A Spark for Collective Action: Challenges and Opportunities for Self-governance in Temporary Fisher-designed Fish Refuges in Mexico

by

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Dissertation submitted in partial fulfillment of
the requirements for the degree of Doctor of Philosophy
in Marine Science and Conservation
in the Graduate School of Duke University

2020

ABSTRACT

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Abstract

Despite decades of study, the question of how to achieve sustainable small-scale fisheries is unresolved. Because small-scale fishing is diverse and hard to control, one management approach places fishers at the center of decision-making. Common-pool resource theory has assembled a large body of evidence that resource users, without top-down state control, are able to devise and enforce rules that lead to long-term sustainable resource harvest. The social and ecological characteristics ("design principles") are well known for systems where this collective action is predicted to emerge and persist in the absence of top-down control. However, it is poorly known what precipitates collective action when some design principles are absent. This dissertation draws insights about this question from a seemingly successful case from Baja California Sur, Mexico, where fishers have voluntarily created no-fishing areas ("Fish Refuges" or "Zonas de Refugio Pesquero") in collaboration with the government fisheries agency and a non-governmental organization, Niparajá, in the absence of several design principles. This work is based on an in-depth study of these Fish Refuges including 180 days in the field from 2016-2018, participant observation, informal interviews, journaling, and semi-structured interviews (n=66). First, I argue that collective action was possible because stakeholders had three competing visions about what the Fish Refuges were, each associated with criteria and evidence of whether the

Fish Refuges were effective, which allowed different actors to imagine the Fish Refuges in alignment with their needs and worldview. This implies that policy flexibility to accommodate competing goals and evaluation criteria could facilitate collaboration for fisheries management between fishers and government agencies. Second, I argue that fishers' knowledge was integrated in a process that did not recognize its legitimacy because fishers had decision-making power at the design phase. In contrast to previous work documenting failed knowledge integration, this work implies that policies may be able to integrate multiple knowledge systems through dynamic hybridization, wherein different groups of stakeholders (including fishers) have decision-making power at different steps, and can draw on their own knowledge systems. Third, I argue that a property rights regime change away from *de facto* open access was possible because fishers traded narrow formal harvesting rights for broad informal management rights, closing a fishing area to gain government trust and partnership. This work implies that insecure, unofficial, and tenuous property rights may be a first step of property rights regime change to achieve sustainable fisheries. In conclusion, bottom-up approaches to fisheries management may benefit from processes where different stakeholders can define the goals and methods used, and draw on their own knowledge systems to assess success. Shifts away from open access may be precipitated when fishers demand decision-making rights, even if these rights are tenuous.

Dedication

For A. Hudson Weaver, whose vision, energy, and action made this study possible, and whose friendship made this study fun.

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1. Introduction

1.1 Overview

The message from global syntheses seems clear: fisheries are in decline, and managing them sustainably is a wicked problem with no single policy solution (Jentoft and Chuenpagdee 2009; Pauly et al. 2002; Worm et al. 2009). However, seen from the water, many case studies offer a more hopeful picture: fishers working together to manage their fisheries sustainably, often for decades or centuries (Gelcich et al. 2006; McCay and Acheson 1987). Insights from collective action in fisheries has been a major building block of common-pool resource theory (Ostrom 2005; Ostrom 2002; Ostrom et al. 1994), a body of scholarship concerned with natural resource management led by the resource users themselves, when resources are held in common rather than privately owned (Boettke and Aligica 2009).

There is a large body of evidence that resource users are likely to design rules associated with sustaining these common-pool resources when particular conditions are present, like sharing a common understanding of the resource (Cox et al. 2010; Ostrom 1990). One area of active research is understanding how transitions might occur when some of these conditions are not present (Gari et al. 2017). In-depth case studies provide an excellent way to gain insight into the characteristics of these processes, what they look like, and how they are perceived by the actors involved in them (Poteete et al. 2010). This dissertation discusses lessons from a case in Mexico where there was a

governance transformation over ten years (2009-2018) from effectively open access conditions towards collaborative management between fishers, a non-governmental organization (NGO), and a government agency. While the ultimate goals of governance transform were ecological (i.e., to rebuild declining fish stocks), this process did not design the policy according to ecologically optimal characteristics. Rather, this process prioritized fisher decision-making, with the aim to build long-term collaboration between fishers and the government agency responsible for managing fishing.

In this dissertation, I describe how collective action was possible despite substantial barriers between these three sets of diverse actors: fishers, the NGO, and the government agency. This work contributes to several debates about barriers to collaborative management, relating to divergent objectives (Chapter 2); incompatible knowledge systems (Chapter 3); and the assignation of roles and responsibilities (Chapter 4). This work addresses gaps in common-pool resource theory through intersection with the fields of Science and Technology Studies (STS) and Political Ecology, engaging the concepts of co-management, boundary objects, local ecological knowledge, and property rights.

A major contribution of this work is that a common understanding – one of the characteristics associated with the emergence of endogenous collective action for sustainable resource management (Ostrom 1990) – may not be necessary for collaboration between diverse actors to sustain the commons. Indeed, differing

understandings about the objectives and approaches for management seemed to accommodate the needs of different actors and facilitate collective action. Similarly, differing knowledge systems (including fishers' experiential knowledge, which fisheries management often considers as less objective or true than fisheries science) were not blended but were rather separately accommodated through a dynamic decision-making process, where fishers had a key role in policy design early on. Through their collaboration with an NGO that prioritized fisher decision-making, fishers were able to drive governance transformation by giving up some fishing rights in order to gain management and exclusion rights to their broader fishing area.

1.2 Theoretical background

1.2.1 Definition of key terms

I use several terms throughout this dissertation that have contested or variable meanings. Below I define these terms as I use them and briefly describe their relevance to this study. Their relationship to key concepts and the scholarly literature is described later in the introduction.

Co-management. There is evidence linking certain types of co-management with improved outcomes in small-scale fisheries where top-down (i.e., centralized or state-led) or bottom-up (i.e., community-based or user-led) approaches have led to fisheries decline (Cisneros-Mata 2010; Finkbeiner and Basurto 2015; Jentoft 1989). Co-

management has been basically defined as joint management by resource users and the State (Carlsson and Berkes 2005), but it is a broad term. Natural resource co-management encompasses a large range of power-sharing governance arrangements between private and public actors, including resource users, central governments, local governments, non-governmental organizations, and private companies. In this dissertation, I consider power sharing as including both formal (*de jure*) and informal (*de facto*) sharing of governance tasks, such as decision-making, monitoring, enforcement, and conflict resolution (Finkbeiner and Basurto 2015). With regards to fisheries in particular, co-management is so broad as to include token consultation or manipulation of fishers by managers in a mostly top-down arrangement, as well as fisher-created management plans that receive government endorsement in a mostly bottom-up arrangement (Finkbeiner and Basurto 2015). Part of the goal of this dissertation is to generate insights about the particular characteristics of co-management processes that facilitate collective action in implementation and adaptation.

Institution. I define institutions as formal and informal rules and norms that structure human behavior in repeated interactions through consistent and predictable ways (Ostrom 2005). This definition is the primary one used in common-pool resource theory, the theoretical framework of this dissertation, which is approximately aligned with the definition of institutions in new institutionalism and new institutional economics (Boettke and Aligica 2009).

Self-governance. I define self-governance as exercise of the dominant functions of regulation by members of a group without significant intervention from an external authority. In this category I include *de facto* self-governance, wherein the governing functions performed by external authorities may exist in legal documents but in practice are ineffectual. Governance here includes all formal and informal tasks of governing, including but not limited to those of government.

Sustainability. This dissertation is broadly concerned with the management of small-scale fisheries, which often has a number of objectives including poverty alleviation, food security, livelihoods, culture, wellbeing, and commercial income (Allison and Horemans 2006). Some, but not all, of these objectives depend upon the long-term persistence without decline of particular fish stocks and the ecosystems that maintain them, which I define as resource sustainability. In some places to increase readability, I refer to this simply as 'sustainability'. In this dissertation, I also refer to the sustainability of institutions for the self-governance of fisheries, defined as the persistence and as necessary adaptation of social-ecological systems to maintain systems of rules (e.g., through belief, enforcement mechanisms, etc) in the long-term. 'Sustainability' is a normative term both in society and in the literature this dissertation contributes to, and is often interpreted as a desirable outcome of resource management. However, within this dissertation, I recognize that sustainability does not serve all actors equally, and is not always the primary objective for resource users (Fabinyi et al. 2015).

1.2.2 Theoretical Framework: Common-pool resource theory

A major concern of natural resource management has been the perceived challenge of sustaining the commons, such as fisheries. Commons are resource systems where there are no clearly established private property rights (Anderies and Janssen 2016), and may include common-pool resources: resources that are subtractable (i.e., one person's use of it subtracts from the total available) but not excludable (i.e., it is challenging to prevent others from using it) (Schlager 2002). Economic models from the mid-1900s first popularized the "tragedy of the commons" concept, which predicted inevitable overharvesting and collapse of the commons in the absence of external management interventions (Gordon 1954; Hardin 1968). These models identified several perverse incentives that make the commons prone to overuse and decline: for example, users individually receive all the benefit of the resources they harvest, while losing only a fraction of potential future harvest proportional to the size of the group (Hardin 1968). These models thus predicted that commons like fisheries and pastures would collapse when managed by the resource users dependent on them ('the fox guarding the henhouse') (Gordon 1954; Hardin 1968).

In the decades since, many case studies have been published wherein self-governance has led to long-term sustainable harvesting of common pool resources in the absence of strong state control (McCay and Acheson 1987; Ostrom 2005; Ostrom 2002).

In many of these cases, resource users created institutions (formal and informal rules) through collective action and voluntary compliance, which in economic language effectively changed their incentives and thus avoided the trap of the 'tragedy of the commons' (Ostrom 1990; Ostrom 2005; Ostrom 2002). In addition to numerous case studies, another line of evidence that resource users can sustainably manage their own resources comes from economic experiments and economic games (Ostrom et al. 1994; Poteete et al. 2010). In simulated games involving undergraduates in labs (Ostrom et al. 1994; Poteete et al. 2010) and also resource users in field settings (Cardenas and Carpenter 2008), the tragedy of the commons often occurs when users are anonymous and cannot communicate; however, when they can communicate and establish even informal norms, they often harvest at near optimal levels for long-term resource maintenance (Ostrom et al. 1994).

Rooted in these two lines of evidence, common-pool resource theory has coalesced around the question of when and how common-pool resources are managed sustainably (Boettke and Aligica 2009). A major contribution has been the identification of characteristics associated with the emergence and maintenance of institutions associated with long-term sustainable resource harvest (Baland and Platteau 1996; Netting 1976; Ostrom 1990; Wade 1989). Elinor Ostrom first proposed eight characteristics (such as the existence of a resource monitoring system) based on cases I analyzed of long-enduring self-governance of the commons ("design principles")

(Ostrom 1990), and meta-analyses have since supported the statistical association of these design principles with resource sustainability in self-governing systems (Cox et al. 2010; Stern 2011). Another set of characteristics of resource systems and resource users have been linked to the emergence of collective action to manage the commons, such as a common understanding between resource users of the resource and of the benefits of developing rules to manage it (Ostrom 2003; Schlager 2004).

What is less well known is how collective action to govern the commons can emerge when some of these characteristics are absent – that is, in systems where common-pool resource theory would not predict the emergence of collective action among resource users to develop rules to sustain their commons (Ostrom 2003; Schlager 2004). For these systems, one outstanding question is whether there are external processes or policies that can support or spark collective action among relevant stakeholders (Ostrom 2002).

Some scholars have suggested that co-management – power sharing between states and resource users, and increasingly also involving other actors like non-governmental organizations (NGOs) – could take advantage of the strengths of each resource users and states in natural resource management (Armitage et al. 2010; Marschke et al. 2012; Plummer et al. 2012), particularly in the management of common-pool resources like fisheries (Finkbeiner and Basurto 2015).

1.2.3 Theoretical intersections with co-management

Co-management is dependent on collective action among resource users, as is studied by common-pool resource theory, but, in its idealized form, has complementary support from public policies and state enforcement (Armitage 2005; Armitage et al. 2010; Plummer et al. 2012). Co-management is a broad concept. The most basic definition of co-management includes all governance arrangements with formal or informal power-sharing, and thus effectively includes most community-based natural resource management schemes, which are typically nested in higher governance structures from central governments (Pomeroy and Berkes 1997). One thing that unites co-management is that it depends upon collective action between diverse actors, such as resource users, central government officials, local government officials, non-governmental organization staff, scientists, and local stakeholders who are not resource users (Adger et al. 2005). There is heterogeneity within these actor groups (Agrawal and Gibson 1999), who often operate at different and/or multiple levels (e.g., local, regional, state, and national) (Adger et al. 2005).

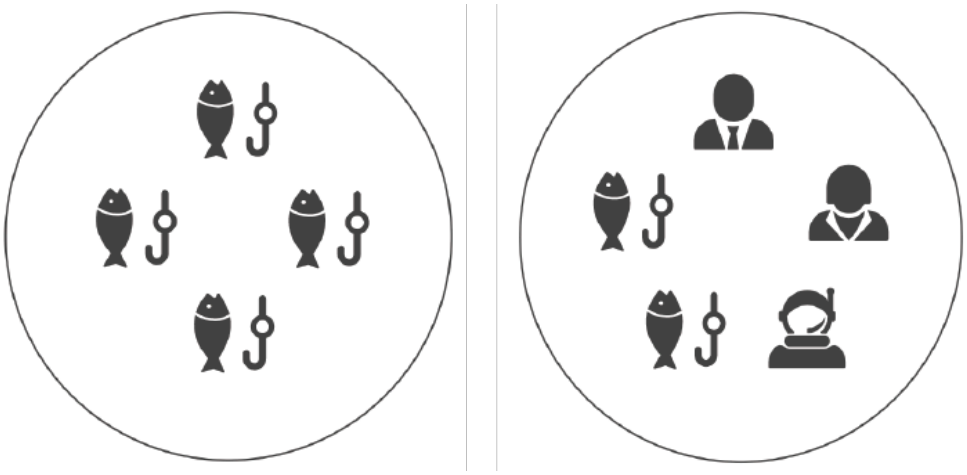

Figure 1: Comparison of idealized collective action in self-governance (left) and co-management (right), in the context of fisheries management

The need for collective action between diverse stakeholders has meant that there are a number of tensions inherent to co-management (Gelcich et al. 2006; Nadasdy 2007; Plummer 2009; Pomeroy et al. 2001). I discuss three tensions in this dissertation: differing objectives (Chapter 2), differing knowledge systems (Chapter 3), and the challenge of delegating roles and responsibilities (Chapter 4).

The first tension of co-management relevant to this dissertation is that diverse stakeholders may have different conceptualizations about what management is needed or desirable, as well as what they consider appropriate objectives and approaches for this management (Jeanrenaud 2002). This can create problems because one of the characteristics associated with 'successful' co-management is the joint development of and agreement to objectives among stakeholders, as well as conflict-resolution mechanisms to resolve differences (Pomeroy et al. 2001). However, in many small-scale fisheries (as in other natural resources), state objectives may be primarily concerned

with maintaining particular fish stocks, while fishers and other stakeholders may have broader objectives concerned with maintaining coastal livelihoods, food security, and cultural practices (Pascoe et al. 2014; Schwach et al. 2007). Joint development of objectives can be further hampered by a history of mistrust and power asymmetries between fishers and state agencies (Jentoft 1989), which can result in the prioritization of state objectives over those of fishers and even the manipulation of fishers (Jentoft 2000). Given this, what would 'successful' co-management look like between diverse stakeholders (particularly, between fishers and state agencies) with different understandings of the desired outcomes of and approaches to management? I address this in Chapter 2.

