and secondary data. It provides site-specific data that feeds directly into the TURF-Reserve design process.

Why is it useful?
This survey design is useful in obtaining more defined information of the site – including people and marine resources, particularly when data is not readily available and there are resources to conduct data gathering.

Required Data
The data needed includes stakeholder knowledge, on-site visual surveys (coral, seagrass, mangroves) for coastal habitat health, condition, structure, and secondary data (previously collected, reported, published). Specific templates of surveys are available at the tool's website.

Recommendation
Use TURF-Reserve Design Survey in communities to gather in-depth information on habitat, marine resources, uses, and factors affecting ecological system. This tool can be used in during the Engagement and Creation phase that will help feed into the design.

Marine Reserve Evaluation Tool (MARET)

This tool is used to evaluate the reserve side of TURF-reserves, gathering information on existing marine reserve(s) to assist and promote informed decision-making for TURF-Reserve design at a Fish Forever site. It uses a scoring system to evaluate the biophysical, governance, non-fishing impacts, and performance attributes for a thriving and successful marine reserve. The outputs of MARET serve as inputs for the TURF-Reserve Design Tool.

Why is it useful?
This is a quick and systematic way to obtain a snapshot status of an existing marine reserve that will be combined with a TURF design. Even if that is not the case, MARET can easily be used by technical staff of facilitating organizations to obtain a preliminary evaluation of the status of the marine reserve.

Required Data
Since this is specific to existing marine reserves that will be part of a TurfReserve design, data includes the FLAGS and TurfReserve Design Survey results, existing zoning maps, management plans, and secondary data.

Recommendation
Use MARET only if there are existing marine reserves. This tool can be used in the Creation phase.

Turf-Reserve Tool

This tool is a decision support tool that incorporates species and habitat information to create TURF-Reserve design options. It uses an excel-based model that analyze and weight tradeoffs among reserve designs – comparing fishery abundance, harvest and fisher profits. This tool uses biological, economic, and spatial information that comes primarily from the TURF-Reserve Design Survey and the TURF-Reserve species selection, as well as secondary sources where needed. This design tool provides explicit and transparent technical guidance on some of the key biological and socio-economic tradeoffs associated with proposed TURF-Reserve design options. The more accurate and specific the data, the more representative of the community conditions the trade-off analysis will be.

Why is it useful?
This tool is adequate for data limited areas where there is interest to manage marine resources, using TURF and marine reserves. It heavily relies on habitat characterization of the areas, target species life history parameters and other fishery specific information.

Required Data
Data for this tool are obtained from TURF-Reserve design survey, FLAGS Toolkit, existing zoning maps and/or management plans, and any other secondary data readily available. The community maps featuring habitat characterization (obtained from FLAGS or MARET) will be transposed into a 10 by 10 grid to further develop a spatial habitat characterization and highlight areas of interest such as fishing grounds, spawning, among others. Other data required are the list of target species for the TURF; home range, intrinsic growth rate, and species preferred habitat type; economic data such as price of target species and cost of fishing for target species; qualitative status of the fish population in important habitats; primary gear; illegal fishing and qualitative trend estimates. Other recommended data includes life history data collected from local studies and scientific literature.

Recommendation
This tool, although specific for marine reserves and TURFs, can be used in areas that have access rights (like fishing concessions in Mexico) and where no-use zones will be placed for target species (like fishing refuge zones in Mexico). This tool can be used in the Creation and Implementation Phase.

Marine Reserve Evaluation Application (MAREA-TurfEffect Tool)

This tool uses a framework that evaluates effectiveness of no-take reserves by considering biophysical, socioeconomic, and governance indicators (Villasenor-Derbez et al 2018). It uses an online application that automates the necessary analyses to evaluate the no-take reserves. The outputs are easy-to-interpret as they are color-coded scores for each indicator as well as an overall score of the reserve. It also generates a technical report that includes graphs and regression tables. Thus, is apt for users with varying level of experience in data analysis.

Why is it useful?
This tool is useful in evaluating existing marine reserves. It was created considering the no-take marine reserves in Mexico's Pacific side but can be used other areas. It caters to the needs of users like fishers who want to be participative in the management of their resources and fisheries. The biological underwater data needed to run this tool are mainly richness and abundance data and does not require more specific data collection information (for example species morphometric data).

Required Data
Biophysical data include underwater visual survey including species, size, size class, counts, including richness and abundance. Species-specific allometric growth parameters, trophic levels, and size at maturity can be obtained from literature. Socioeconomic data includes regional landings and average annual price per kilo for each species. Governance data can be obtained from perception-based survey data administered to fishers and community leaders.

Recommendation
Use MAREA to evaluate existing fish refuge zone or marine reserves. This can be used in the Implementation and Learning & Enhancement phases.

MPA Management Effectiveness Assessment Tool (MPA MEAT)

This tool was developed for the Philippines marine protected areas to assess governance in terms of enforcement, implementation, and maintenance (National Coral Triangle Initiative Coordinating Committee, 2011). It measures MPA effectiveness using an objective evaluation-based tool that includes a scoring scheme and threshold governance processes to evaluate management effectiveness outputs and outcome. This tool uses a sequential level system where each level of the MPA MEAT have criteria and activities that needs to be satisfied. For each level, there are governance thresholds such as management plan, patrol and surveillance, funding, ecological and socioeconomic impact assessments. In each level, a score or governance level is given. The minimum threshold scores should be satisfied to pass the level.

Why is it useful?
This tool is useful since it is practical and can be done by assisted self-evaluation or by using key informant interviews. The scoring system identify overall effort placed in MPA management as well as identify and incorporate activities that will help in effective management. Although this tool is specific to MPA, its scoring and indicator system can be adapted to marine reserves.

Required Data
Data to input into the tools are collected via community perception surveys and the MPA Management Effectiveness Assessment Tool survey form.

Recommendation
Use this tool during the Learning & Enhancement phase to identify gap areas and develop a plan for improvement.

Integrated Valuation of Ecosystem Services and Tradeoffs (INVEST)

INVEST, a product of Natural Capital, is a series of tools developed using iterative engagement with stakeholders to aid in decision-making (Sharp et al. 2016). It is an open-source software model used to map and value ecosystems goods and services. The model assesses tradeoffs with alternative management choices and identify areas where investment in natural environment can enhance human development and conservation. It explores how changes in ecosystems can translate to changes in benefits to people by quantifying and valuing ecosystem services. INVEST incorporates various models that can quantify, map and value the benefits provided by marine systems.