A second tension of co-management between diverse stakeholders is incongruence of knowledge systems – especially, that the knowledge systems used by resource users may face barriers to integration in management processes involving state scientists (Nadasdy 1999; Nadasdy 2005). A principle of co-management associated with long-term resource sustainability is respect among stakeholders for each others' knowledge (Pomeroy et al. 2001). However, fishers' knowledge may not be legible (i.e., understandable or readily usable) to government managers, many of whom depend upon standardized methods developed in fisheries science (Olsson et al. 2004). Because of power asymmetries between resource users and government actors, the integration of local knowledge in management often ends up as the cooptation of local knowledge for

managerial projects that may ultimately be against the interests of the providers of this knowledge (Nadasdy 1999; Nadasdy 2005). What are the characteristics of processes of co-management that navigate this knowledge-power to seemingly integrate fishers' knowledge? I address this in Chapter 3.

A third tension of co-management is that the allocation of rights and duties is blended and mixed, which can set up complicated incentive structures for managing resources sustainably (Ayers et al. 2018; Galik and Jagger 2015; Ostrom 2003; Ribot and Peluso 2003). Property rights theory has suggested that a long-term and secure bundle of rights including harvest, management, and exclusion rights are associated with strong incentives for sustainability (Galik and Jagger 2015; Schlager and Ostrom 1992). However, in transitions to co-management, these rights are often insecure, short-term, and/or held by different actors (Agrawal and Ostrom 1999; Coleman 2011; Marschke et al. 2012). Furthermore, under co-management schemes, the rights and duties are often unevenly distributed among actors. Resource users may consider the duties and costs of management to fall to government actors rather than themselves, particularly in places where there is a history of paternalism (Pálsson 2003). On the other hand, government actors may expect resource users to bear the majority of the cost where they perceive users to benefit most. How are property rights perceived and negotiated throughout property rights regime changes? I address this in Chapter 4.

1.2.4 Theoretical gaps and contributions of this dissertation

This dissertation broadly contributes to understanding the factors that facilitate collective action among diverse actors in natural resource co-management when the principles associated with long-term resource sustainability through collective action are not all present. Specifically, I contribute to three knowledge gaps related to tensions of collective action among diverse actors: competing objectives, differing knowledge systems, and assigning rights and responsibilities. The relevance of these gaps to co-management is described above; here I describe these gaps in further detail and briefly explain the complementary theory I draw on to address these theoretical gaps.

The first gap concerns the tension of competing or different objectives in resource co-management between diverse actors. As discussed above, different actors may have different objectives for co-management. They may even have completely different understandings of the meaning of a policy and how it is supposed to work (Corson et al. 2014). One theoretical concept for analyzing and understanding collaboration between actors with different understandings is through "boundary objects" (Star and Griesemer 1989). Boundary objects are a theoretical concept from the field of Science and Technology Studies (STS), and are defined as objects which are plastic enough to adapt to the meanings assigned to them by different actor groups, but concretely understood within each actor group (Clarke and Star 2008; Star and Griesemer 1989). Previous work has suggested that policies that act as boundary objects facilitate collaboration between

diverse stakeholders because actors can agree to implement their own interpretation of the policy without consensus on a single understanding (Abson et al. 2014; Gray et al. 2014; Lee 2007; Marheineke et al. 2016). However, it is not well understood how boundary objects mediate collaboration between actors with asymmetrical power relationships – as is often the case in co-management of natural resources between resource users (often poor, rural, and marginalized) and state officials or NGO staff (Njaya et al. 2012).

I address this gap in Chapter 2, by exploring the evolution of a boundary object policy. Unlike previous work in which boundary objects are created by powerful actors to facilitate consensus (Fujimura 1992; Lee 2007; Star and Griesemer 1989), in this case a flexibly defined policy allowed marginalized actors to re-imagine the purpose of the policy without formally changing it and without needing to negotiate with powerful actors. This work suggests that flexible policies that do not define objectives and metrics *a priori* may facilitate engagement of resource users.

The second gap concerns the tension of knowledge politics in co-management. One of the main theoretical benefits of co-management is the ability of each states and resource users to contribute knowledge to management (Carlsson and Berkes 2005). However, state agencies are often accustomed to integrating standardized scientific knowledge in decision-making (Schwach et al. 2007) but unaccustomed to integrating other types of knowledge such as the tacit and experiential knowledge of resource users

(Soto 2006). The types of information and knowledge systems that resource users in decision-making may include standardized scientific information but may also be much broader, and is often called Local Ecological Knowledge (LEK) or Traditional Ecological Knowledge(TEK) (Berkes 1999; Berkes et al. 2000). Many papers have called for greater integration of LEK and TEK in natural resource management (Adams et al. 2014; Aswani et al. 2018; Drew and Henne 2006; Jackson et al. 2014; Stephenson et al. 2016). However, given the substantial barriers to integration (Soto 2006), some scholars suggest that integration is unlikely without transforming LEK to be legible to managers (Hind 2014), and there are few well-described examples of what knowledge integration looks like (Aswani et al. 2018).

I address this gap in Chapter 3. I describe how a co-management process where different actor groups had decision-making power at different times allowed for the integration of different types of knowledge systems and different types of information. Through this process, resource users were able to draw on their broader social-ecological knowledge including experiential and tacit knowledge to inform decision-making even though this was not legible to the government agency, which only uses and recognizes standardized scientific methods. This work suggests that a dynamic decision-making process where the locus of decision-making starts with resource users facilitates the integration of multiple knowledges in co-management.

The third gap concerns the tension of assigning rights and responsibilities in co-management. When the state recognizes formal, long-term decision-making and exclusive access rights for groups of resource users, there are strong incentives for self-governance that leads to resource sustainability (Galik and Jagger 2015; Ostrom 2003; Schlager and Ostrom 1992). However, states are often reticent or unable to give up decision-making rights, enforce exclusion rights, or prioritize certain groups of resource users over others (Finkbeiner and Basurto 2015). As a result, many resources like fisheries are in de facto open access conditions, where well-defined property rights are absent (Sumaila et al. 2017). Under such open-access conditions, it is unclear how resource users can demand rights or precipitate a property rights regime change without being 'given' expanded rights. I address this gap in Chapter 4.

I describe how resource users were able to negotiate and trade property rights to drive a property rights regime change, transitioning from open access towards increased incentives for sustainability. They did this through partnership with an NGO and an extensive process of negotiation over years that demonstrated commitment to local management. Through this process the local resource users have positioned themselves as the rightful recipients of tenure over their coastal seas, over resource users from other regions and states that have historically harvested from the area. In contrast to previous work, this work suggests that property rights regime shifts can be driven from the

bottom-up (i.e., by resource users) by starting with informal, *de facto* rights and propagating into formal (legal) rights.

1.3 Study case: Mexico's Fish Refuges

To address the research gaps above, I conducted an in-depth study of the first Fish Refuges. Fish Refuges (Zonas de Refugio) are area-based tools intended to protect or rebuild fisheries in Mexico, typically through no-take zones (DOF 2014). Fish Refuges are governed differently than other area-based resource management tools in Mexico. While the majority of these are implemented by the National Commission on Protected Areas (Comisión Nacional de Áreas Naturales Protegidas, CONANP) in the Ministry of the Environment and Natural Resources (Secretaria de Medio Ambiente y Recursos Naturales, SEMARNAT), Fish Refuges are implemented by the Commission on Fishing (Comisión Nacional de Acuacultura y Pesca, CONAPESCA) in the Ministry of Agriculture and Rural Development (Secretaría de Agricultura y Desarrollo Rural, SADER; until 2019, SAGARPA). Also, Fish Refuges are typically implemented by CONAPESCA in response to demand (in the form of a formal, written proposal) from fishing organizations or fishers coordinated by non-governmental organizations. Thus, the process of creating Fish Refuges typically reflects greater power sharing and co-management than other area-based tools. Finally, Fish Refuges are typically (but not

necessarily) established for 5 years at a time before they expire, while most other area-based tools in Mexico are permanent.

While they are governed differently in many aspects, Fish Refuges share some characteristics with other marine area-based tools in Mexico, which I compare below. Mexico's Protected Areas (Areas Naturales Protegidas, ANPs) are the most prevalent area-based management tool, and aim to preserve or restore ecosystems (Koch 2015). Their legal definition as far as what is permitted within their boundaries is very vague, with the result that many Protected Areas allow extractive activities in much of their area. For example, in the Loreto Bay National Park (Parque Nacional Bahia de Loreto), fishing was allowed in more than 99% of the park until this year (Rife et al. 2013). However, resource users like fishers often view Protected Areas as threats to their long-term livelihoods, based on cases of Protected Areas that have completely banned resource harvest, or certain types of harvest, with the stated objective to restore or protect biodiversity. Contrast Protected Areas with Fishing Concessions, an area-based form of fisheries management where exclusive harvest over an area is granted to a particular fishing entity, often a fishing cooperative. The aim of Fishing Concessions is much more similar to Fish Refuges: to maintain long-term sustainable fisheries harvest. However, the mechanism of a Fishing Concession is different from a Fish Refuge: rather than using no-take zones to restore Fish Stocks, Fishing Concessions incentivize sustainable harvest through medium-term harvest and exclusion rights in a designated

area, where a given fishing entity is expected to establish its own rules to maintain a sustainable fishery. Fishing Concessions have been considered a type of Territorial Use Right in Fisheries (TURF) (McCay 2017). Fish Refuges are thus tools that look and act like Protected Areas as far as the mechanism they use to accomplish their goal, but which serve an objective that is more similar to a Fishing Concession. The table below compares three area-based resource management tools in Mexico: the Protected Area (Area Natural Protegida), the Fish Refuge (Zona de Refugio), and the Fishing Concession (Concesión) (Crespo-Guerrero and Jiménez-Pelcastre 2018; DOF 2012; DOF 2014).

Table 1: Comparison of three area-based resource management tools in Mexico: the Protected Area, the Fish Refuge, and the Fishing Concession

Name	***Protected Area***	***Fish Refuge***	***Fishing Concession***
Area-based tool	✓	✓	✓
Size (typical)	Large	Very small	Small
Duration (typical)	Permanent	5 years	20 years
Secretary	Ministry of the Environment and Natural Resources (SEMARNAT)	Ministry of Agriculture and Rural Development (SADER)	Ministry of Agriculture and Rural Development (SADER)
Legal management unit	Commission on Protected Areas (CONANP)	Commission on Fishing (CONAPESCA)	Commission on Fishing (CONAPESCA)
Legal focus	Ecosystem protection and restoration	Fisheries exploitation	Fisheries exploitation
Mechanism	Ecological: Restricted harvest; No-take areas	Ecological: No-take areas	Economic/incentives: Long-term exclusive access rights
Enforced by	CONANP	Self	Self
First legal example (contemporary form)	1917	2012	1933

Fish Refuges were first established as a legal tool for fisheries management in the national fisheries law of 2007 ("Ley General de Pesca y Acuacultura Sustentables") (DOF

2007). The law defined Fish Refuges as "Areas delimited in federal waters, with the primary aim of conserving and contributing, naturally or artificially, to the development of fishing resources through reproduction, growth, or recruitment, as well as preserving and protecting the surrounding environment" (page 6) (DOF 2007). Beyond this, the law gave little direction, mentioning Fish Refuges three times in 71 pages. This left great latitude, and great onus to demonstrate their utility, to the first Fish Refuges, which were established in 2012. Since 2012, more than 40 Fish Refuges have been established, accounting for more than 20,000 km^2. Not all Fish Refuges are equivalent. It was not until 2014 that the federal government published a 4,400-word protocol defining the purpose, mechanisms, and legal steps of Fish Refuges in Mexico. While most Fish Refuges were proposed by fishing organizations or non-governmental organizations on behalf of fishers, there are exceptions (e.g., the Gulf of Ulloa Fish Refuge). Also, while most Fish Refuges are temporary, and expire after a designated period (usually 5 years), some are permanent. Finally, while most Fish Refuges are no-take zones which prohibit all fishing activities, some are partial-take zones, allowing limited fishing activity (for example, allowing hand line fishing but no other forms). Some of these Fish Refuges were established together as a network in a single piece of legislation, as in the case I examine in this dissertation.

Table 2: Fish Refuges in Mexico, as of November 2019.

State	Name (Distinct Legal Framework)	# Fish Refuges	Total Km^2	Date established	Type
Baja California Sur	Punta Coyote to San Cosme	12	69.66	15/11/2017	11 Total Temporary 1 Partial Temporary
	Gulf of Ulloa	1	19932	6/25/18	Partial Temporary
	Isla Natividad	2	2.00	7/6/18	Partial Permanent
Quintana Roo	Espiritu Santo	8	10.49	30/11/17	Total Temporary
	Banco Chinchorro	1	122.57	31/5/19	Total Temporary
	Akumal	1	9.88	13/4/15	Partial Temporary
	Canal Nizuk	1	0.08	24/4/18	Total Permanent
	Bahia Ascension	2	32.11	23/9/16	Total Temporary
Sinaloa	Teacapan	7	3.49	3/12/14	Partial Permanent
	Bahía de Altata-Ensenada del Pabellón	1	0.02	24/4/18	Total Permanent
Sonora	Isla San Pedro Nolasco	3	1.38	12/7/17	Total Temporary
	Puerto Libertad	1	0.74	12/7/17	Total Temporary
	Bahía Jitzamuri-Agiabampo	1	0.03	24/4/18	Total Permanent

Temporary Fish Refuges have the potential to adapt to climate change by requiring the full process of renegotiation, reassessment, and re-approval every time they expire, creating the opportunity for adaptation and resilience (Armitage et al. 2010; Armitage et al. 2009; Olsson et al. 2004; Plummer et al. 2013). They are arguably the only area-based tool in Mexico that does have a high potential to adapt to climate change. Fish Refuges thus create the opportunity to answer my research question about the

property rights structure created by an area-based management tool that has the potential to adapt to climate change, within the context of Mexican fisheries. Along many indicators, Mexico is in the middle of small-scale fisheries management globally, comparable to other middle-development countries like Malaysia, the Philippines, Peru, Ecuador, and Brazil (Pitcher et al. 2009). Similar to these countries, the vast majority (97%) of fishing boats in Mexico are small-scale, less than 36 feet with an outboard motor (FAO 2003). Fisheries management is a challenge in Mexico; fisheries are in decline, poorly managed, and largely de-facto open access (Cinti et al. 2010; Finkbeiner et al. 2015; Giron-Nava et al. 2018; Sala et al. 2004). Fisheries rights accumulate in the wealthy and powerful (Basurto et al. 2012). High uncertainty caused by violence from the narcotic trade, volatility of prices, economic crises, and climate change (Micheli et al. 2012) exacerbates the management challenges created by multi-specific, data-poor, and notoriously complex fisheries (Salas et al. 2007). Managers from other countries where rule of law is low, fishing is poorly controlled by central governments, and fishing is in decline are likely to be interested in the findings from this case.

1.4 Study site: Baja California Sur, Mexico

The case of Fish Refuges that I use to answer the research objectives of this dissertation is the first-ever network of Fish Refuges created in November 2012. They were established in the northwestern Mexican state of Baja California Sur in the

"Corredor" region between San Cosme and Punto Coyote on the Gulf of California coast, north of the capital of La Paz. A map of the study region is below.

Figure 2: Map of study site, the "Corredor San Cosme to Punta Coyote" (hereafter, the Corredor), Baja California Sur, Mexico

The Gulf of California is the inland body of water that separates the Baja California peninsula from mainland Mexico, and produces 71% of Mexico's total fisheries volume (OECD 2006). The reason it is so productive is because of upwelling,

which supports huge primary productivity. Adaptation in this region is crucial, as oceanographic conditions like El Niño Southern Oscillation cause extreme fluctuations in productivity (Pérez-Brunius et al. 2006). In response, fishers distribute risk through mobility and diversification of gear, targeted species, and livelihoods (Sievanen 2014). There exists the widespread perception that fishing is in decline, with evidence of "fishing down food webs" (Basurto 2005; Sala et al. 2004) and rapidly shifting baselines in fishers (Saenz-Arroyo et al. 2005). Such is the case within the Corredor San Cosme to Punta Coyote where this study takes place, a region with 150km of coastline, 13 permanent towns, 659 residents, and 104 fishing vessels (Niparajá 2016). No paved roads serve the area, although there are some dirt roads; 40% of towns are only accessible by sea. No centralized water or electricity serves these towns, but most houses have solar panels and some towns have wells, springs, or both. Most people are dependent on fishing for their livelihoods, although there is some ranching and tourism. 91% of fishers only fish, and 95% of fishers have lived in the same place for more than 10 years (Niparajá 2015). Fishers in the region have noticed and been affected by the decline in fishing (Niparajá 2009).