Why is it useful?
This tool is useful since the decision-making are done with stakeholders via consultations that includes policy makers, communities and conservation groups. Stakeholders are given the opportunity to query about services provided by the seascape and how new programs, policies or laws will affect the services in the future. In addition, stakeholders have the opportunity to develop "management scenarios" and explore changes in the marine resources and ecosystem service value by using biophysical and economic models that produce several types of outputs. InVEST can estimate the amount and value of ecosystem services that are provided on the current landscape or under future scenarios.

Required Data
The data used by InVEST includes spatial data, maps, biophysical data (species, landscape, region), monetary estimates based on existing literature and population size. The higher resolution data inputted into InVEST, the more accurate the results.

Recommendation
Use InVEST when efforts are at a more regional level and data are readily available to serve as input into the model. This tool can be integral throughout the four phases describe in this manual since it uses an iterative process of stakeholder engagement and validation of model outputs.

Marxan

Marxan is a decision-support tool for systematic conservation planning (Ardron et al. 2010). It is widely used in designing marine and terrestrial reserves as well as evaluating the performance of existing reserve systems. This tool has been used globally to identify areas that achieve conservation goals at minimal costs and meet spatial requirements while including data on ecological processes, threats and conditions. Marxan is able to produce various options to meet socio-economic and conservation objectives.

Why is it useful?
Marxan is useful since uses an integrated and systematic approach in reserve design and conservation planning on a whole. Reserve designs in Marxan are based on specific goals, current and future threats and priorities and alternative management options to make adequate decisions. This tool relies on accurate scientific information to project costs and benefits of alternative decision options.

Required Data
Data includes maps of human uses; threats; land tenure; and best available ecological, socio-economic, and cultural data. The data type includes fishing areas, developed areas, leases, or tenure areas. In addition, data on habitat types and distribution of biodiversity. Data acquisition, quality, preparation and management is the responsibility of the user.

Recommendation
Use Marxan when efforts are at a regional and/or national level particularly if data are easily available. Use this tool throughout the four phases described in this manual.

Web-based hub

As highlighted in this report there are an array of toolkits, publications, and reports that inform how best to create a marine reserve. One main challenge facing facilitators of marine reserves is the lack of information in one centralized location. Through our research we developed a marine reserve manual that identifies best practices, design principles, challenges, and tools that inform the design of a marine reserve. This manual will be distilled into a user-friendly web-hub. Figure 10 provides a schematic outline of how the user will navigate the website. In the initial development of the hub, we refer to marine reserves as Fish Refuges given that one of the main case study analyzed for this project is based in Mexico.

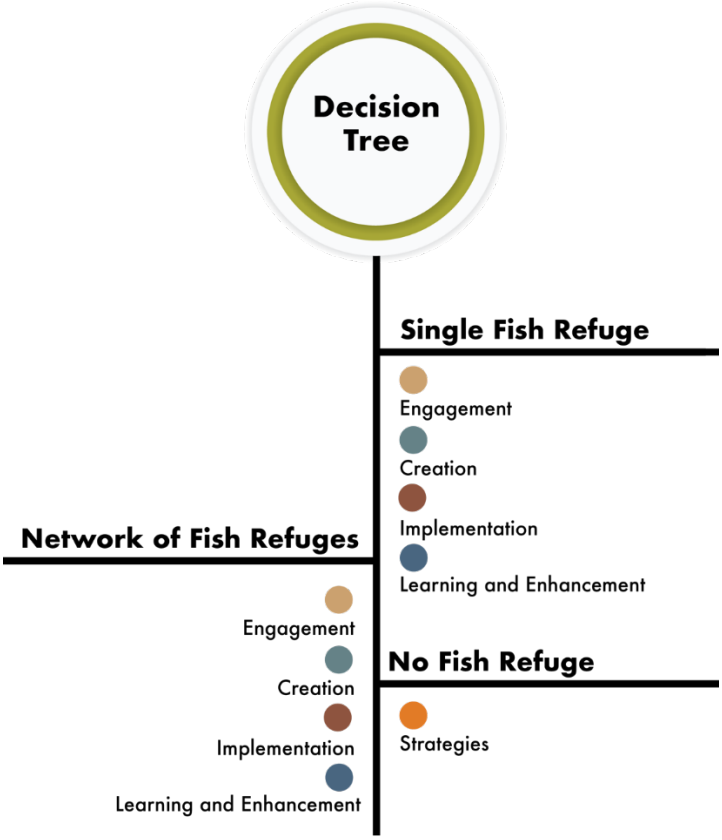


Figure 9: Schematic diagram of Marine Reserve/ Fish Refuge Web Hub page.

The first interaction the user will encounter is the Decision Tree. The Decision Tree was programed using R Studio Shiny application (Figure 11). After answering a few questions through the Decision Tree, the user is lead to one of three outputs, No Fish Refuge, Single Fish Refuge, and Network of Fish Refuge. Within each design approach, the user will find that each design option has quick links based on the phases of creating a fish refuge.