The reason that the first Fish Refuges came to be established in the Corredor is because of the confluence of fisher support and strong promotion by the non-governmental organization (NGO), Sociedad de Historia Natural Niparajá A.C. (hereafter, Niparajá). Niparajá is an NGO based in Baja California Sur's capital of La Paz

dedicated to regional conservation within the state; it has four programs, one of which is Sustainable Fishing (Pesca Sustentable). The mission of this program is to foment social structures that can create and maintain rules that support long-term survival of fishing livelihoods and their associated cultural, social, and economic values. While they have some broader projects, much of their work is concentrated in the Corredor region. In 2009, Niparajá started systematic data collection on problems and proposed solutions within fisheries of the Corredor. Through a process which spanned 3 years, described below, a network of 11 Fish Refuges were finally established in 2012 in the Corredor, with a 5-year duration. In 2017, the Fish Refuges were reinstituted and expanded for another 5 years.

1.5 Overview of research methods

This study is primarily based on qualitative, in-depth data that I collected from 2016-2018 in Baja California Sur, Mexico, across the Corredor region and in the capital city of La Paz. This dissertation contributed to and was supported by a larger project studying social-ecological resilience of small-scale fishing communities and coasts in Baja California Sur called MAREA, funded by a National Science Foundation Coupled Natural-Human Systems Grant (award #1632648). Quantitative data collected for this larger project as used to contextualize the qualitative findings that I present here.

This study involved six total months of fieldwork in the Corredor that occurred during different periods between 2016 and 2018, and that included observation, informal interviews, and semi-structured interviews. In May 2016, I was invited on the annual ecological monitoring trip to assess the Fish Refuges (a 10-day scientific cruise on a liveaboard boat) coordinated by Niparajá. On this cruise I conducted preliminary interviews about monitoring and knowledge with the eight "Buzos Monitores", fishers from the Corredor trained in scientific ecological monitoring, and observed their interactions with scientists, INAPESCA staff, and Niparajá staff. From June-August 2016, I conducted in-depth interviews with these "*buzos monitores*", visiting six of them who resided in the three largest towns of the Corredor: Puerto de Agua Verde (278 residents), San Evaristo (90 residents), and Tembabiche (80 residents). For these field visits I accompanied a team of students and field technicians who were conducting Niparajá and Duke's socioeconomic survey, mentioned above, with field support from Niparajá. During these field visits in 2016, I conducted 39 semi-structured interviews with fishers (n=22), their families (n=14), INAPESCA staff (n=2), and Niparajá staff (n=1), of which 29 were recorded and transcribed (duration 16-154 minutes, 37 minutes on average). During these interviews, I asked about the role of the Buzos Monitores in management, trust in the information they produce, and the effect of the program on the participants. These interviews relate to the hybrid information used in renewal of the Fish Refuges.

From October to December 2017, a period overlapping the renewal of the Corredor Fish Refuges, I conducted three months of fieldwork in the largest town of the Corredor, Puerto de Agua Verde (hereafter, Agua Verde), with several visits to the capital city of La Paz, with regional offices for CONAPESCA and INAPESCA. During this time, I conducted numerous informal interviews, kept a field journal for observations and reflections, and conducted 26 semi-structured interviews with Corredor residents (including leaders in the fishing sector (n=2), fishers involved in different programs for ecological data collection (n=3), members (n=6) and nonmembers (n=1) of fishing cooperatives, and Agua Verde community leaders (n=8) university scientists (n=2), INAPESCA scientists involved in the Fish Refuges (n=3), CONAPESCA leadership (n=1), and Niparaja staff involved in the Fish Refuges (n=3). Of these, 25 were recorded and transcribed in full; length ranged from 31-404 minutes, averaging 79 minutes.

Because the bulk of fieldwork was conducted in one town out of the thirteen in the Corredor, albeit a town with approximately half of the Corredor's population, my conclusions are strongly influenced by the sentiments of Agua Verde residents who, in the 2016 survey, were more supportive of Fish Refuges reported seeing more positive results than fishers from other towns. While livelihoods and lifestyle is shared across the Corredor's thirteen towns, Agua Verde is different in that it has the most and largest fishing cooperatives; has the longest time working with Niparajá; and, in the 2017

renewal, was the only town to change its Fish Refuge, more than doubling its size. So, results may be more positive here than throughout the region.

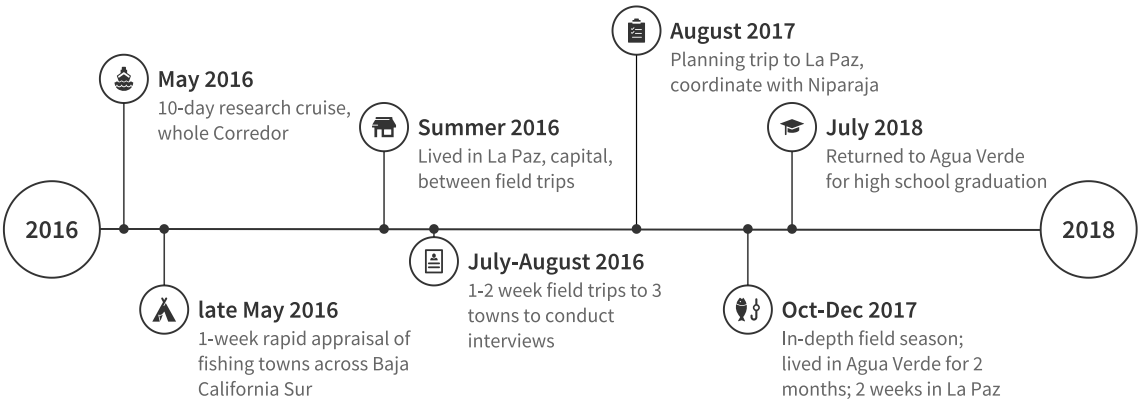

Figure 3: Timeline of major research activities I undertook for this dissertation between 2016 and 2018. Spacing not scaled to time.

In addition to the fieldwork that I conducted (observation, field notes, interviews), I also draw on the socioeconomic survey of fishers (n=102) that Niparaja and Duke conducted in 2016. A team of trained enumerators conducted this survey using pen and paper in every town in the Corredor from June to December 2016. A third of respondents were selected purposively, if they participated in a similar survey from 2009, in order to compare results; the other two-thirds were selected randomly. I also contextualize these results in the ecological data that has been collected, analyzed, and reported by Niparajá. This data includes fisheries independent data (fish and invertebrate counts along transects, statistically analyzed inside and outside the Fish Refuges) and fisheries dependent data (size, reproductive potential, and species composition measures of fish catch, collected by fishers from the Corredor, as well as

journals of catch quantity and poundage maintained by cooperative presidents and fish buyers in the Corredor).

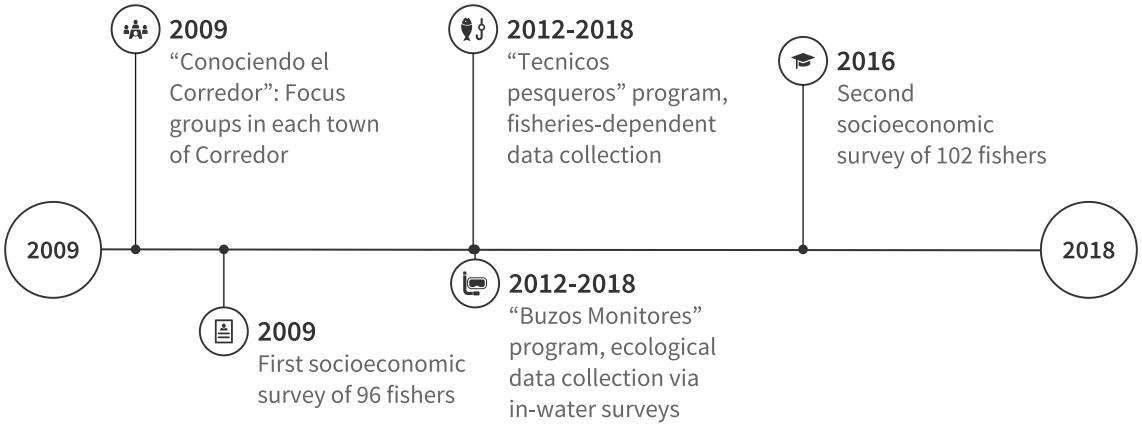

Figure 4: Timeline of contextualizing data provided by the NGO, Niparajá. Spacing not scaled to time.

1.6 Outline of the dissertation

This chapter (Chapter 1) introduced the research problems I address in this dissertation and defined the scope and purpose of the study within the theoretical framework of common-pool resource theory. Chapters 2, 3, and 4 are prepared as stand-alone manuscripts in submission or to be submitted for publication in peer-reviewed journals. As a result, there is some repetition among chapters of methods and case description. In Chapter 2, I sought to understand how different stakeholders, including fishers, government officials, scientists, and NGO staff, understood the Fish Refuges' purpose and function to be. I found that the stakeholders involved viewed the Fish Refuges through three different narratives each suggesting different evaluation criteria,

blurring the line between conservation and fisheries management. I argue that collaboration to establish Fish Refuges was possible because of disagreement about what the Fish Refuges were. This implies that policy flexibility to accommodate competing goals and evaluation criteria could facilitate collaboration for fisheries management. In Chapter 3, I sought to understand how the process of establishing Fish Refuges was able to accommodate different knowledge systems of fishers and government scientists, especially given historic barriers to integrating fishers' knowledge in management. I found that multiple types of knowledge were integrated through a process I call "ping-pong hybridization" because the decision making locus moved between stakeholders who could draw on their own knowledge systems. In Chapter 4, I sought to understand how the property rights regime was able to evolve from *de facto* open access and declining fisheries towards greater incentives for sustainability. I found that fishers were able to trade *de jure* fishing rights for *de facto* management rights, closing a fishing area to gain government trust and partnership. This work implies that insecure, unofficial, and tenuous property rights may be a first step of property rights regime change to achieve sustainable fisheries. Chapter 5 concludes the dissertation by reviewing research questions and major findings of chapters 2-4, and discusses their theoretical and practical implications.

2. Blurry definitions help cooperation: Coexistence of three narratives accommodates competing stakeholder visions for coastal co-management in Mexico

2.1 Introduction

The International Union for the Conservation of Nature (IUCN) has advanced a definition of marine protected areas (MPAs) requiring their primary objective to be conservation of nature (WCPA 2018). This definition has political consequences by informing international conservation targets, such as the Convention on Biological Diversity's Aichi Biodiversity Targets with a deadline of 2020 (CBD-COP 2010); Target 11 calls for the conservation of 10% of coastal and marine areas through marine protected areas (MPAs) and other effective area-based conservation measures (OECMs). This target has driven the expansion of MPAs and OECMs in the past decade (Campbell and Gray 2019), but there is disagreement about the extent to which this target has been met (Boonzaier and Pauly 2016). The World Database on Protected Areas currently documents over 7% coverage of the oceans by MPAs (IUCN 2020), but others count only 3.6% coverage by fully implemented MPAs (Sala et al. 2018). Even stricter definitions suggest only 2% coverage if counting only strongly or fully protected MPAs that forbid most extractive activities (Sala et al. 2018) and which are associated with the strongest biodiversity outcomes (Edgar et al. 2014; Gill et al. 2017). There is even less known about the area covered by OECMs (Garcia 2019), which one study suggests have no detectable ecological effect in any case (Donald et al. 2019). In a 2018 webinar, top IUCN and

NOAA administrators agreed on the need for a standardized, clear, and detailed MPA definition given the "confusion around the plethora of types of MPAs" (OCTO 2018). This is one reflection of attempts by experts at the International Union for Conservation of Nature (IUCN) and elsewhere to establish clear criteria (such as the conservation objective from the first sentence of this paper) for MPAs (IUCN 2012a; IUCN 2012b; WCPA 2018) and OECMs (CBD-COP 2018; Laffoley et al. 2017) aiming to increase their effectiveness at accomplishing nature conservation objectives.

One reason for this confusion is that there are divergent opinions about the best objectives and approaches for effective area-based management, and contested understandings of effectiveness (Büscher et al. 2017; Campbell and Gray 2019; Corson et al. 2014). These divergent opinions are supported by different scientific claims from different types of studies on area-based management. For example, there is some agreement among meta-analyses and comparative studies that ecological effectiveness is associated with criteria like large size (Halpern 2003), good enforcement (Edgar et al. 2014), total prohibition of fishing (Gill et al. 2017; Lester and Halpern 2008), and network connectivity with nearby areas (Gaines et al. 2010; McLeod et al. 2009). However, there is also increasing evidence that ecological effectiveness depends on the process through which MPAs are designed, not just the shape of the final outcome (Giakoumi et al. 2018). The 'human dimensions' of area-based management are increasingly studied (Bennett et al. 2017; Charles and Wilson 2008; Christie et al. 2017). Top-down MPAs designed and

enforced by central governments have been critiqued as "fortress conservation" or "ocean grabbing" that excludes users from decision-making processes (Benjaminsen and Bryceson 2012; Bennett et al. 2015; Brockington 2002; De Santo et al. 2011). There is scientific evidence that bottom-up approaches to conservation (Kareiva and Marvier 2012; West et al. 2006) improves ecological and social outcomes because of increased compliance, rapid adaptation, and other factors (Armitage et al. 2009; Jentoft 2000), while simultaneously addressing ethical issues about local people's right to a voice in decisions that affect them (Agrawal and Gibson 1999; Büscher et al. 2012).

Given the diversity of objectives and approaches to MPAs supported by a diversity of scientific claims, confusion (and contestation) about the definition of MPAs and OECMs is, at the least, unsurprising. A focus on conservation as the primary goal of MPAs will likely sideline alternative approaches and priorities (Gruby et al. 2017; Pendleton et al. 2017). There is some reason to believe this could be counterproductive for the global conservation community (Corson et al. 2014). Flexibility in interpreting Aichi Target 11 has thus far accommodated a wide variety of social and ecological objectives, governance, processes, and outcomes (Barnes 2015; Venter et al. 2014). This has included, for example, locally-managed marine areas that allow sustainable use and prioritize local governance (Jupiter et al. 2017), and very large, no-take MPAs based on the best available ecological science (Day et al. 2012). Indeed, the consensus needed to establish global targets may have been possible precisely because of the broadness of the

concepts of MPAs and OECMs to accommodate competing viewpoints (Gray et al. 2014). Drawing on a conceptual framework from Science and Technology studies, Gray and coauthors have argued that MPAs are "boundary objects", objects that allow for different interpretations by different actors and so facilitate cooperation without alignment of vision (Bowker and Star 2000; Star and Griesemer 1989). Prioritizing conservation-focused approaches to and objectives for MPAs and OECMs could reduce their ability to travel across boundaries, and alienate groups of actors from conservation processes.

Conservation-focused criteria for area-based conservation policies to count towards global targets may be particularly problematic for bottom-up approaches (Failler et al. 2019; Zafra-Calvo et al. 2019). These criteria for MPAs and OECMs generated by international bodies of scientific experts aim to establish the objectives and mechanisms of these policies *a priori* – but taking bottom-up conservation approaches seriously means that local people must have the power to establish their own objectives (Bennett and Dearden 2014; Campbell 2007) and adapt those objectives in response to learning and social, institutional, and environmental change (Armitage et al. 2008). There is reason to believe that local resource users may establish different objectives than the international conservation community for area-based conservation because they conceive of it differently (Gruby et al. 2017). Understanding how resource users conceptualize area-based conservation, and how these align with the knowledge claims

described above, is a critical first step to understanding the long-term outcomes of advancing conservation-focused criteria for MPAs and OECMs (Bennett and Dearden 2014; Campbell and Vainio-Mattila 2003; Goldman et al. 2011). Previous work has used Science and Technology Studies (STS) tools like boundary objects to understand how environmental knowledge claims are circulated and applied (García López et al. 2017; Goldman et al. 2011; Zurba and Berkes 2014), including in the implementation of area-based conservation (Gray 2016; Gray et al. 2014). Here, I use the boundary object concept to interpret how actors involved in a co-managed no-fishing area understood it, connected it to broader claims about area-based management, and the role of these understandings in collaboration. In the section that follows, I describe the theoretical framework for this study, followed by a description of my case and research questions.

2.1.1 Theoretical framework: Science and Technology Studies (STS)

Global targets for MPAs and OECMs stand on their promise to benefit ecosystem health, based on scientific claims about their role in biodiversity, fisheries, and fishing-dependent communities (CBD-COP 2010). Studying how environmental knowledge claims (i.e., arguments based on evidence) are created and circulated is important because they underpin environmental action (Goldman et al. 2011). At the international level, the simultaneous existence of multiple claims based in vastly different evidence and literatures has led to what Corson and coauthors call the "hegemonic" expansion of

MPAs (Corson et al. 2014) because they can be fit in various narratives and agendas (Jeanrenaud 2002). That is, MPAs and OECMs serve as boundary objects (Gray et al. 2014). Boundary objects are a concept from the field of Science and Technology Studies (STS), which studies how scientific claims travel and become accepted as fact ("social fact") (Callon 1984; Latour 1988). Boundary objects are part of the "social worlds" framework, which conceptualizes people as organized in groups that construct meaning together such that the meaning of phenomena depends on the relationships they are embedded in (Clarke and Fujimura 1992; Clarke and Star 2008; Goldman et al. 2011). In this framework, social worlds facilitate collective action amongst their members because of shared meaning, identity, commitments, resources, and ideologies (Clarke and Star 2008), while conflict and negotiation are predicted between social worlds where the meanings of things are different (Fujimura 1988; Strauss 1978). The boundaries between social worlds are thus contested sites where certain claims pass through and others do not (Star and Griesemer 1989).

Boundary objects, defined as "objects which are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites" (p.393) (Star and Griesemer 1989), help ideas move across these boundaries because they are vaguely defined across social worlds, but precisely defined within each social world to fit its specific needs (Bowker and Star 2000). Within social worlds, boundary objects can gain meaning by fitting in

narratives, robust stories that connect them with actions and mechanisms to particular outcomes (Campbell 2002; Roe 1991). Scholars of collaborative work propose that boundary objects are critical for collective action among multiple communities of practice (Bowker and Star 2000; Star and Griesemer 1989; Wenger 1999). They may be particularly important in multisectoral work like conservation because they allow multiple differing viewpoints to coexist, which can benefit less powerful actors (Brand and Jax 2007; Zurba and Berkes 2014). For example, in the case of MPAs and OECMs, Gray and coauthors argue that agreement on a broad definition enabling multiple interpretations allowed for consensus around Aichi Target 11; proponents of large no-take areas and those of self-governance through traditionally managed areas could equally invoke MPAs as a means of achieving their goals (Gray et al. 2014). However, boundary objects are often initially proposed or created by powerful actors to gather consensus, and recent scholarship has explored how end users negotiate, contest, and adapt the original boundary object (Chung et al. 2016; Lee 2007; Paine and Lee 2017). These contestations are expected when there is "torque" caused by tension in particular concrete interpretations of boundary objects (Clarke and Star 2008). There is a research gap in understanding how boundary objects function for end users – especially, whether they can facilitate collaboration – in the face of torque, when boundary objects are interpreted and adapted such that they are no longer "plastic".

Gray and coauthors (2014) have suggested that international consensus on a broad definition of MPAs could lead to conflict in implementation, although this has not been examined. Studying the implementation of bottom-up area-based conservation provides a good opportunity to generate insights about how boundary objects function for end users because there is likely to be torque (Clarke and Star 2008), given the tensions between knowledge claims about MPAs and bottom-up approaches described above. One such case is the Mexican case of Fish Refuges.

2.1.2 Applying the boundary object concept to understand collaboration in Fish Refuges

Fish Refuges ("Zonas de Refugio Pesquero") are an atypical case of area-based conservation; they are no-take areas (fishing prohibited within their boundaries) that emerged in response to nationwide interest in promoting MPAs, but their legal purpose is to promote sustainable fisheries and so they do not count as MPAs according to the IUCN (IUCN 2012a). Still, Mexico is counting them in progress towards the Aichi Targets, as OECMs (Protegidas 2016; REDPARQUES 2018), despite the fact that many are small and temporary, which is not consistent with recommended guidelines for OECM design (Garcia 2019). The rapid expansion of Fish Refuges makes this study relevant, as they have increased in number from none in 2011 to more than 40 in 2017, covering more than 20,000 km^2 (CONAPESCA 2017).

Fish Refuges are a particularly interesting case for studying how boundary objects function for end users on several counts. They are not consistent with many of the scientific best-practices for area-based conservation nor with guidelines for OECMs from the IUCN, yet they derive support from being aligned with international ideas about area-based conservation. If I would expect to find torque between vague international definitions for area-based conservation and its expression in actual implementation, I would expect to find it in the Fish Refuges. Also, while they are typically designed by fishers, they depend upon support from civil society organizations, government fisheries scientists, and government fisheries agencies; any one of these actors can effectively halt the process of establishing Fish Refuges (DOF 2014). Since enactment depends upon successful collaboration between actors from different social worlds, this case is one where boundary objects are likely to play an important role.

In this paper, I characterize (1) how actors involved in implementing Mexico's first Fish Refuges (fishers, fisheries scientists, and civil society organization staff) conceptualized the Fish Refuges in relation to scientific claims about area-based conservation, and (2) how this related to their support for the Fish Refuges. My contribution builds on an active area of boundary object scholarship regarding how boundary objects, usually created by powerful actors, are negotiated and adapted by less-powerful end users (Lee 2007; Melville-Richards 2015; Melville-Richards et al. 2019).

I used primarily qualitative methods, including document analysis and 6 months of fieldwork consisting of observation and interviews. I provide empirical evidence of three narratives being simultaneously mobilized in the collaborative process of implementing community-based no-fishing areas in Mexico called "Fish Refuges" (Zonas de Refugio Pesquero). Paradoxically, while the legal designation of these areas means that they do not fit the IUCN definition of MPA (IUCN 2012a; WCPA 2018), about half of the community members I interviewed described them in a way that does fit this definition of an MPA. I build on previous work using Science and Technology Studies (STS) tools like boundary objects to understand how environmental claims are circulated and applied (García López et al. 2017; Goldman et al. 2011; Gray et al. 2014; Zurba and Berkes 2014).

2.2 Methods

2.2.1 Study site: Fish Refuges of El Corredor, Baja California Sur, Mexico

Mexico's first Fish Refuges were established in the Gulf of California, a large inland sea on Mexico's Pacific coast. Because of upwelling that brings deep, nutrient-rich waters to the surface, the Gulf of California is one of Mexico's most productive fishing grounds (Lluch-Cota et al. 2007) and the states surrounding it produce 71% of the country's fisheries volume (OECD 2006). These same highly productive waters attract migratory whales (blue, humpback, fin, orcas, and others) and sustain large populations

of dolphins and sea turtles, which attract tourists (Leslie et al. 2015). The particular geography of the Gulf of California has led to a high degree of endemism in its marine species, attracting conservationists and marine researchers. The first 11 Fish Refuges were established together as a network in the state of Baja California Sur, Mexico's least dense state by population (INEGI 2015).

The study site where the first Fish Refuges were established is a 100-mile stretch of remote coastline called the Corredor San Cosme a Punta Coyote (hereafter, the Corredor) with a population of about 650 distributed across nine small towns (Niparajá 2009). There are no paved roads, no central electricity or water, and almost no cellular network coverage. The primary source of income in the region is small-scale commercial fishing for finfish, although there is some ranching of cattle and goats. Since the mid-2000s, a civil society organization called Sociedad de Historia Natural Niparajá (hereafter, Niparajá) has been working in the region on building capacity among local fishers to sustain their fisheries; in 2009, Niparajá started gathering data to determine whether there was interest in a network of Fish Refuges across the Corredor region. In response to a positive answer from fishers, in 2010 Niparajá facilitated a process for fishers to design, edit, and agree to a single proposal for a network of temporary Fish Refuges in the Corredor to expire after five years, which was combined with a large justificatory document to become a proposal. This proposal was assessed by the national fisheries research agency (Instituto Nacional de la Pesca, hereafter INAPESCA) and in

2012, the Mexican government legally approved the Fish Refuges (DOF 2012). In this paper, I refer to the whole process from initial design to final legalization as "implementation". The process was repeated from 2016-2017, when fishers proposed to keep and in some cases expand their Fish Refuges for another five years; this proposal was assessed, approved, and legalized in 2017 (DOF 2017).

2.2.2 Data collection methods

This study is based on qualitative data about perceptions of Mexico's first Fish Refuges from six months of in-depth fieldwork including observation, journaling, and informal and semi-structured interviews with stakeholders involved in implementing and evaluating them, as well as document analysis of legal documents and white papers. Following IRB approval (Duke University permit 2018-0130) the first author spent approximately 180 days from 2016-2018 in the field, recorded 66 semi-structured interviews, collected notes and observations in a field journal. This study draws primarily on interviews conducted during 3 months of fieldwork from October to December 2017 (n=26), which were focused on understanding how respondents understood the Fish Refuges, and whether and in what ways they were perceived to be effective. Of the formal interviews conducted during these three months, local interview respondents (those based in the Corredor; n=15) included fishers (n=7) and leaders of fishing organizations (n=2), local leaders (government appointee, policeman, teacher,

nurse, n=5), and leaders of women's cooperatives (n=3), with overlap between categories. Respondents based in the capital city of La Paz included government fisheries agency (CONAPESCA) staff involved in implementing Fish Refuges (n=1), government fisheries research agency (INAPESCA) staff involved in evaluating Fish Refuges (n=3), Niparajá staff involved in facilitating the implementation (n=3), university scientists (n=2), and commercial fishing sector leaders peripherally involved in supporting or denouncing the Fish Refuges (n=2).

I transcribed recorded interviews and coded all interviews using NVivo 11.4.3 (transcripts and notes). I used a combination of deductive codes based on scientific claims about area-based conservation (such as 'spillover', 'biodiversity', and 'results of Fish Refuges') as well as inductive codes that emerged from respondents' answers (such as 'tourism', 'participation', and 'fishing income') (Bernard 1988). Three narratives (i.e., stories that connect outcomes to actions and a mechanism) emerged from thematic analysis of codes and memo writing, with iterative re-reading of interview transcripts. After I identified these three narratives, I coded sections of interviews that identified with one or more of these narratives, with attention to where they diverged from or challenged these narratives. I then connected how respondents described the results of the Fish Refuges to the narratives they used to describe the Fish Refuges. I do not report names of respondents to protect their privacy.

2.3 Results

I found that respondents used three distinct, coexisting narratives to describe the Fish Refuges. These are discussed separately below. Legally, Fish Refuges are fisheries tools intended to use area-based conservation to protect juveniles and generate spillover; this first fisheries narrative was promoted in legal documents, by Niparajá staff, and by about half of fisher respondents. Yet on this basis alone, the majority of the respondents were not convinced of the efficacy of Fish Refuges. A second participation narrative was used by some government officials and Niparajá staff to explain why the Fish Refuges were worth implementing even without evidence of fisheries benefits, because fishers were participating (proposing and agreeing to follow) in fisheries regulations. A third conservation narrative was commonly expressed by local fishers and their families (about half of local respondents), but never by other respondents, that the Fish Refuges were for the explicit purpose of biodiversity conservation, which could support tourism. From my interviews, it seems that the coexistence of these competing narratives facilitated the establishment of the Fish Refuges in 2012 and renewal in 2017.

2.3.1 The fisheries narrative: Fish Refuges support fishing through spillover to nearby fisheries

The official conceptualization of the Fish Refuges, expressed in most legal documents, is that they are fisheries management tools to increase commercial fish stocks. This narrative draws on claims from ecological and fisheries science about

marine reserves, especially whether marine reserves are effective tools for increasing fish stocks through spillover. For example:

> "That is the real logic of a Fish Refuge: to protect the vulnerable part of the population, for the spillover effect. A Refuge is there so that the system recuperates and you fish it again" (university scientist, 11/30/17)

> "For us in the community, it was like a light bulb went off: this is good; it will be like a natural nursery of fish reproduction… If we protect this area, in 3 or 4 years, instead of landing small fish we will land bigger ones" (Corredor fisher, 11/4/17)

Proponents of this narrative argued that success of the Fish Refuges should be measured through scientific assessment of fish stocks or fish catches. As the legal definition of the Fish Refuges, this narrative is widely used in official documents establishing and governing Fish Refuges (DOF 2012, DOF 2017, Ley de Pesca 2007, NOM-049 2014, MIR 2012, MIR 2017), government staff from CONAPESCA and INAPESCA, university scientists, Niparajá documents and personnel, and to some extent by local fishers.

For example, the legal document which first documents Fish Refuges as a legal tool defines them clearly as fisheries tools: "Areas delimited in waters of federal jurisdiction, with the primary goal of conserving and contributing, naturally or artificially, to the development of fishing resources" (Ley General de Pesca y Acuacultura Sustentables 2007). A fishery focus is echoed in the document detailing the procedure for establishing Fish Refuges, Norma Oficial Mexicana NOM-049-SAG/PESC-

2014 (hereafter, NOM-049) published in 2014. NOM-049 defines six possible objectives for a Fish Refuge, all associated with recuperating overexploited fisheries and increasing fisheries productivity, and provides guidance on collecting data on dozens of ecological and fisheries variables primarily associated with a fisheries objective (NOM-049, 2014). Similarly, the legal documents establishing the Fish Refuges in the Corredor region in 2012 state its purpose as, "the protection or recuperation of finfish species, elasmobranchs, crustaceans and mollusks, of commercial importance, in juvenile or reproductive life stages, to increase long-term catches in the surrounding areas" (DOF 2012). An additional legal document calculating the cost-benefit analysis of establishing Fish Refuges claimed potential benefits of 66x the cost of establishment, based on the remarkable assumption of a 30% increase in fisheries income per year from the Fish Refuges' contribution to increased abundance and size of catch (Comisión Federal de Mejora Regulatoria-MIR 2012). Legal documents thus focused on Fish Refuges' potential to benefit fisheries, evaluated through ecological and economic metrics.

University scientists that I interviewed from two marine science institutions in Baja California Sur (Universidad Autónoma de Baja California Sur and the Centro Interdisciplinario de Ciencias Marinas) also mobilized the fisheries narrative to define Fish Refuges, focusing on academic debate about whether marine reserves can be effective at increasing fish stocks. For example, a professor of ecology explained:

> "I agree with Nick Polunin, who has studied no-take zones. They say that a no-take zone is the last option for increasing fish stocks. There are lots of no-take

> zones that don't work, and lots that do work. It depends on the country: in developed countries with high compliance and capacity, they should use other forms of fisheries management. In countries that don't work like Mexico, the no-take zone is better, because it is the only thing that people respect. If people don't respect laws, or rules, then the no-take zone is the best option" (university scientist, 11/29/18).

Scientist respondents were skeptical about the small size of the Fish Refuges, but given evidence that fish biomass was increasing within the reserve and some small evidence of increased fish catches outside, were willing to support them as fisheries management tools. Similarly, Niparajá staff defined the Fish Refuges as strict fisheries management tools: "Fish Refuges are one of the tools to improve fishing… with the objectives of recuperating populations of fished species that have been collapsed, very exploited, or that are very important" (Niparajá staff, 11/28/18).