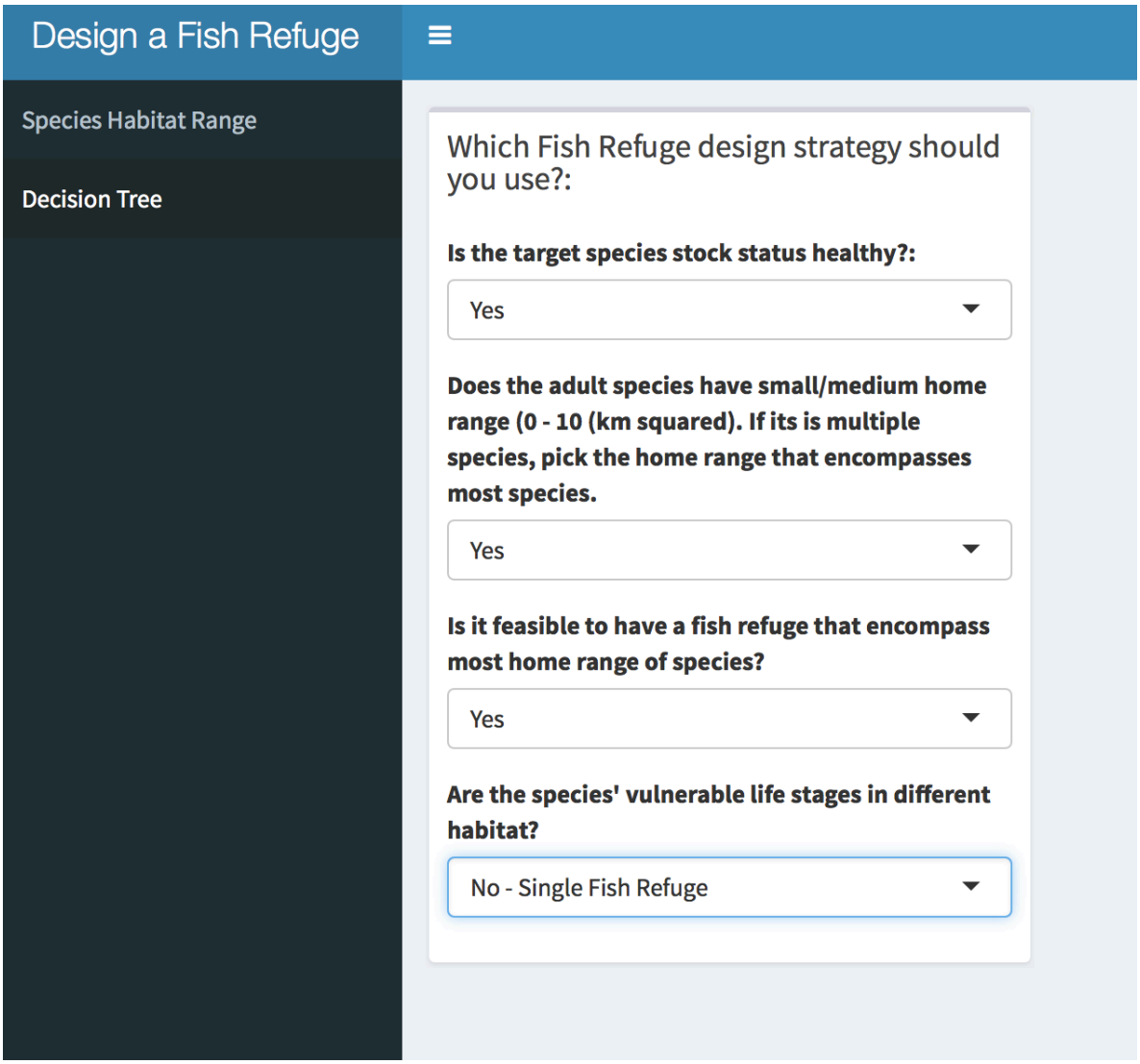


Figure 10: Decision Tree interface designed in Shiny R Studio. This screen shot referees to Marine reserves as Fish Refuge given that our case study was based in Mexico.

Additionally, each output connects the users to a webpage that focuses on one of the three design options, as seen in Figure 12. Each design approach is divided into the four phases and further broken down into four components (Figure 12 right side). The hub also provides information of several case studies and tools associated with each phase (Figure 12 right side). This allows the user to know what approaches the best fit for their specific region are.

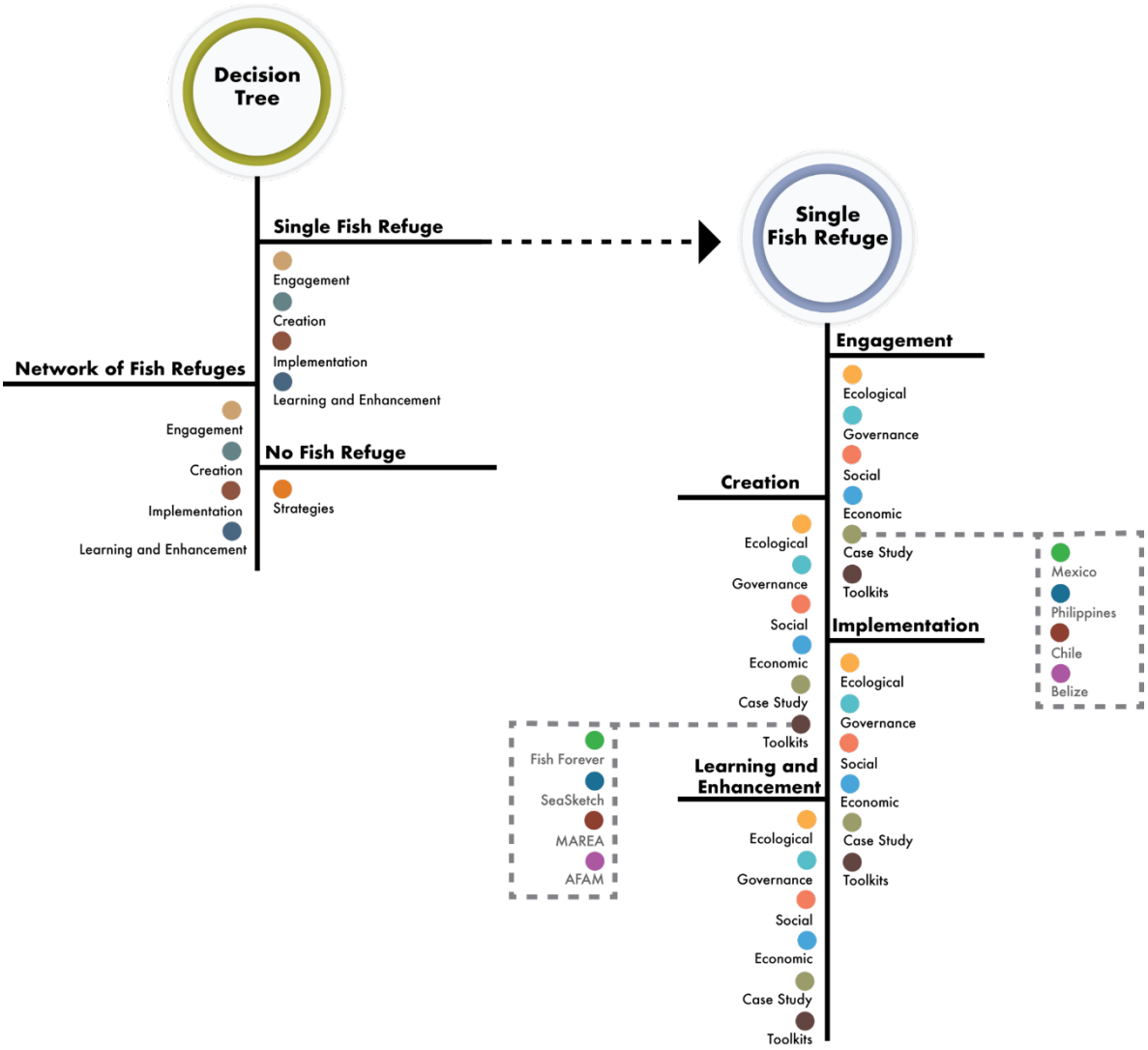


Figure 11: Website schematic design from Decision tree to interaction with four phases, components, case studies (Mexico, Philippines, Chile, Belize) and tools (Fish Forever, Sea Sketch, MAREA AFAM).

The website is meant to serve as a central area of information and best fit practices that can be utilized globally. Additionally, the user will have a toolkit guide that will help make the most appropriate tools are utilized during the entire design process.

Recommendations

Regarding the Mexican experience in the creation and implementation of Fish Refuges, we recommend the following:

- Increase the use of analytical tools in the processes of designing and implementing FR, especially regarding its biogeographic design and the analysis of costs and benefits. This could help to include a stronger science-based approach, and therefore enhance efficiency and sustainability. The different available tools, that we include in the Manual and Web-Based Hub, perform analyses which have variable levels of complexity and robustness. We suggest that these tools should be evaluated in terms of the appropriateness and feasibility of their use.
- Improve the level of data collection, based on the requirements of the analytical tools selected as appropriate to be used in the creation and implementation of FR. For each level, specific data are required. The type of data defined to be collected, and also the types of analyses to be applied with them, should be appropriate to the technical capacities found in the Core Group.
- Develop an economic strategy using the content of the Manual and the Web-Based Hub, in order to reduce economic barriers to success, including (1) finance implementation activities such as monitoring and surveillance, whose costs often fall heavily on the communities, and (2) improve local livelihoods, particularly to overcome the initial losses following the creation of FRs that necessarily precede the eventual economic opportunities that FR can bring.

Recommendations for the continuity of the web-based hub:

- Through this project we compile the necessary and up to date information about the process of creating marine reserve. However, the purpose of this hub is to serve as a guide for institutions who want to implement marine reserves. This hub is a living space that should be updated using the best available science and case studies. For this, it is necessary to develop a strategic plan for the continuity of the hub. This plan must consider logistics of who will be responsible for updating the content of the website and adding new tools that area developed through time.
- We also believe that the impact of the hub for diverse users would be greatly increased if the tools described in this project were integrated into a single interconnected platform that does not require the user to deal with the separate approaches and interfaces of the different tools. This could be achieved by creating partnerships with scientists that have develop each tool or by building common interface that allows users to apply all the tools from within the hub.
- Moving forward, we think the hub has the potential to have a repository with available data relevant for data-poor assessments. For example, include the range of movement and biological parameters of different species around the world according to the best science available.

- In the future, the hub can be a repository itself that collects all data input to the tools. This information can be valuable to assess case studies around the world and be able to learn for each marine reserve initiative. It can also help to identify patterns, gaps, challenges and successes.
- Finally, we think that in order for the hub to be successful it needs to have an outreach plan. This will help spread the information and reach out to those who are implementing or want to implement marine reserves.

Discussion and Conclusions

The main objective of this project was to systematize the process of creating effective MRs. We did this through analyzing the process in QR and conducting literature reviews on best practices, design principles, challenges, and available tools that can better inform the process of creating MRs. We have compiled this data and developed a web-based hub that soon will be available to facilitators around the world wanting to assist in initiatives such as the one in Mexico. It incorporates the necessary information (ecological, governance, social and economic) in the four phases needed to create effective FRs (Engagement, Creation, Implementation and Learning and Enhancement). Even though the hub compiles a tremendous amount of valuable information, there is always room for improvement (e.g. updates on new available scientific evidence and incorporation of ecological information of different target species).

Our project incorporates scientific, empirical, and theoretical material supported by associated tools to provide a platform that eases the access to users wanting to adopt MRs as a management tool. Through this we provide an effective pathway to communicate scientific knowledge and incorporate experiences around the world to provide a wider range of possibilities and highlight commonalities. These common principles are reflected throughout our manual.

It is important to acknowledge that creating a MR is a dynamic process. It is necessary to constantly reevaluate management strategies to make sure the system is moving toward achieving the desired goal. This idea is reflected in the Learning and Enhancement phase of the manual, which opens a new research opportunity to develop an effective mechanism of sharing information and adapting MRs according to areas of improvement.

Appendix

Appendix A: Fisher's Surveys

Survey Procedures:
In this survey we are going to ask you about your perception on the Fish Refuges and the Alliance. In order to do this, we are going to be using an interactive scale that goes form "Extremely Negative" to "Extremely Positive" or "indifferent" in the center. [Show scale]. Each question will require you to move the indicator across the scale, allowing us to document your answer.

For example: To what extent do you enjoy fishing? [await interviewees answer].

Survey General Information:

Date	
Location	
Cooperative	

1. Cooperative Member's Information:

1. Age	
2. Gender	
3. Main resource (fishing)	
4. How much of your livelihood depend on this fishery (Percentage)?	
5. What other source of income do you have?	
6. Do you have any role in the cooperative? Which one?	
7. Are you part or have you been part of a monitoring group? (yes/no)	
8. To what extent have the FR impacted your livelihood?	**Score:**

2. Objectives and Success

1. To what extent do you value FR	**Score:**

2. What are the main objectives that the cooperative envisions for the FR? (Please state three in order of importance)?	1.
	2.
	3.
3. To what extent have these objectives been achieved?	**Score:**

		Score
4. Ecological	To what extent do you think the FR has impacted the overall ecosystem?	
5. Social	To what extent do you think the FR has impacted the overall social dynamic of the cooperative and its members?	
6. Economic	To what extent do you think the FR has impacted the overall cooperative and its members' economy?	