When I interviewed local stakeholders who had participated in proposing the Fish Refuges, almost all of the respondents at first used the fisheries narrative to explain the Fish Refuges. By the time of my interviews (2016), these fishers had been invited to dozens of meetings, trainings, and workshops about Fish Refuges over 6 years, mostly facilitated by Niparajá using their material emphasizing the fisheries narrative. In the answers they gave at first, they echoed the official purpose of a Fish Refuge as a closed area to repopulate nearby fish stocks. For example, an official local leader defined the Fish Refuges as "a future livelihood that they will have…where small fish grow bigger and bigger and leave, so there is more catch" (town official, 11/3/17). Another leader and

fisher in the town defined them as "zones of fish reproduction, of fish of a small size, fish that are still babies. The Refuge is very good because that is where the fish manage to grow to the size we want, so we don't catch them or exploit them before. Fish grow to a bigger size there" (Corredor fisher, 11/2/17). Most local respondents emphasized noticeable increases in fish catch and increased income as mechanisms to assess success of the Fish Refuges. I interpreted their initial answers as what they thought of as the correct or legal definition of a Fish Refuge. About half of these respondents later in my interviews, after I pushed for their personal interpretations, mobilized the conservation narrative, described below, in some cases disparaging a Fish Refuge's capacity to benefit fishing at all.

Because the network of Fish Refuges in the Corredor region has 12 distinct Fish Refuges (as of 2017; originally 11 in 2012), there were differences in the narratives that local respondents used to describe different Fish Refuges. The fisheries narrative was especially mobilized in the creation of La Brecha, the most recently created Fish Refuge in the Corredor (established November 2017). A fisher explained that they designed it as a nursery for young *huachinango* or red snapper; by all agreeing not to fish it, the *huachinango* could grow to be bigger and thus fetch a price premium for large size:

> "If you go fish a place with tiny huachinango, with small fish that aren't the right size, you'll fish [land] them if you catch them. For example, here in the island you can catch tiny huachinango that we call "mojarras". And you can catch 150, 100, 80 kilos, and, yes, you land them because you are excited, but you are killing the species… So the reason we say "yes, yes" [to the Fish Refuges] is because we want to care for the species, to protect it. This protection will bring us, in 3 or 4

years, instead of fishing the tiny ones, we will fish bigger ones where we have that area" (Corredor fisher, 11/4/17).

2.3.2 The participation narrative: Fish Refuges create opportunities for fisher engagement

In contrast to the focus on spillover and catch in the fisheries narrative, the participation narrative focuses on social and governance outcomes. In this narrative, Fish Refuges are a first step to engage fishers as part of a larger movement towards participatory fisheries management in Mexico. For example:

> "The idea was never to just only do Refugia. The idea is to have fisheries management plans that could make up a whole slew of management tools." (Niparajá staff, 10/11/10)

> "What we have to be conscious of is that the implementation of a Fish Refuge is not just a decree that you emit… When the producers accept a Fish Refuge, it is obvious that they will work with you on this project, that they will respect the rules and regulations." (government fisheries official, State Secretariat of Fishing, 11/28/17)

This narrative is consistent with claims from common-pool resource theory and community-based natural resource management, which connect participation by local resource users in local governance to a higher likelihood of better natural resource outcomes for local actors. The results relevant to this narrative are whether fishers are engaging and participating, demonstrated by metrics like meeting attendance, number of signatories in a proposal, compliance with the Fish Refuges, self-monitoring, and self-enforcement.

Upper-level government staff, civil society staff, and leaders from the commercial fishing sector mobilized this narrative. Most of my interviews with fisheries agency staff (INAPESCA and CONAPESCA) ultimately focused on social rather than ecological outcomes in explaining the value of Fish Refuges. They largely drew on instrumentalist claims about participation. For example, a recently retired high-level official of CONAPESCA explained that fishers' participation is critical in Mexico because of the impossibility of controlling small-scale fishing:

> "Small-scale fishing exists along the country's entire coastline. There are many fishers, and there is no practical way to control them… If species are deteriorated, you have to close the fishery or create Fish Refuges so that the population recovers. But I have always insisted that we have to put the fisher at the center. If you do not put the fisher at the center, your solution won't work" (Interview 12/1/17).

Our interviews suggest that the participation narrative was also important in the positive assessment of the first Fish Refuges by INAPESCA (the fisheries research branch), which is supposed to technically assess proposals for their potential to benefit fisheries. One INAPESCA staff member that I interviewed first emphasized the ecological outcomes of Fish Refuges but later told us,

> "Since the beginning, the fishers have agreed to the implementation of [the Fish Refuges]. And this really influenced INAPESCA's decision to give a positive decision… Restrictions in the past have always been top-down… The fishers always see it as a punishment. In this occasion, we saw that the community was interested. Ultimately, you are restricting their fishing area for 5 years. So when you see that they say, "we want it", you say, "OK, good", and you go ahead" (INAPESCA staff member, 12/1/17).

Similarly, Niparajá staff defined Fish Refuges using the fisheries narrative but described whether or not they were effective in both ecological and social terms. One staff member told us that the Fish Refuges have been moderately effective ecologically, and they have been very effective socially: "In the biological or ecological sense, I think that the trends in the data and the results that we have seen do not show decrease, at least… And from the social side, I think we have seen many benefits. What I have observed is that the community has built a lot of capacity to manage" (Niparajá staff, 11/28/17). Another staff member explained to us that the Fish Refuges are only one part of a larger plan of working with fishers, emphasizing the importance of collaboration and participation for fisheries management. This sentiment was echoed by leaders in the fishing sector, who were not involved directly in implementing the Fish Refuges but who have provided support and incentives. While these leaders mostly mobilized the fisheries narrative – stating that Fish Refuges are working "little by little" for fish stocks – they also describe Fish Refuges as an achievement in terms of fisher participation. The president of an organization of fishers in the capital city of La Paz told us, "In the end, it isn't Fish Refuges that we want, it is awareness."

In my interviews, respondents from outside the Corredor often mobilized both the fisheries narrative and the participation narrative. When asked to define Fish Refuges, many respondents first defined the Fish Refuges as operating for fish stocks

through spillover (fisheries narrative) but later identified fisher participation as the major indicator of success of the Fish Refuges (participation narrative).

2.3.3 The conservation narrative: Fish Refuges conserve biodiversity within their boundaries for tourism

The conservation narrative claims that Fish Refuges protect biodiversity within from fishing pressures outside, with the ultimate objective of transitioning to tourism when the sea around is fished out. For example:

> "Hopefully, in the future we will have very big Fish Refuges, and we will stop fishing completely so that nobody kills the fish. Why? Because we will have a large source of income from tourism" (president of women's cooperative, 11/2/17)

> "I'll repeat: in the future, in case there is no more fishing, they can take tourists out to snorkel and see the fish. That is the only thing that a Refuge can work for" (Corredor fisher, 11/7/17)

In contrast to the fisheries narrative, which claims that Fish Refuges benefit fisheries outside their boundaries, the conservation narrative only focuses on outcomes within the boundaries. This subtle difference has large implications. As discussed in the introduction, the ecological theory that the conservation narrative draws on is less academically controversial (Lester et al. 2009; Pendleton et al. 2017; Sala and Giakoumi 2017). This was paralleled in the respondents from the Corredor, who were largely suspicious of the Fish Refuges' ability to enhance fish catches in their large fishing areas but willing to support them for their potential to protect biodiversity. The conservation

narrative focuses on conservation of biodiversity in addition to stocks of commercially important species. The methods legitimized by this narrative to assess success are monitoring to see if the Fish Refuges are increasing biodiversity and abundance within their boundaries, either through science (e.g., transect-based estimates) or fishers' direct monitoring (e.g., baiting or sample-fishing within the Fish Refuges).

Biodiversity conservation alone as a legitimate goal for Fish Refuges was not supported by NGO staff, government staff, and academic scientists, who all emphasized that the Fish Refuges have to "work" for fisheries to be considered effective. The idea that Fish Refuges must serve primarily for fishing was reiterated throughout interviews with fisheries government staff, for example: "A person asks for a Fish Refuge because he is a fisher from that zone and has a permit… If you live there but you aren't a fisher, why are you asking me for a Fish Refuge? It must be a fisher that asks for it, with a permit" (CONAPESCA official, 12/1/17). A university scientist told us: "I don't agree with some NGOs that say that a community with a Fish Refuge won't fish anymore. No. A Fish Refuge is there so the system recuperates and you fish it again" (university professor, 11/30/17). All actors I formally interviewed who were not from the fishing sector or the Corredor region, including academics, government staff, and NGO staff, emphasized during the interview that Fish Refuges were for fisheries, either the fish themselves (fisheries narrative) or building governance capacity (participation narrative).

However, many people I interviewed from the Corredor (about half of local respondents, including fishers and presidents of women's cooperatives) saw the Fish Refuges as part of a future without commercial fishing in the Corredor, as a way to maintain enough biodiversity and abundance in the Refuges to bring tourism and alternative livelihoods to the Corredor region. These respondents described the Fish Refuges as banks, or boxes, where fish could gather and reproduce, but instead of focusing on spillover to their fisheries, they talked about "many beautiful fish" inside. Many of these respondents were not convinced that small Fish Refuges could generate enough spillover to materially benefit their fishing:

> "I see the Fish Refuge more as a place to protect fish in that same place, and to attract tourism to that Fish Refuge. But I don't see it as a place to discharge fish to the whole area where we fish; it is impossible. And so, I see it more as a *resguardo*, like box that you have there, where you will see more and more, for a future of tourism rather than a zone for fishing. A little bit, yes it spills over, but not much" (Corredor fisher, 12/12/17).

Several fishers saw the future as either inevitably or likely leading to collapse of fishing, in which case the Fish Refuges could serve as a source of potential future work. For example, an older fisher told us, "I think the Fish Refuges are good because possibly, grandchildren. You have grandchildren and there aren't fish anymore. But there inside there are fish. Possibly they don't fish anymore. Maybe they snorkel. But you have something to show the tourist" (Corredor fisher, 11/7/17). The presidents of women's cooperatives that I interviewed also used this narrative. These women's cooperatives have expressed interest in expanding to a tourism market, and they emphasized the Fish

Refuges as a tourist attraction that they could use to market the Corredor as a tourist destination. If this were the case, it would be one of the few sources of income for women in the Corredor. Table 1 summarizes the three narratives.

Table 3: Summary of the three coexisting narratives about the Fish Refuges

Narrative	Fisheries narrative	Participation narrative	Conservation narrative
Storyline (mechanism and outcome)	Fish Refuges are **fisheries management tools** that increase fish stocks outside their borders through spillover of larvae and adults	Fish Refuges are for **participation by fishers in fisheries management**, a first step to involve fishers in a larger fisheries management plan	Fish Refuges protect **biodiversity within their borders** so when the sea is fished out, it can be a source of alternative livelihoods through **tourism**
Associated scientific theories and claims	**Fisheries ecology** literature on the role of MPAs and no-take zones in increasing size and abundance of fish nearby; focus on **spillover** and fecundity of large females	**Community-based natural resource management and common-pool resource theory** literature identifying sustainable resource management from self-governance	**Biological and ecological** literature on MPA effects within borders, especially on biodiversity
Question to measure success	*Do the Fish Refuges generate more fish for nearby commercial fisheries?*	*Are fishers engaging and participating?*	*Do the Fish Refuges have higher biodiversity inside their boundaries than outside?*
Associated indicators & evidence of success	Transects and stock assessments of biomass and abundance near Fish Refuges Fecundity and reproduction Catches of local fishers Income of local fishers	Meeting attendance Number of signatories of proposal Compliance Self-monitoring and enforcement	Transects and stock assessments of biomass and abundance near Fish Refuges - but rather than for stock assessments, for biodiversity inside Refuges
Actors who used narrative in my interviews	Legal framework and legal documents Government (especially INAPESCA) NGO (Niparajá) About half of Corredor fishers and their families	Government (CONAPESCA and INAPESCA) NGO (Niparajá) Representatives from commercial fishing sector	Corredor fishers Corredor women's cooperatives

2.3.4 Are the Fish Refuges effective, and what for?

One implication of the three coexisting narratives is that there is disagreement about what the Fish Refuges should be achieving, and commensurate disagreement about how to assess whether the Fish Refuges are effective. The fisheries narrative is legally used to assess effectiveness (DOF 2014). However, because the legal framework does not precisely specify methods for assessing effectiveness (e.g., length or number of transects that are considered sufficient; what percent increase would be considered an improvement), this leaves legal latitude for interpreting and representing results as "working" or "not working".

Academic scientists looking at statistical trends in transect data say that the Fish Refuges are working for the fisheries narrative: "I can tell you that, biologically, things have improved…for all ten [commercially important] species except one" (university scientist, 11/29/15). Transect data shows that there is a significant increase in fish size and abundance within the Fish Refuges for most commercial fish suggesting potential for spillover, which academic scientists attribute to the fact that the Fish Refuges, though small, are grouped in a network which makes them effective. The same scientists point to small but significant trends of increased size and abundance of catch in the Corredor. However, while some local fishers agree, many of the fishers argue that the Fish Refuges are not working because these fishers have not noticed a perceptible increase in income from fishing or substantial increase in catch. This disagreement highlights the

differences between what kind of change is considered scientifically significant versus what change is noticeable in variable daily catches and revenue or what change is substantial enough to be worth the investment (of time, energy, money) to create the Fish Refuges.

For the most part, respondents mobilizing the participation narrative perceived the Fish Refuges to be working for associated objectives of engagement of fishers and government in fisheries management. Participation has at times been quite high – at one workshop for the Fish Refuges in February 2017 some 5 hours away by car along dirt roads from one of the towns, Puerto de Agua Verde, "almost the whole town" attended, including families and children (Corredor fisher, 11/2/17). One CONAPESCA official called the Fish Refuges one of the greatest accomplishments of CONAPESCA in terms of fisher participation. However, both local fishers and Niparajá staff have noticed vacillating participation at meetings over the past 6 years since the beginning of the project. One Niparajá staff member told us they did not know why participation has sometimes been quite low. Some local fishers reported disenchantment with their participation in the project, for example:

> "We are always there, and Niparajá never brings in even one resource [subsidy] for us… With all the money they have, with all the money they spend. It is distancing, like that. We are the ones who do all the participation. But from them to us, nothing… Sometimes the people here feel disenchanted… It's all about the attendance list. The more women that go, better. The more people that go, better. Men or women, it is the same. If more people sign, there is more support from the government… We haven't seen benefits. Me, for my participation, I haven't seen benefits" (previous formal local leader, 11/18/17).

In contrast to differing opinions among residents of the Corredor whether the Fish Refuges are working for fisheries or for fishers, many Corredor residents agree that the Fish Refuges are working for conservation (conservation narrative). They report seeing lots of fish ("una cantidad"), especially large fish, when they go to assess the Fish Refuges themselves by throwing bait in the water to attract fish. They draw both on personal experience and formal scientific knowledge (transect data from the Buzos Monitores monitoring program; also informal conversations with biologists) to confirm the quantity and size of fish inside the Fish Refuges. They routinely discuss the possibility of taking tourists to visit the Fish Refuges, express confidence that there are large fish in the Refuges, and indicate that the Fish Refuges are working in this way.

2.4 Discussion

2.4.1 Fish Refuge: OECM or MPA?

As bottom-up policies designed by fishers, the Fish Refuges of the Corredor have emerged as something that is not consistent with the IUCN's categories of "MPA" or "OECM". Mexico is counting Fish Refuges towards their progress on Aichi Target 11 as OECMs (REDPARQUES 2018). They technically count under the definition of OECMs by the Convention on Biological Diversity (CBD-COP 2010; CBD-COP 2018), although, as fisheries management tools, they do not meet some suggested criteria for OECMs

(Laffoley et al. 2017). However, many people involved in implementing (designing, proposing, evaluating, and establishing) them describe them as something other than a fisheries management tool. Government fisheries staff identify their value as participation tools to build collaboration between rural producers and government officials. Civil society organization professionals (Niparajá staff) described the Fish Refuges as one part of a larger coastal and fisheries management vision that could be called Marine Spatial Planning. And about half of the respondents from the Corredor region described the objective of the Fish Refuges as conserving biodiversity, which aligns with IUCN criteria for an MPA.