3. Ecological Impacts

	Score
1. To what extent do you think the FR has influences the number of different species present in the ecosystem?	
2. To what extent do you think the FR has influences the number of fish present in the ecosystem?	
3. To what extent do you think the FR has influences fish biomass?	
4. To what extent do you think the FR has influences the size (ie: length of the fish or other species?	
5. To what extent do you think the FR has affected the overall ecosystem health?	

4. Social Impact

	Score
1. To what extent does the process of establishing a FR and being part of the Alliance affected the Leadership of the cooperative?	
2. To what extent does the process of establishing a FR and being part of the Alliance affected the trust among the member of the cooperative?	
3. To what extent does the process of establishing a FR and being part of the Alliance influence your cooperative relationships with other cooperatives?	
4. To what extent has the process of establishing a FR and being part of the Alliance influence the cooperatives relationship with NGOs?	
5. To what extent has the process of establishing a FR and being part of the Alliance influence the coops relationship with governmental agencies?	
6. To what extent has the process of establishing a FR and being part of the Alliance helped you understand and gain knowledge about the reef system?	
7. To what extent has the process of establishing a FR and being part of the Alliance influenced the coops' internal rules?	
8. To what extent has the process of establishing a FR and being part of the Alliance influenced the surveillance process of illegal fishing?	

5. Economic Impact

	Score
1. To what extent has the process of establishing a FR and being part of the Alliance influence your catches? (the amount of fish per season)	
2. To what extent has the process of establishing a FR and being part of the Alliance influence your income?	
3. To what extent has the process of establishing a FR and being part of the Alliance influence the coops access to funding?	
4. To what extent has the process of establishing a FR and being part of the Alliance influenced your cooperative's finance?	
5. To what extent has the process of establishing a FR and being part of the Alliance influenced your assets?	
6. To what extent has the process of establishing a FR and being part of the Alliance influenced the coops infrastructure?	

6. Efficiency of the process

	Score
1. To what extent do you feel the Alliance has impacted your understanding of the norm 049?	
2. To what extent do you feel the Alliance has contributed to the process of developing a technical study to establish a FR?	
3. To what extent do you feel the Alliance has involved you in choosing the site of a FR?	
4. To what extent do you value the workshops provided by the Alliance?	
5. When establishing a FR, to what extent do you feel the Alliance has facilitated your participation?	
6. To what extent do you feel the Alliance has prepared your cooperative for monitoring FR?	

7. Overall Cost-benefit

1. Overall, what are the major costs of having a FR and being part of the Alliance?	
2. Overall, what are the major benefits of having a FR and being part of the Alliance?	

Interpretation of scores: -10: the costs far outweigh the benefits; 0 the costs and benefits are about the same; 10: the benefits far outweigh the costs"

	Score
3. To what extent do the benefits outweigh the costs of being part of the Alliance?	
4. To what extent do the benefits outweigh the costs of having a FR? -10: the costs far outweigh the benefits	

8. Objective Value

		Nº of coins
We are going to give you 100 coins that represent 100 pesos. Please divide the pesos into 3 piles based on how you value ecological, social, and economic objectives of the FR. Please use all the coins you are given.	Ecological	
	Social	
	Economic	

9. General questions

1. How do you see the FRs 10 years from now?	
2. What do you envision for the Alliance 10 years from now?	

	Score
3. If the Alliance did not exist what is the likelihood your cooperative would establish a FR?	

Appendix B: NGO Surveys

General Instructions

Thank you for taking part in this survey. Your participation is much appreciated and will help inform our ongoing research into the implementation of Fish Refuges within the Quintana Roo region in Mexico.

We understand that as a member of the Kanan Kay Alliance (Alliance), there are many mutual benefits and challenges associated with your organization's participation with the alliance. For the purposes of our research and this survey, we kindly ask you to please only consider the cost and benefits directly associated with the implementation of the Fish Refuges in the Quintana Roo region. Your responses are confidential and will only be used for the purposes of our research. Thank you!

In this survey we are going to ask you about your perception of Fish Refuges implemented through the Kanan Kay Alliance. We are going to be using a continuous scale that goes from "Extremely Negative" at -10 to "Extremely Positive" at 10 or "indifferent" at 0 in the center (see figure below). Answers to questions alternate from open-ended (OE) to scale system (SS). When using the scale system, please answer using the numbers on your keyboard. Make sure to add a negative sign when needed.

Examples using the scale system:
A. To what extent do you appreciate eating lobster? (Answer: SS): 8
*This means I very positively value eating lobster.

B. To what extent do you value going to the cinema? (Answer: SS): 0
*This means I am indifferent towards going to the cinema to watch a movie

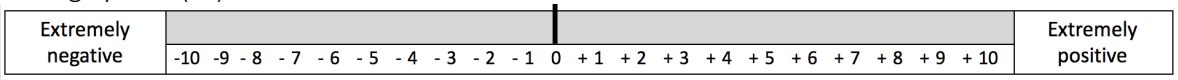
C. To what extent do you value riding a bike? (Answer: SS): - 4
*This means riding a bike has a negative impact on me.

Example using Open Ended answers:
A. Name 3 benefits of putting on sunscreen (Answer: OE):
1. Protects you from getting burned.
2. Protects against skin cancer.
3. Protects against early-aging.

Each question will clearly state how to answer, using OE or SS, accordingly.
YOUR ANSWERS TO OE CAN BE WRITTEN IN SPANISH.

* Required

Scaling System (SS)



Date *

Insert answer

Name of your Organization *
Insert answer

1. General Information

All the answers to this section are open-ended (OE)

1. Please indicate what are the overall objectives of your organization? *
Insert answer

2. Number of years your organization has been part of Kanan Kay Alliance (Alliance)? *
Insert answer

3. Number hours per week on average your organization spends working on Alliance goals (Establishing FR, capacity building workshop, meetings, etc.)? *
Insert answer

4. Are any of the organization's employees part of the coordinating committee of the Alliance? If so, how many and which roles? *
Insert answer

2. Objectives and Motivation

1. You are given 100 points, please divide your points based on how your organization values ecological, economic, and social aspects of creating a FRs. Please clearly state: Ecological= xx, Social= xx and Economic =xx (note the three point allocations must total to 100) *
Insert answer

2. Considering your organization's mission, what are the main objectives of creating FRs? (Please state three in order of importance)?(Answer: OE) *
Insert answer