Furthermore, the Fish Refuges fail to meet many scientific guidelines for area-based conservation aimed at benefitting fisheries (Salomon et al. 2011). The Fish Refuges are small, with a mean size of 5.8 km^2 and a median size of 1 km^2 (ranging from 0.4 to 32.9 km^2). Most of the Refuges are thus smaller than ecologists' recommended sizes for no-fishing zones aimed at fisheries management, ranging from 4-6 km^2 (Shanks et al. 2003) or 10-100 km^2 (Halpern and Warner 2003) depending on the intended species. Also, the Fish Refuges are temporary and must be renewed every 5 years. This goes against scientific design principles that no-take zones should be permanent or long-lasting for fisheries management (Claudet et al. 2008), such as a 15-40 year duration for the predatory fish that are often targeted species by fisheries as in the Corredor (Russ and Alcala 2004), or preferably permanence where feasible (Lauck et al. 1998) (although

social scientists have shown that temporary MPAs may be preferable to reduce negative impacts on fishers (Bartlett et al. 2009) and there is growing interest in mobile MPAs to combat climate change (Maxwell et al. 2020)). Finally, in spite of calls for science-based design of area-based conservation (Halpern and Warner 2003; Leslie et al. 2003; Sale et al. 2005), the Fish Refuges were designed by fishers in the Corredor, most of whom have only a primary or secondary school education, without optimizing based on scientific data. Despite these discrepancies between global claims and the Fish Refuges, they are identified as "working", largely because they do visibly and measurably succeed in their other goals: improving participation in fisheries management and biodiversity conservation.

Does legal definition of area-based conservation matter more than how it is defined by those who are most involved and most affected by it? If many fishers of the Corredor saw the opportunity for biodiversity conservation in what is legally a fisheries management tool ("OECM"), it seems possible that stakeholders implementing a legal MPA might similarly see the opportunity for fisheries management, instead. This case study suggests that attempts to precisely define MPAs and OECMs in international guidelines, particularly around conservation objectives, may still be resisted and reshaped when these policies are implemented on the ground. Targets like the Aichi Targets and the Sustainable Development goals make these categories important. What "counts" towards targets matters, because this generates will from central governments

to support conservation measures. The Fish Refuges were initially pushed in national level meetings in 2007 and 2008 by support for MPAs generally in Mexico, even though today they are no longer considered MPAs at the IUCN; definitional strictness may actually hinder local conservation efforts rather than support more effective conservation.

2.4.2 Fish Refuges are boundary objects, which allowed for implementation and ongoing collaboration

The definitional blurriness discussed above with three coexisting narratives seems to have actually facilitated implementation of the Fish Refuges in the first place. Diverse actors with minimal previous collaboration were involved in implementing the Fish Refuges: fishers, a civil society organization (Niparajá), fisheries scientists (INAPESCA), and fisheries managers (CONAPESCA). In this complicated process, a majority of local permit-holding fishers had to propose the sites. Niparajá had to write a long justificatory proposal to support the selection of those sites. INAPESCA had to issue a positive technical opinion about the proposal's viability and likelihood of producing fisheries results. Finally, CONAPESCA had to legally review, justify, implement, and agree to enforce the Fish Refuges. Had any of these groups of actors not agreed affirmatively to support the Fish Refuges, they would not have been implemented (NOM-049-SAG/PESC-2014; interview 12/1/2017).

It seems plausible that this collaboration was possible because of multiple coexisting narratives about the Fish Refuges. Many of the different actors were initially doubtful about the Fish Refuges, but ultimately convinced by arguments aside from their benefits to fisheries. For example, INAPESCA struggled to evaluate the Fish Refuges because of doubts about their ability to function for fisheries, but according to my interviews ultimately approved the proposal because it was a step forward for fisher participation in management. If the diverse actors involved could not agree to implement a single conceptualization of the Fish Refuges, perhaps they could at least agree to implement their own conceptualization of the Fish Refuges.

This suggests that Fish Refuges are boundary objects, even as they have been implemented and renewed. Gray and coauthors (2014) suggested that conflict at the implementation stage might result from MPAs as boundary objects in international agreements. In the case of the Fish Refuges of the Corredor, conflict did not prevent implementation, in part because the Fish Refuges, as implemented, continue to allow for different interpretations. Even the process of evaluating their success for their renewal in 2017 did not lead to agreement on a single conceptualization; my interviews with stakeholders were predominantly after renewal in 2017.

As in initial establishment in 2012, renewal in 2017 seemed facilitated by the continued coexistence of three narratives. This can be most clearly seen among the Corredor fishers, a majority of whom needed to support the proposal for Fish Refuges

according to CONAPESCA's unofficial guidelines (legally, anybody can submit a proposal). Most fishers who exclusively mobilized the fisheries narrative argued that they were not seeing enough catch and income benefits to justify the Fish Refuges, and in informal interviews I heard that many fishers opposed renewal on this basis. However, from my interviews, it seemed like there was enough support from Corredor fishers considering conservation and tourism benefits from the Fish Refuges to result in a majority of fishers signing the proposal for their renewal and expansion. Similarly, government officials at INAPESCA cited governance benefits, not fisheries benefits, as the reason that they eventually gave the proposal a positive assessment, so that it could ultimately be passed.

If fisheries in the Corredor respond to no-take zones as many cases have (Di Lorenzo et al. 2016; Halpern et al. 2009; McClanahan and Mangi 2000), it is possible that, with more time, more trust, and perhaps larger areas, the Fish Refuges of the Corredor will generate clearer fisheries benefits, in terms of detectable catch and revenue. If this is the case, Corredor fishers could decide that Fish Refuges are working for fishing, and move away from the conservation narrative. If all actors perceive fisheries benefits, the fisheries narrative may emerge as the dominant one. For now, it seems like starting with three coexisting, conflicting narratives is what facilitated collaboration to allow the Fish Refuges to emerge.

This emergence as three coexisting narratives was likely facilitated by a legal policy for Fish Refuges that left much open to interpretation by the implementers of the first ones in the Corredor region of Baja California Sur, Mexico. There was no prescribed process for evaluation, and the low capacity of government staff to conduct their own studies meant that they depended on the data and interpretations provided by Niparajá. The combination of little legal guidance and low government capacity to conduct studies could be an incubator for boundary object policies more generally. Such policies could facilitate collaboration between diverse actors like rural resource users, civil society professionals, and government staff. However, such circumstances are not always positive. When I asked a leader in the process about the effects of working within sparsely defined policy, they replied,

> "It makes the agency that is in charge of implementing the fisheries law, CONAPESCA, have a huge amount of discretion… I see it as a huge barrier with corruption. Because there is only discretion. Can discretion help you? Sure, if it is working in your favor. But if it's not, then you lose because who's going to actually question how it's supposed to be? Well who knows, because there's no rules published" (12/1/17).

2.4.3 Vulnerabilities of marine policies that are boundary objects

While they may facilitate collaboration between diverse stakeholders, this case also suggests that policies that are boundary objects may be vulnerable. The Fish Refuges may not deliver on the expected benefits for any of the three narratives, especially given some characteristics critiqued by the scientific literature, which could

cause support for them to wane. The fisheries narrative depends on fisheries benefits from spillover, which is highly contested in the scientific literature (Hilborn 2017; Pendleton et al. 2017; Sala and Giakoumi 2017). There is empirical evidence that MPAs can improve nearby fishery catches in overfished areas (Kerwath et al. 2013; Vandeperre et al. 2011), but from a regional perspective, MPAs may simply be displacing fishing effort rather than reducing it (Greenstreet et al. 2009; Halpern et al. 2004). Spillover is especially debated for mobile species of fish with ranges larger than the size of a given reserve (Aceves-Bueno and Halpern 2018; Di Lorenzo et al. 2016; Villegas-Ríos et al. 2017). The Fish Refuges are aimed at targeting some such species, such as red snapper (*Lutjanus peru*) and yellowtail (*Seriola lalandi*), although other targeted species are less mobile, with relatively smaller ranges, such as parrotfish (e.g., *Scarus ghobban*, *Scarus compressus*) (Niparajá 2017). This opens them to critique, which could affect their funding in the future; given the debates over the effectiveness of MPAs for spillover to adjacent fisheries, defining the Fish Refuges using the fisheries narrative opens them to the critique that spillover has received poor scientific support. Similarly, a failure of the Fish Refuges to improve fish catch or income that local fishers perceive could lead to reduced support for the Fish Refuges in the future. Critiques related to the participation narrative include ethical concerns about obligating fishers to participate in the limitation of their own fishing activities (Silver and Campbell 2005). Also, drawing on other cases of small-scale fisheries, sustainability may be less important to fishers than other values

like equality (Fabinyi et al. 2015). This could complicate the association of fishers participation with long-term sustainable fisheries, a claim of the participation narrative. Finally, the conservation narrative opens Fish Refuges to a large host of critiques about impacts, challenges, and pitfalls of (eco)tourism and alternative livelihoods (Campbell 2007; Duffy 2008; Meletis and Campbell 2007; Schweinsberg et al. 2012). While, so far, most stakeholders seem to draw on their own narrative to see the possibilities of the Fish Refuges, a determined critic could equally draw on the drawbacks and potential for failure within each narrative.

The plurality of objectives under the different narratives also means that assessing effectiveness of the Fish Refuges will have to be continuously negotiated. This process is especially complicated because there is only one official goal (fisheries management), making progress towards the other goals not part of the legal mandate of the Fish Refuges. The implications are that formal fisheries knowledge may be favored over other types of knowledge, although this will require future research to investigate. Answering whether the Corredor Fish Refuges are working is complicated, especially when multiple narratives are confused or strategically mixed together. Not recognizing the multiple ways in which stakeholders define the Fish Refuges could result in a misunderstanding of what Fish Refuges contribute to coastal livelihoods. A limited assessment based on a single narrative (say, the legal definition supported by the fisheries narrative) could thus find them ineffective and result in their dismantling, even

if they were providing other benefits according to other conceptualizations of their purpose. Boundary objects may be brittle policy objects; future research will have to investigate what makes boundary object policies work in the long run, and who they benefit most.

2.5 Conclusion

I demonstrate here that stakeholders used three distinct narratives (the fisheries, participation, and conservation narratives) to conceptualize goals and mechanisms for Fish Refuges in Baja California Sur, Mexico. I argue that these narratives show that the Fish Refuges are a boundary object, and as such were able to promote collaboration. An implication of this work is that requiring MPAs to have conservation objectives (WCPA 2018) may end up being counterproductive. In contrast to the continued demarcation of area-based conservation tools as either conservation or fisheries management in international guidelines and targets (Laffoley et al. 2017), the case of the Fish Refuges suggests that local people living with and applying these tools do not have such a delineated vision. Legally Fish Refuges are fisheries management tools, and Mexico is counting them as OECMs (but not MPAs) in progress towards the Aichi targets – and yet they depend on support from fishers who conceptualize them as more similar to MPAs. Furthermore, while stakeholders disagree about whether Fish Refuges are working for fisheries (e.g., fish catch), there is general agreement that they are

generating positive results for conservation (e.g., biodiversity). Ultimately, it is important for managers to realize that their priorities may not align with those of people affected by area-based management projects, and that what is "working" depends on the beholder:

> "The fishers say they [the Fish Refuges] are working… They have worked because now, you catch more red snapper, or the top grade fish that are here, which are the ones that leave people with a little bit more money. But this thing that you are talking about, people don't live, they survive, because we don't even have the resources to go to the town, to live there to work, no? As I say, what is this, a life? We don't have electricity. Because we don't have electricity, we don't have refrigerators… The more that we work with [this organization] on fishing, I ask, who here has become rich? Nobody. Nobody has become rich" (Corredor resident, 11/18/17).

For bottom-up conservation that is led by rural resource users, not establishing objectives and approaches *a priori* may actually facilitate collaboration with powerful actors like government officials and professional scientists. Initial definitions and conceptualizations of area-based conservation tools may shift and adapt as resource users learn from their experiences; the objectives of areas may switch between fisheries and conservation, or be both. Even though the IUCN agrees on what an MPA is, this may be muddled at the level of implementing particular policies.

3. 'Ping-pong hybridization' navigates barriers to local ecological knowledge (LEK) integration in fisheries co-management: lessons from Mexico

3.1 Introduction

Local Ecological Knowledge (LEK) seems caught in a tragedy: just as the recognition of its importance seems to become mainstream and international guidelines call for its integration in fisheries management (FAO 2015; FAO 2017), some authors suggest LEK is undergoing generational loss (Aswani et al. 2018). For more than twenty years, researchers have argued that fisheries managers should listen to and respect the knowledge that fishers have, including LEK (Johannes et al. 2000; Neis et al. 1999; Olsson and Folke 2001). Twenty years later, some observers are disappointed by the amount of listening that has happened (Hind 2015). Views differ on whether the integration of LEK in fisheries management can ever be successful, and what 'success' means (Gray 2016; Holm and Soma 2016; Stephenson et al. 2016). Many LEK scholars are skeptical that state-led natural resource management systems could ever accommodate LEK, unless it is transformed (e.g., codified, quantified, or validated by academic science) (Davis and Ruddle 2010; Hind 2015; Soto 2006). In contrast, scholars of participatory resource management have argued that fishers' knowledge can be (and has been) included in management specifically when there is a process designed to receive and use it (Stephenson et al. 2016). They argue that participatory approaches to

fisheries necessarily integrate fishers' knowledge, and the current expansion of these approaches creates increasing demand for this knowledge (Stephenson et al. 2016).

This disagreement highlights diverging views about what counts as integration – a complicated issue because integration is likely to look different in different contexts (Schwach et al. 2007). For example, in highly developed and mechanized fisheries where fishers are already collecting a large amount of (scientific) data, 'integration' may mean the provision of fisher-collected data to managing bodies (Johnsen et al. 2009). For small-scale fisheries with low levels of control and enforcement from the central government, where participatory approaches may be most important (Jentoft and McCay 1995), 'integration' may mean informal management devised by fishers based primarily on their tacit knowledge (Mills et al. 2011). When fishers perceive that management is based primarily on their knowledge, they may consider the rules to be more legitimate, and thus comply more (Jentoft 2000). The details of how fishers' knowledge is integrated in different management schemes are likely to influence their perceived legitimacy (Pinkerton and John 2008), but are not well known (Young et al. 2016). Amidst a plethora of calls for integrating LEK in fisheries management (Adams et al. 2014; Ballard et al. 2008; Charnley et al. 2007; Gagnon and Berteaux 2009; Hill et al. 2012; Jackson et al. 2014; Palsson 2000), actual studies describing integration and its effects on fisheries management are sparse; this paper contributes to filling this gap (Bohensky and Maru 2011).

We explored these issues through the Mexican case of Fish Refuges (Zonas de Refugio Pesquero) in Baja California Sur, small no-take zones designed by fishers and legally enforced by Mexico's fisheries agency. In this context, fishers' involvement and participation was explicitly sought out from the design stage, providing an excellent opportunity to observe and understand how the integration of local fishers' knowledge in management can play out. We studied this process through an in-depth study, primarily based on interviews, observation, and journaling conducted during six months of fieldwork, contextualized in survey results and ecological monitoring data.

In the next section we elaborate on the conceptual and theoretical positioning of this paper, followed by a brief description of the case and research methods. In the results we discuss the dynamic interplay of fishers' knowledge and science in the process of implementing the Fish Refuges, followed by a discussion of the implications for fishers' knowledge in fisheries management.

3.2 Conceptual and theoretical background

3.2.1 Barriers for the integration of LEK in management

In this paper we primarily refer to "fishers' knowledge" which we define as including biological fishery information as well as wider ecological, economic, social, and institutional knowledge related to fishing, and the interpretation and analysis of that information given a particular worldview or belief system (Soto 2006; Stephenson et

al. 2016). This helps avoid an inadvertent focus on solely 'ecological' dimensions as suggested by LEK's name (Davis and Ruddle 2010; Gilchrist et al. 2005; Silvano and Valbo-Jørgensen 2008), to include broader social-ecological information situated within practices and beliefs (Murray et al. 2005; Soto 2006). Where relevant, we draw on arguments from scholarship about Traditional Ecological Knowledge (TEK) and indigenous knowledge, while recognizing that these terms have distinct meanings (Aikenhead and Ogawa 2007; Houde 2007). In this paper, we use the terms "science" and "LEK" or "fishers' knowledge" as idealized categories established in the literature, but this dichotomy is a false one as we discuss below (Agrawal 1995; Negev and Teschner 2013). The separation and stabilization of these idealized concepts can uphold false assumptions about both LEK and science (Holm 2003), which can hinder the integration of fishers' knowledge in management (Stephenson et al. 2016). We use the terms "LEK", "fishers' knowledge", and "science" as points of departure that connect my study to larger scholarship on knowledge and co-management.