3. To what extent have these objectives been achieved? (Answer: SS) *
Insert answer

4. To what extent does your organization value FRs? (Answer: SS) *
Insert answer

5. List the FRs your organization has helped establish. (Answer OE) *
Insert answer

6. For each FR your organization has helped establish, please describe the reasons why these sites were selected? (Answer: OE) *
Insert answer

3. Ecological Impacts

All the questions in this section must be answered using the scale system: continuous scale from extremely negative -10 to extremely positive 10

1. To what extent have FRs impacted the overall ecosystem health of Mexico's Mesoamerican Reef? (Answer: SS) *

Insert answer

2. To what extent do you think FRs have influenced species diversity in the ecosystem? (Answer: SS) *
Insert answer

3. To what extent do you think FRs have influenced the abundance of species present in the ecosystem? (Answer: SS) *
Insert answer

4. To what extent do you think FRs have influenced species size (ie: length, weight, etc.) (Answer: SS) *
Insert answer

5. To what extent do you think FRs will contribute to overall ecosystem health in 10 years? (Answer: SS) *
Insert answer

4. Social Impact

All the questions in this section must be answered using the scale system: continuous scale from extremely negative -10 to extremely positive 10

1. To what extent does the process of establishing FRs and being part of the Alliance influence the objectives of your organization? (Answer: SS) *
Insert answer

2. To what extent does the process of establishing FRs and being part of the Alliance influence your organization's collaboration with other member organizations? (Answer: SS) *
Insert answer

3. To what extent has the process of establishing FRs and being part of the Alliance influence your organization’s relationship with fishing cooperatives? (Answer: SS) *
Insert answer

4. To what extent has the process of establishing FRs and being part of the Alliance influence your organization’s relationship with governmental agencies? (Answer: SS) *
Insert answer

5. To what extent has the process of establishing FRs and being part of the Alliance helped you understand/gain knowledge about the Mesoamerican Reef system? (Answer: SS) *
Insert answer

5. Economic Impact

Questions in this section alternate from scale system (SS) and open ended (OE).

Scale System: continuous scale from extremely negative -10 to extremely positive 10.

1. To what extent has the process of establishing FRs and being part of the Alliance influence your organization's access to funding? (Answer: SS) *
Insert answer

2. Has the Alliance influenced and/or affected how much funding your organization allocates to achieve your organization's goals? *
Yes
No

3. Indicate in what areas and briefly explain how. (Answer: OE) *
Insert answer

4. How much funding does your organization allocate to the Alliance and FRs related activities on a yearly basis, including administrative costs? (Answer: OE) (Please clearly state: Alliance= xx and FR= xx) *
Insert answer

6. Efficiency of the Process

All the questions in this section must be answered using the scale system: continuous scale from extremely negative -10 to extremely positive 10

1. To what extent do you feel the Alliance works effectively in implementing FRs? (Answer: SS) *
Insert answer

2. To what extent do you think the Alliance has enhanced the process of creating FRs? (Answer: SS) *
Insert answer

3. To what extent do you value the Alliance's general assembly? (Answer: SS) *
Insert answer

4. Please explain your response to question 3. *
Insert answer

5. Do you participate in workshops provided by Alliance for the fishing cooperatives? *
Yes
No

6. If yes, to what extent do you value the workshops provided by Alliance? (Answer: SS)
Insert answer

7. Overall Cost-Benefit

Questions in this section alternate from scale system (SS) and open ended (OE).

Scale System: continuous scale from extremely negative -10 to extremely positive 10.

1. What are major costs for your organization associated with creating FRs and being part of the Alliance? (Answer: OE) *
Insert answer

2. What are the major benefits for your organization associated with the creation of FRs and being part of the Alliance? (Answer: OE) *
Insert answer

3. To what extent do the benefits outweigh the costs of being part of the Alliance? (Answer: SS) (-10: the costs far outweigh the benefits; 0: the costs and benefits are about the same; 10: the benefits far outweigh the costs) *
Insert answer

8. General Questions

1. What do you envision for FRs 10 years from now? (Answer: OE) *
Insert answer

2. What do you envision for the Alliance 10 years from now? (Answer: OE) *
Insert answer

3.Why is your organization part of the Alliance? (Answer: OE) *
Insert answer

4. If the Alliance did not exist, what is the likelihood your organization would participate in establishing FRs? (Answer: SS) *
Insert answer

Appendix C: Funder Survey

General Instructions

Thank you for taking part in this survey. Your participation is much appreciated and will help inform our ongoing research into the implementation of Fish Refuges within the Quintana Roo region in Mexico.

We understand that as a member of the Kanan Kay Alliance (Alliance), there are many mutual benefits and challenges associated with your organization's participation with the alliance. For the purposes of our research and this survey, we kindly ask you to please only consider the cost and benefits directly associated with the implementation of the Fish Refuges in the Quintana Roo region. Your responses are confidential and will only be used for the purposes of our research. Thank you!

In this survey we are going to ask you about your perception of Fish Refuges implemented through the Kanan Kay Alliance. We are going to be using a continuous scale that goes from “Extremely Negative” at -10 to “Extremely Positive” at 10 or “indifferent” at 0 in the center (see figure below). Answers to questions alternate from open-ended (OE) to scale system (SS). When using the scale system, please answer using the numbers on your keyboard. Make sure to add a negative sign when needed.

Examples using the scale system:
A. To what extent do you appreciate eating lobster? (Answer: SS): 8
*This means I very positively value eating lobster.

B. To what extent do you value going to the cinema? (Answer: SS): 0
*This means I am indifferent towards going to the cinema to watch a movie

C. To what extent do you value riding a bike? (Answer: SS): - 4
*This means riding a bike has a negative impact on me.

Example using Open Ended answers:
A. Name 3 benefits of putting on sunscreen (Answer: OE):
1. Protects you from getting burned.
2. Protects against skin cancer.
3. Protects against early-aging.

Each question will clearly state how to answer, using OE or SS, accordingly.
YOUR ANSWERS TO OE CAN BE WRITTEN IN SPANISH.

* Required

Email address *
Your email

Scaling System:

Extremely negative	-10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5 +6 +7 +8 +9 +10	Extremely positive

Date *
Insert answer

Name of your organization: *
Insert answer

Main location of your organization: *
Insert answer

1. General Information

Answers to this section are open-ended (OE)

1. Please indicate what is the overall objective of your organization? (Answer: OE) *
Insert answer

2. How long has your organization been allocating funds to marine conservation initiatives in Quintana Roo? (Answer: # of years) *
Insert answer

3. How long has your organization been part of the Kanan Kay Alliance (Alliance)? (Answer: # of years) *
Insert answer

2. Objectives and Motivation

1. You are given 100 points, please divide your points based on how your organization values ecological, economic, and social aspects of creating FRs. Please clearly state: Ecological= xx, Social= xx and Economic =xx (note the three point allocations must total to 100) *
Insert answer

2. What are the objectives of your organization in regard to supporting the creation of FRs in the Quintana Roo region? (Please state 3 in order of importance) (Answer: OE) *
Insert answer

3. To what extent does being part of the Alliance help your organization achieve these objectives?(Answer: SS) *
Insert answer

4.To what extent does your organization value FRs? (Answer: SS) *
Insert answer

3. Ecological, Social and Economic Impacts

All the questions in this section must be answered using the scale system: continuous scale from extremely negative -10 to extremely positive 10

1. To what extent have FRs impacted the overall ecosystem health of Mexico's Mesoamerican Reef? (Answer: SS) *

Insert answer

2. To what extent do you think FRs have impacted your overall relationship with other Alliance members? (Answer: SS) *
Insert answer

3. To what extent have FRs impacted your organization's overall yearly budget, in regard to meeting objectives? (Answer: SS) *
Insert answer

4. To what extent does your relationship with the Alliance and involvement with the established FRs influence the amount of funds designated for the Quintana Roo area? (Answer: SS) *
Insert answer

5. What percentage of your total yearly grant funding is allocated to FRs in Quintana Roo? (Answer: OE) *
Insert answer

6. What percentage of your total yearly grant funding is allocated to the Alliance (including any organizations, group, or activity related to Alliance)? (Answer: OE) *
Your answer

4. Efficiency of the Process

All the questions in this section must be answered using the scale system: continuous scale from extremely negative -10 to extremely positive 10

1. To what extent do you feel the Alliance has provided a platform for your organization to reach its goals? (Answer: SS) *
Insert answer

2. To what extent do you feel the Alliance works effectively in implementing FRs? (Answer: SS) *
Your answer

5. Overall Cost-Benefit

1. What are major costs for your organization associated with creating FRs and being part of the Alliance? (Answer: OE) *
Insert answer

2. What are the major benefits for your organization associated with the creation of FRs and being part of the Alliance? (Answer: OE) *
Insert answer

3. To what extent do the benefits outweigh the costs of being part of the Alliance? (Answer: SS) (-10: the costs far outweigh the benefits; 0: the costs and benefits are about the same; 10: the benefits far outweigh the costs) *
Insert answer

6. General Questions

1. Do you fund other marine conservation projects elsewhere? *
Yes
No

2. If yes, how do the implementation of FRs through the Alliance compare in effectiveness and costs? (Answer: OE) (If your answer above was No, please write NA) *
Insert answer

3. What do you envision for FRs 10 years from now? (Answer: OE) *
Insert answer

4. What do you envision for the Alliance 10 years from now? (Answer: OE) *
Insert answer

5. Why is your organization part of the Alliance? (Answer: OE) *
Insert answer

6. If the Alliance did not exist what is the likelihood your organization would contribute to initiate the implementation of FRs? (Answer: SS) *
Insert answer

Appendix D: Preliminary Bio-Economic Model to assess costs and benefits of a Fish Refuge

Methods

We adapted a deterministic model, based on logistic growth, with additional terms to simulate movement of the target specie between parcels, as well as the effect of fishing / not fishing. The model is single species, non-age structured, and is closed to emigration and immigration of organisms from the modeled area. The spatial configuration of the fishery is modelled through a matrix of *m x n* parcels of equal size connected by organism movement. The movement is wrapped at the edges of the modelled area (Ovando et al., 2016).

The general model equation is:

$$N_{i,j,t+1} = N_{i,j,t} + N_{i,j,t} r \left(1 - \left(\frac{N_{i,j,t}}{K}\right)\right) - U_{i,j,t} + M_{i,j,t} - E_{i,j,t}$$

Where:

- $N_{i,j,t}$ = Number of extractable lobsters in parcel *i, j* at time *t*
- r = Population growth rate
- K = Parcel carrying capacity
- $U_{i,j,t}$ = Number of lobsters extracted from parcel *i, j* at time *t*
- $M_{i,j,t}$ = Number of lobsters migrating into parcel *i, j* at time *t*
- $E_{i,j,t}$ = Number of lobsters migrating out of parcel *i, j* at time *t*

The movement of the organisms is calculated as shown in the following formulas:

$$U_{i,j,t} = uN_{i,j,t}$$

$$E_{i,j,t} = m\left((1 - u_{i,j,t})N_{i,j,t}\right)$$

$$M_{i,j,t} = \left(\frac{m}{4}(1 - u_{i,j,t})\right)\left(N_{i-1,j,t} + N_{i+1,j,t} + N_{i,j-1,t} + N_{i,j+1,t}\right)$$

Where:

- u is the proportion of lobsters captured each year
- m is the proportion of the lobsters that move out of a parcel each year

For calculating profits of the fishery we used the following formulas:

Within the model, total catches at time can then be derived from $U_{i,j,t}$ and calculated as:

$$C_t = \sum_{i=1}^{m}\sum_{j=1}^{n} u_{i,j,t}N_{i,j,t} = \sum_{i=1}^{m}\sum_{j=1}^{n} U_{i,j,t}$$

And profits can be calculated as:

$$R_t = C_t p - c$$

Where:

- C_t represents catches at time *t*
- R_t represents profits at time *t*
- p is equal to the price of a lobster
- c is the cost of fishing in a year

Total profits were calculated by:

$$\sum_{t=0}^{t=50} \frac{C_t p - c}{(1+\delta)^t}$$

This model assumes that organisms are recruited once a year, with no age or size structure, and that populations grow after movement and fishing has occurred. The model is designed for a closed population. There is an assumed homogeneous distribution of target species within parcels and fishing mortality is constant throughout parcels (except for those assigned as Fish Refuge where fishing mortality is 0). For calculating profits, we assume that the fishery from our case study is not large enough to control the market, and set price and costs are constant through time and independent of stock size.