Early support for integrating fishers' knowledge in fisheries management stemmed from cases of collapse when fishers were disregarded – "ignore fishers' knowledge and miss the boat" (Johannes et al. 2000). Citing data gaps in fisheries management globally (Beddington et al. 2007; Worm et al. 2009), many scientists call for drawing on fishers' knowledge as low-cost information, especially in "data-poor" settings (Berkström et al. 2019). Support for LEK has also grown from its perceived

complementarity with several trends in natural resource management, including ecosystem-based management (Bundy and Davis 2013), integrated social-ecological systems (Gadgil et al. 2003), and adaptive management (Armitage et al. 2010). For example, fishers' knowledge is often multi-species, contextualized in particular places, and includes temporal variation, and thus may be more closely aligned with an ecosystem approach to fisheries than single-stock models associated with a traditional scientific approach (FAO 2015). The result has been, today, widespread support for integrating fishers' knowledge in management (Díaz et al. 2019; FAO 2015), especially through an ongoing process of learning, discussion, and evaluation of multiple knowledge claims and epistemologies (Bohensky and Maru 2011).

Despite this support, there are still substantial barriers to integrating fishers' knowledge in management, such as epistemological differences, lack of trust between resource users and managers, and institutional barriers, among others (reviewed in (Hind 2015; Mistry and Berardi 2016; Soto 2006; Thornton and Scheer 2012)). From these we identified two interrelated types of barriers that were most relevant to this case: issues of legibility and issues of power.

3.2.2 Barrier 1: LEK is not legible to managers

The first barrier is that fishers' knowledge is not legible to most systems of fisheries management (Holm 2003). By legible, we mean both understandable and

readily usable (Scott 1998). The problem of not being legible is that fishers' knowledge must be transformed to be integrated, which can undermine the reasons for integrating it in the first place: e.g., its legitimacy to resource users, its ability to represent the lived experience, and its alternative focus from formal science (Shackeroff and Campbell 2007).

The theoretical problem of legibility is well described by James Scott (1998), who has argued that states use abstract and generalized knowledge in order to simplify the complex task of governing a large area; he argues that this type of abstract knowledge is at odds with the knowledge that citizens use, which is deeply embedded and location-specific, analyzed within its context. Scott argues that states thus struggle to integrate local knowledge in its raw form; instead, they render it legible by transforming it through simplifying, coding, mapping, etc. (Scott 1998).

In fisheries, the transformation of local knowledge into its state-legible form is often done by LEK researchers (Holm 2003; Murray et al. 2008; Neis et al. 1999). These researchers take fishers' knowledge, which is variable, embedded in practice and belief, unevenly distributed amongst resource users, dependent on user characteristics like gear type and position, and held by fishers rather than managers (Martin et al. 2007; Murray et al. 2005; Murray et al. 2006) – and they neaten it through standardization, documentation, and external evaluation (Holm 2003). The final product is what Holm (2003) calls "FEK*" – Fishers Ecological Knowledge (FEK) that has been rendered legible

(Figure 1). Holm uses the "*" to differentiate FEK*, the outcome of transformation, from FEK, the 'raw' knowledge held by fishers already (Holm 2003). Holm (2003) argues that the two most common types of transformation are either using fishers' knowledge to generate hypotheses that can be validated using traditional scientific methods (statistics, observation, etc.) (e.g., (Berkström et al. 2019; Wroblewski 2000)), or using fishers' knowledge as data that can be integrated into scientific models or analyses (e.g., (Ban et al. 2017; Carr and Heyman 2012)). Over the past 20 years, LEK researchers have identified 'best practices' to transform fishers' knowledge to FEK* through one or both of these pathways, for example accounting for fishers' bias, identifying experts, and synthesizing diverse opinions (Davis and Ruddle 2010; Davis and Wagner 2003; Gilchrist et al. 2005; Hall et al. 2009; Lopes et al. 2019; Neis et al. 1999; Silvano and Valbo-Jørgensen 2008). Figure 1, below, shows a conceptual diagram of the legibility (i.e., understandability and usability) of fishers' knowledge to state fisheries management agencies (right) and to the fishers themselves (left), built from Scott (1998) and Holm (2003). While fishers' knowledge is typically not legible to state agencies, the transformed and refined form, FEK*, is readily integrated in some forms of management.

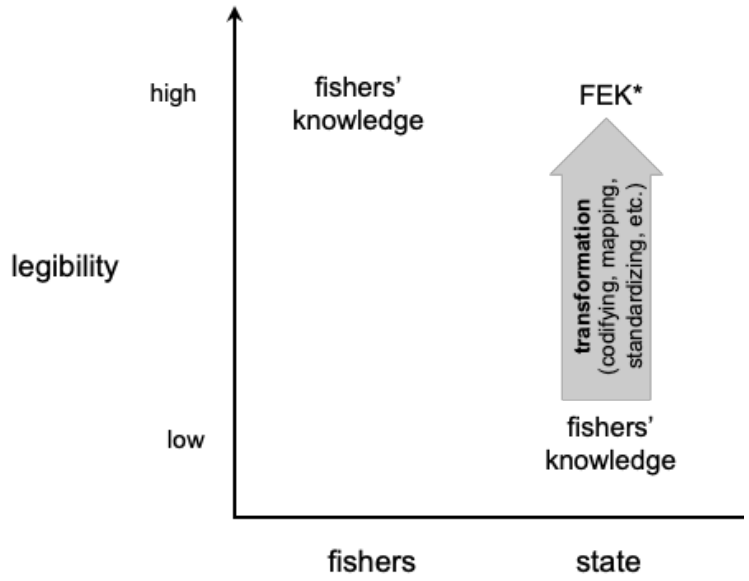

Figure 5: The legibility gap: conceptual diagram of the legibility of fishers' knowledge, built from Scott (1998) and Holm (2003)

The irony of this well-intentioned transformation is that it potentially undermines the very reasons researchers call for the integration of fishers' knowledge in fisheries management. Both of Holm's pathways of transforming fishers' knowledge to FEK* (hypothesis testing and using FEK as data) use 'science' to validate fishers' knowledge, which rather than empowering fishers, can give their knowledge a second-class status compared to 'science' (Holm 2003). Fisher's knowledge perceived to fail the supposedly rigorous tests of science can sometimes be rejected as wrong (Ortiz 1999). Additionally, the process of distilling FEK* decontextualizes and dissociates it from the systems of practice and belief in which it is embedded, where it makes most sense and has meaning (Gibbs 2001; Shackeroff and Campbell 2007). This dissociation of fishers' knowledge from associated practices and beliefs can reduce its dynamism and

adaptiveness to environmental change (Agrawal 2002). Additionally, fishers have expressed concern about their own knowledge being transformed and used to support management policies that negatively affect their livelihoods (Silver and Campbell 2005). Nonetheless, by making fishers' knowledge intelligible to systems of management, this transformation allows fishers' knowledge to enter management processes (Figure 1) often where it never had before, which some scholars have argued is preferable to excluding fishers' knowledge altogether (Haggan et al. 2007; Ommer et al. 2012).

3.2.3 Barrier 2: LEK is entangled in power asymmetries

A second major barrier to integrating LEK in natural resource management is the historical and actual power asymmetry between LEK and science (Agrawal 2002; Nadasdy 2004). Power asymmetry has meant that attempts to integrate LEK in natural resource management often end up as the appropriation of LEK (or rather, its legible and transformed version) into scientific knowledge systems (Mistry and Berardi 2016). This can be compounded with legibility issues, wherein LEK must be expressed in ways that are compatible with scientific resource management, to further concentrate power in administrative centers (Nadasdy 1999). Thus, rather than lessening power inequities or increasing power of resource users, integrating LEK can further marginalize them by serving market logics and incentive-driven resource management (Mistry and Berardi 2016). This can be a barrier to integration because resource users may not wish to share

their knowledge in a project that disempowers them, and both resource users and managers may become disenchanted with poor outcomes from imbalanced integration of LEK and science.

This power asymmetry can be seen most clearly where the management implications of fishers' knowledge conflict with those of science. While inshore fishers were praised when their knowledge 'accurately' predicted the collapse of cod (Neis et al. 1999), fishers' knowledge that contradicts scientific findings is typically assumed to be have systematic bias that either must be scientifically corrected or be excluded from management (Daw 2008; Daw et al. 2011; O'Donnell et al. 2010). Conversely, the famous cases where LEK has seemingly overturned scientific assertions, including the case of cod, have depended on (other) scientists to document, map, and provide scientific evidence to support LEK (Harris 1999; Leach and Fairhead 2000; Leach and Mearns 1996; Neis et al. 1999).

The second-class status of LEK and fishers' knowledge is also evidenced by the typical arenas where they are invited to contribute their knowledge: in "data-poor" settings where there are no alternative sources of data available (Berkström et al. 2019), or to fill "gaps" in fisheries science (Bevilacqua et al. 2016). Such language frames LEK as an inferior but potentially useful alternative to science for resource management. The second-class status of LEK has led to skepticism (Holm 2003; Shackeroff and Campbell 2007) about whether including LEK in management really has the potential to challenge

power relationships and lead to equitable inclusion of marginalized resource users, as some have suggested (Drew 2005; Drew and Henne 2006).

Given this power asymmetry, there is some evidence that trust between resource users, scientists, and decision-makers mediates the extent to which fishers' knowledge, FEK*, or neither is integrated in management (Holm and Soma 2016; Stephenson et al. 2016; Wilson et al. 2006). While cases with high trust between fishers and managers have been deemed to have "successful integration" (Holm and Soma 2016), building this trust is a challenge because of the historic lack of trust (Berkes 2009) and knowledge exchange (Johnson 2009) between fishers and fisheries scientists. Having sufficient trust to overcome power asymmetries between LEK and science is the exception rather than the rule, such that power asymmetry is still a major barrier to integrating fishers' knowledge in fisheries management (Hind 2014; Mistry and Berardi 2016; Shackeroff and Campbell 2007).

3.2.4 A dilemma: Co-management depends on knowledge integration

Given these barriers to the integration of LEK in fisheries management (i.e., lack of legibility for managers and power asymmetries), one might ask what successful integration could look like. A prominent review has argued that fishers' knowledge has actually been extensively integrated in management when there are governance systems

set up to receive and use it (Stephenson et al. 2016). The governance systems they identify are various forms of co-management (Stephenson et al. 2016).

Co-management is defined as management with power sharing between resource users and states (Carlsson and Berkes 2005), although there is increasing recognition of the important role that non-governmental organizations (NGOs) play in environmental co-management (Gray 2016). Given the large number of variables and uncertainty in natural resource management (Ostrom 2009), especially fisheries (Jentoft and Chuenpagdee 2009), compounded with some documented failures of traditional state-led management (Worm et al. 2009), co-management is an increasingly popular governance regime (Gutiérrez et al. 2011). The promise of co-management resides partly in its ability to take advantage of the knowledge of both states and resource users (Dale and Armitage 2011); local resource users might rapidly detect change, have contextualized social-ecological knowledge, and know local rules and norms, while governments are positioned to monitor large-scale patterns and learn across many sites (Armitage et al. 2009). Knowledge integration is here described as social learning and knowledge sharing between actors, and thus involves a type of cooperative knowledge hybridization wherein actors recognize the legitimacy of and trust each others' knowledge (Armitage et al. 2010). One embodiment of this is the co-production of blended, hybrid knowledge by teams of resource users, managers, and scientists (Armitage et al. 2011; Campbell et al. 2016; Dale and Armitage 2011). In this idealized

vision of co-management, knowledge integration plays to the strengths of users and governments, leads to learning and adaptation, and countervails existing power structures between users and authorities (Armitage et al. 2010; Carlsson and Berkes 2005; Plummer 2009).

However, co-management is often precisely what precipitates the problems of knowledge integration described above, as with Sami reindeer (Johnsen et al. 2017) and whitefish in Alberta (Natcher 2000). Co-management brings resource users and government managers in close contact and has been critiqued for ignoring politics and power in this exchange, as well as for assuming that users and states have compatible goals, among a host of other critiques (Nadasdy 2007). However, there is huge variation in co-management, ranging from manipulative and token participation by users in state-driven governance, to user-created management with minimal legal support from the state (Armitage et al. 2010). Stephenson and colleagues suggest that the key to integrating fishers' knowledge in fisheries management lies somewhere within this range of co-management (Stephenson et al. 2016).

However, while there are reviews on how integrating science with fishers' knowledge for co-management "might be achieved" (Ommer et al. 2012, page 316), there is very little on how it has been achieved in particular contexts, beyond speculation (Bohensky and Maru 2011). This means that there are gaps in understanding what characteristics of co-management processes lead to different types of integration of

fishers' knowledge, how this knowledge integration might occur, what it would look like, and what elements of fishers' knowledge can be integrated through these processes. Understanding how and what elements of fishers' knowledge are integrated in fisheries co-management, which depends on fishers, could pave the way to expand the role of LEK in natural resource management more broadly.

One type of co-management where the integration of fishers' knowledge is likely to be particularly important is in the emergence of a new framing for marine protected areas (MPAs) that centralizes the role of fishers and aims to rebuild declining fisheries (Jupiter et al. 2014). Supported by evidence of positive ecological outcomes in MPAs that prioritize fisher engagement (Charles and Wilson 2008; Cudney-Bueno and Basurto 2009; Giakoumi et al. 2018) and critiques of MPAs that are imposed upon fishers with little of their input (Bennett et al. 2015; Campbell and Gray 2019; De Santo et al. 2011), this new framing of co-managed MPAs includes fishers starting from the design stage, and involves them in management (e.g., monitoring, enforcing) (Jupiter et al. 2014). As fisheries management tools, these areas (also called no-take zones or fishing refugia) do not fit some definitions of 'MPA' (WCPA 2018), but their support internationally is largely derived from MPA literature (Basurto 2017; Hilborn 2017). Mexico has been at the forefront of implementing these new fisheries tools, which it calls Fish Refuges (Zonas de Refugio Pesquero) (Ayer et al. 2018), and similar areas have been implemented in Fiji (Bonaldo et al. 2017), Indonesia (McClanahan et al. 2006),the

Solomon Islands (Govan 2009), Papua New Guinea (McClanahan et al. 2006), and the Philippines (Stockwell et al. 2009). Because these areas prioritize fisher engagement from the beginning, they provide an excellent opportunity to study how integration of fishers' knowledge navigates the barriers described above.

One prominent example is Mexico's first network of Fish Refuges, established in the state of Baja California Sur in 2012. Fish Refuges are an emerging policy tool for co-management in Mexico's fisheries, and is one of the few ways that fishers can participate in designing regulations. They are geographically-defined areas where fishing is banned ("no-take zones") or where only certain fishing activities are permitted such as fishing for bait ("partial-take zones"), and are typically temporary with an average duration of five years with the option of reassessment and renewal (CONAPESCA 2019; DOF 2014). We label them as a form of co-management because the process of establishing Fish Refuges requires involvement of both the state and fishers: fishers design them and the state legally establishes them. Fish Refuges are largely self-enforced by fishers, although they are nominally enforced by the state, and typically require support from NGOs. The Mexican government has called Fish Refuges a major contribution to fishers' participation in governance (CONAPESCA 2019) but the role of fishers' knowledge in their establishment has not yet been studied. Drawing on in-depth qualitative data we collected from 2016-2018 in Baja California Sur, contextualized in quantitative data

collected by collaborators working in the region since 2009, we address the following research questions:

> *How did actors engaged in establishing and renewing Fish Refuges navigate barriers of legibility and power to the integration of fishers' knowledge throughout the process? What type of knowledge integration resulted? What was the role of fishers' knowledge and science in decision-making processes?*

3.3 Methodology

3.3.1 Case study: Mexico's Fish Refuges, no-take zones proposed by fishers

As of December 2019, there are 36 Fish Refuges in Mexico covering 20,500 km^2 (CONAPESCA 2019). In this paper, we study the case of the first Fish Refuges in Mexico: a group of 11 areas designated in 2012 as no-take zones in Baja California Sur (DOF 2012), a state where fishing is of primary importance (Sala et al. 2004). The Gulf of California which borders the state produces 71% of Mexico's fisheries volume (OECD 2006), but the region is one of conflict and uncertainty from the narcotic trade, volatile prices, economic crises, and climate change (Micheli et al. 2012). Mistrust between managers and fishers has led to mismanagement and ecosystem degradation (Young 2001, Cudney-Bueno and Basurto 2009, Zepeda Dominguez 2017). Top-down fisheries management measures by the fisheries management agency (Comisión Nacional de Acuacultura y Pesca, hereafter CONAPESCA) have not succeeded at either limiting

fishing effort, with strong evidence of overcapacity across the country (Giron-Nava et al. 2018), nor maintaining healthy fish stocks (Saenz-Arroyo et al. 2005). Regionally, there is evidence of fisheries decline (Sala et al. 2004).