We applied the model to the lobster fishery in Banco Chinchorro, QR. To retrieved the necessary parameters for the model we did an in-depth literature search for studies on lobster fishery stock status and related biological parameters for this region. The search resulted in at three studies focusing on lobster population in the Banco Chinchorro Biosphere Reserve (Ramírez-Estévez et al., 2010; Ley-Cooper and Chavez, 2009) and the Sian Ka'an Biosphere Reserve (Ley-Cooper et al., 2013). SAGARPA (2012) and Sullivan (2012) provided an overall description of the status of the lobster fishery while other studies focused on lobster recruitment, settlement, and movement patterns (Butler et al., 2009, Fourzan-Briones et al., 2008, and Lozano-Alvarez & Fourzan-Briones, 1991).

Mexico's Secretariat of Fisheries describes the lobster stock in 2012 as being at its "maximum sustainable use" based on lobster C_{max} of 517 tons of tail for the Quintana Roo fishing region (SAGARPA, 2012). Sullivan (2012) reports the Mexican Caribbean spiny lobster stock status is of moderate concern based on Seafood Watch scoring system and the fishing mortality exploited at MSY as reported by the FAO (2011).

However, Ley-Cooper and Chavez (2009) conducted a bio-economic model or Caribbean spiny lobster in the Banco Chinchorro atoll to reconstruct the fishery using stock biomass, age structure, and socio-economic indicators to diagnosis the lobster fishery with in a slightly overexploited status post- 1994.

Using Ley-Cooper and Chavez (2009) study of Banco Chinchorro atoll, the following parameters were sourced and used as inputs into our model.

Table 1: Parameters used as input for the bio-economic model.

Parameter	Unit	Description
Fishing Mortality	0.21	F per year
Catch	30,915	In Kg. Catch for year 2004-2005 (30.9 ton)
Price		$25.42 USD/Kg. Consumer Index applied
Initial Biomass	147,214	In Kg. Catch/F
Carrying Capacity	428,000	In Kg. Estimated based on F_{MSY} and corresponding yield (32.1 tons)
Initial Population	147,214	Per parcel

Ramírez-Estévez et al. (2010) conducted studies on juvenile lobster growth, movement, and prevalence of PaV1 virus in the Banco Chinchorro region. Movement rate of tagged lobsters averaged at 215 meters between 21 and 245 days. Thus, on average, lobsters move 579 meters per year.

Preliminary Results

No Fish Refuge Scenario

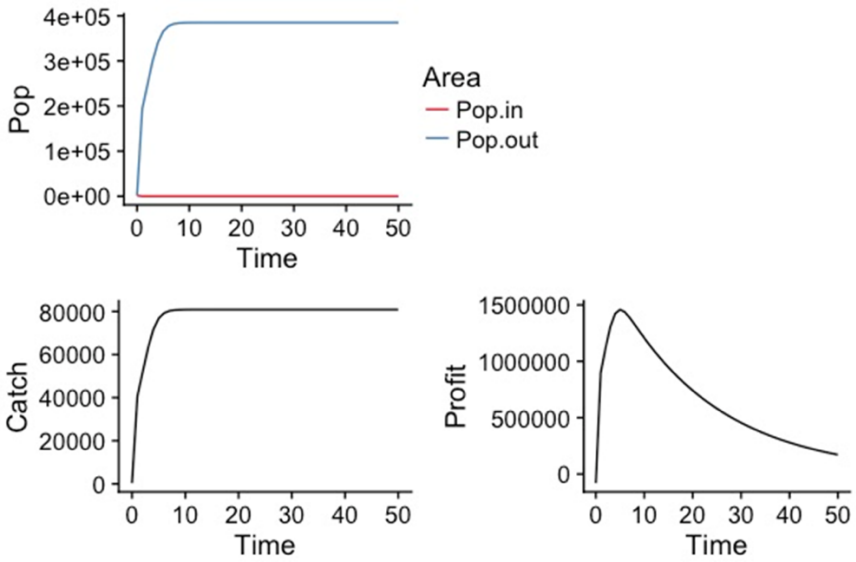


Figure A1. Results of model in a No-Fish Refuge scenario. Top left graphs shows the population in the patch. Bottom left shows expected catches in time and bottom right total profits.

Fish refuge 10% of the area, simulating Banco Chinchorro's concession with FR.

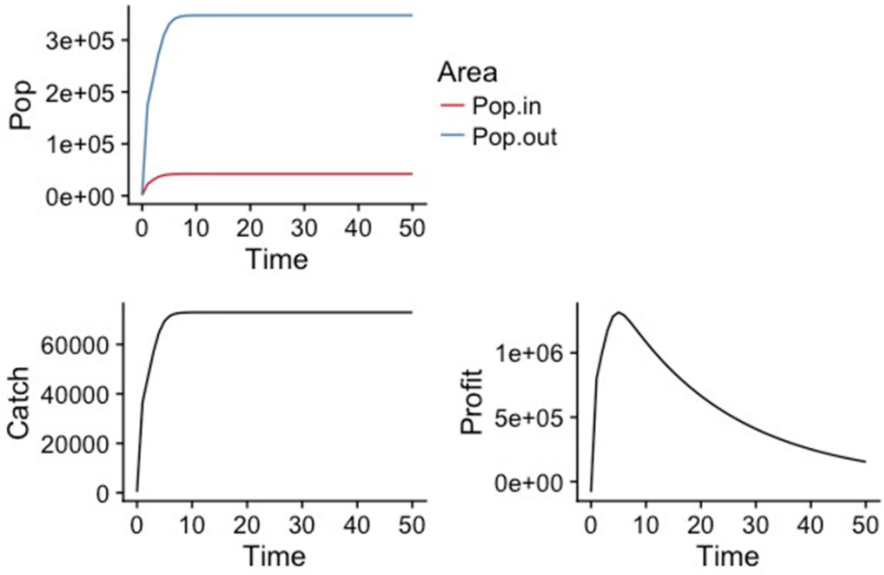


Figure A2. Results obtained by the model when 10% of the concession is set to be a FR. Top left graphs shows the population in the patch. Bottom left shows expected catches in time and bottom right total profits.

Appendix E: Extended Version of Manual

[SEE ATTACHED FILE]

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