Decline has certainly been noticed by fishers of my study region (Niparajá 2009; Niparajá 2015), 100-miles of coastline called El Corredor San Cosme a Punta Coyote, hereafter the "Corredor". This region has 13 small towns and about 650 full-time residents that depend almost entirely upon fishing for their livelihoods, with some income provided by tourism and ranching. These towns are remote, some accessible by dirt roads and others only by sea, with no central electricity or water. Starting in the late 2000s, an NGO called Sociedad de Historia Natural Niparajá (hereafter, "Niparajá) started working on facilitating sustainable fisheries in the Corredor. One of the potential fisheries management tools they presented to the fishers of the Corredor was the Fish Refuges.

The process of establishing the first Fish Refuges started in 2009 and ended in 2012 with their establishment for five years. These Fish Refuges were renewed and slightly changed in 2017 upon their expiration. From 2012-2017, Niparajá coordinated and provided most of the funding to conduct social and ecological monitoring of the Fish Refuge sites, with support from university scientists and INAPESCA staff – and with monitoring conducted primarily by fishers from the Corredor. In 2012, Niparajá trained eleven Corredor fishers to count fish, invertebrates, and ground cover using

standardized transects and scuba gear, and from 2012-2017, these "*buzos monitores*" conducted annual ecological monitoring of the Fish Refuges alongside university students and Niparajá staff. In 2016, Niparajá in collaboration with Duke University conducted a standardized socio-economic survey of 102 fishers, of 173 total fishers in the region, to assess the perceived effects of the Fish Refuges. The first author participated as a field assistant to deploy these surveys, which brought her into contact with the region and its issues, as well as the subjects of the study.

3.3.2 Study design and data collection

This study involved six total months of fieldwork in the Corredor that occurred during different periods between 2016 and 2018, and that included observation, informal interviews, and semi-structured interviews. In May 2016, the first author was invited on the annual ecological monitoring trip to assess the Fish Refuges (a 10-day scientific cruise on a liveaboard boat) coordinated by Niparajá. On this cruise I conducted preliminary interviews about monitoring and knowledge with the eight "Buzos Monitores", fishers from the Corredor trained in scientific ecological monitoring, and observed their interactions with scientists, INAPESCA staff, and Niparajá staff. From June-August 2016, the first author conducted in-depth interviews with these "*buzos monitores*", visiting six of them who resided in the three largest towns of the Corredor: Puerto de Agua Verde (278 residents), San Evaristo (90 residents), and Tembabiche (80

residents). For these field visits I accompanied a team of students and field technicians who were conducting Niparajá and Duke's socioeconomic survey, mentioned above, with field support from Niparajá. During these field visits in 2016, I conducted 39 semi-structured interviews with fishers (n=22), their families (n=14), INAPESCA staff (n=2), and Niparajá staff (n=1), of which 29 were recorded and transcribed (duration 16-154 minutes, 37 minutes on average). During these interviews, I asked about the role of the Buzos Monitores in management, trust in the information they produce, and the effect of the program on the participants. These interviews relate to the hybrid information used in renewal of the Fish Refuges.

From October to December 2017, a period overlapping the renewal of the Corredor Fish Refuges, the first author conducted three months of fieldwork in the largest town of the Corredor, Puerto de Agua Verde (hereafter, Agua Verde), with several visits to the capital city of La Paz, with regional offices for CONAPESCA and INAPESCA. During this time, I conducted numerous informal interviews, kept a field journal for observations and reflections, and conducted 26 semi-structured interviews with Corredor residents (including leaders in the fishing sector (n=2), fishers involved in different programs for ecological data collection (n=3), members (n=6) and nonmembers (n=1) of fishing cooperatives, and Agua Verde community leaders (n=8) university scientists (n=2), INAPESCA scientists involved in the Fish Refuges (n=3), CONAPESCA leadership (n=1), and Niparaja staff involved in the Fish Refuges (n=3). Of these, 25 were

recorded and transcribed in full; length ranged from 31-404 minutes, averaging 79 minutes. Relevant questions focused on the role of different types of information and interpretations of that information in designing and assessing the Fish Refuges.

Because the bulk of fieldwork was conducted in one town out of the thirteen in the Corredor, albeit a town with approximately half of the Corredor's population, my conclusions are strongly influenced by the sentiments of Agua Verde residents who, in the 2016 survey, were more supportive of Fish Refuges reported seeing more positive results than fishers from other towns. While livelihoods, lifestyle, and what it means to "fish right" is shared across the Corredor's thirteen towns, Agua Verde is different in that it has the most and largest fishing cooperatives; has the longest time working with Niparajá; and, in the 2017 renewal, was the only town to change its Fish Refuge, more than doubling its size. So, results may be more positive here than throughout the region.

In addition to the fieldwork that we conducted (observation, field notes, interviews), we also draw on the socioeconomic survey of fishers (n=102) that Niparaja and Duke conducted in 2016. A team of trained enumerators conducted this survey using pen and paper in every town in the Corredor from June to December 2016. A third of respondents were selected purposively, if they participated in a similar survey from 2009, in order to compare results; the other two-thirds were selected randomly. We also contextualize my results in the ecological data that has been collected, analyzed, and reported by Niparajá. This data includes fisheries independent data (fish and

invertebrate counts along transects, statistically analyzed inside and outside the Fish Refuges) and fisheries dependent data (size, reproductive potential, and species composition measures of fish catch, collected by fishers from the Corredor, as well as journals of catch quantity and poundage maintained by cooperative presidents and fish buyers in the Corredor).

3.4 Results

We sought to understand how actors engaged in establishing and renewing Fish Refuges (fishers, managers, scientists, and NGO staff) integrated fishers' knowledge throughout the process, especially focusing on how they navigated power asymmetries and knowledge legibility and the roles of fishers' knowledge and science in informing decision-making. We found that this process involved what we call "ping-pong" hybridization, where the type of knowledge used bounced between what is generally classified as fishers' knowledge (Berkes et al. 2000; Hind 2015) and academic (ecological and fisheries) science, as well as a third type of blended knowledge conceptually between the other two. In this sense, the process of establishing Fish Refuges did not integrate a single, mixed hybrid knowledge, but rather, hybridization in series (see Discussion). We present the results chronologically (legal basis, design, establishment, evaluation, and renewal), presenting what knowledge was used and how in each step.

3.4.1 The legal basis for Fish Refuges: Few *a priori* knowledge requirements

One facilitating factor for the integration of fishers' knowledge was that the law gave no guidance on implementing Fish Refuges, such as how to write or evaluate a proposal (DOF 2007), until after the first ones were established. The legal basis of Fish Refuges was established in the General Law of Sustainable Fisheries and Aquaculture (Ley General de Pesca y Acuacultura Sustentables) in 2007 through several lines of text, listing Fish Refuges ("Zonas de Refugio") as one of the possible tools for fisheries management. The only guidance in this law was their definition:

> "Areas delimited in federal waters, with the primary aim of conserving and contributing, naturally or artificially, to the development of fishing resources through reproduction, growth, or recruitment, as well as preserving and protecting the surrounding environment" (Article 4, Item LI/51 of the Ley General de Pesca y Acuacultura Sustentables)

In 2010 when fishers were designing the first Fish Refuges, no further guidance had been legally published other than the lines of text above. The reason was that the 2007 fisheries law's "Reglamento" (literally, regulation), a document of technical guidelines to interpret and specify the procedures listed in the law, had not been written, and still had not been written as of my interviews in 2017. As such, the fisheries law depended on the Reglamento of the previous fisheries law from 1992, which did not include Fish Refuges in its text.

This allowed for flexible interpretation of knowledge requirements (Quintana et al, in prep). Since there was no official stance on the criteria or design principles for Fish Refuges, all guidance was informal, from individual fisheries agency officials – and thus subject to change from the changing political climate, waffling political will, and rapid turnover of agency leadership. However, there was some agreement on basic criteria of Fish Refuges through a series of discussions and meetings between fisheries officials and NGO staff from Niparajá and other NGOs working in Mexican fisheries in 2008 and 2009. One Niparajá staff person who had been involved since the beginning discussions told us:

> "The criteria that were set up before were: they had to be fishing areas, they had to be places with habitats that were important, they had to be places where we recognized and knew what biological or ecological process happened there, they had to be places where the people who were proposing them had to raise their hands and say, 'I will follow the rules and be compliant', and they had to be places that were feasible to enforce." (Niparajá staff, December 2017)

Formal guidance for Fish Refuges was finally published in 2014 (two years after the first Fish Refuges were established) as an administrative protocol for establishing Fish Refuges, known as "Norma-049" (Norma Oficial Mexicana NOM-049-SAG/PESC-2014). Norma-049, several pages long, describes the steps for creating Fish Refuges. It states that any parties interested in creating a Fish Refuge must send a proposal to the Director General of the national fisheries agency (Comisión Nacional de Acuacultura y Pesca, CONAPESCA), accompanied by a justificatory document. It states that the

justificatory document must contain 25 categories of information, which must then be validated by government's fisheries research agency (Instituto Nacional de Pesca y Acuacultura, INAPESCA). These categories include fisheries (stock status; value of fishery; historic catch), oceanographic (depth, temperature, currents), ecological (list of species in area; distribution of species), and socioeconomic (economic use of area; fishing effort; gear types) data, as well as the specific goals of that Fish Refuge. Norma-049 states that INAPESCA must then assess the proposal on its likelihood of achieving listed goals, and send its evaluation ("Technical Opinion") to CONAPESCA, which decides whether or not to establish the Fish Refuge as a secretarial agreement.

Nonetheless, in 2010, four years before Norma-049 was published, there was no official process nor instruction on what information was valid justification for a Fish Refuge.

3.4.2 Design of the Fish Refuges: Starting from science and designed using fishers' knowledge

The process started with the ecological science of MPAs. In response to national-level interest by NGOs and academics to establish Fish Refuges in Mexico following their appearance in the fisheries law of 2007, Niparajá approached the fishers of the Corredor in 2009 to gauge interest in establishing Fish Refuges there. Because of favorable responses, in April 2010 Niparajá held a series of workshops in different towns of the Corredor to teach fishers how to design Fish Refuges, based on the scientific

literature on MPAs. The workshops included discussions about basic marine biology such as food web ecology, partly led by NGO staff but also drawing on ecological knowledge of the fishers. The workshops also summarized and presented ecological theory about MPAs, such as edge effects, larval connectivity, and size recommendations for different goals. Niparajá encouraged fishers to identify specific objectives for their Fish Refuges and design them accordingly, considering concepts like edge effects, food webs, and larval connectivity. A Niparajá staff member told us,

> "We did this course on how to design Refugia [Refuges], or Marine Reserves, and what you should think about when you do it…We talked about big reserves versus small reserves. We talked about the size and shape of reserves, edge effects. We talked about connectivity: how to design reserves that connect different environments. We talked about the percentage of area a reserve should use, compared to the overall area – the overall size. We talked about the time reserves could be in place, and what the effects are of those reserves. And we talked about a whole bunch of design principles" (Niparajá staff, December 2017)

Niparajá staff told us that an important criterion was that the Fish Refuges had to be productive sites already, rather than barren sites. They described Fish Refuges as working like a fish "savings system – if you start with 0, you won't get very far" (Niparajá staff, December 2017). Through these workshops, Niparajá aimed to give fishers from the Corredor the best available science to design effective Fish Refuges that would benefit their fisheries the most.

However, when we interviewed fishers about how they designed the first Fish Refuges, they discussed several ecological and socioeconomic considerations, some of

which fit well into the literature's description of Local Ecological Knowledge (Berkes 1999) and some of which were scientific principles discussed in the workshops with Niparajá. A staff person from Niparajá told us, "The criteria that were used in the actual design of our network, were some of those but not all of those" (Niparajá staff, December 2017). The major scientific principle that fishers used to design their Fish Refuges, at least in some parts of the Corredor, was that they chose productive sites. Many respondents echoed Niparaja's language, using words like "bank" or "savings" to describe how the Fish Refuges worked. One fisher told us, "The place where we established the Refuge was a strong place of work… By 'strong', I mean it is very productive, that place" (fisher, November 2017).

The way that many fishers talked about the Fish Refuges implies that they were convinced of the potential of the Fish Refuges to work by Niparajá, who from my conversations seemed convinced by the scientific literature on the ability of MPAs to benefit fisheries. In describing the initial idea, fishers identified Niparajá as the source of the idea. One fisher, for example, describing when he learned about Fish Refuges from Niparajá, told us, "it was like a light bulb" (fisher, November 2017).

It seems that, following the workshops, the fishers took ownership of the idea (Quintana and Basurto, in review). One fisher in an interview describing being ridiculed by fishers from outside because of their willingness to establish Fish Refuges (" 'How stupid they are'. These are the comments they tell you, as a fisher, when they see you in

town", November 2017) – but he then defended the idea to us, as well as the Fish Refuges they had made. The design they chose for the Fish Refuges ultimately drew on both ecological and socioeconomic considerations. They used ecological characteristics like productivity to identify potential areas, but they used socioeconomic characteristics to select the final areas from those potential sites.

For example, the characteristics Agua Verde fishers used to design their Fish Refuge were high habitat diversity, high productivity in terms of fish catch, and the potential to benefit multiple fish species that they target, especially the most important species they catch, red snapper ("*huachinango*"). One fisher told us that they picked the specific size and boundaries of the Agua Verde Fish Refuge by including one area where *huachinango* breeds, one area where rays (elasmobranchs) breed, and several areas where snapper (*Lutjanus* sp.) and grouper (*Serranidae*) breed. This kind of thinking aligns with the scientific workshops from Niparajá. The length of time that the fishers proposed for the Fish Refuges (five years) also aligned with scientific recommendations. One fisher told us that they considered less time (for example, three years) but that they wouldn't be able to see if there were real changes in three years, and so decided upon five years. This fisher was not asked about the source of this information (that five years but not three would show ecological changes), whether it was from a Niparajá scientist or from his own knowledge, but this kind of ecological thinking at least aligns with what the scientific workshops recommended.

However, while these fishers considered ecological factors for the place they chose, we deduced that the fishers did not optimize for ecology, but rather for social-ecological considerations. When we asked fishers about the characteristics of a good Fish Refuge, they mostly emphasized social aspects like the commitment of local fishers and ability to monitor and enforce it: "The characteristics of a good Fish Refuge are that it is well monitored, well enforced, so that the day of tomorrow we can convince the people who aren't convinced that they do work. We have to understand everything first, to make the rest understand. And so we have to work on convincing people…They have to agree for a Fish Refuge to work" (fisheries sector leader, November 2017). A fishing leader from Agua Verde told us, "For [a Fish Refuge] to work, we need to care for it. If we don't care for it, it can be there, a reserve, for 20 years and it all goes to the pirate[s]. Maybe you don't fish there, but someone else comes and fishes it all" (Agua Verde fisher, November 2017).

Fishers similarly drew primarily on socioeconomic factors to select specific sites. Although they wanted to include important areas for multiple species, these fishers were also cautious not to 'close off' entire fishing grounds for any one species. For example, one fisher told us that, had they extended the border 500 meters further past a particular rock, they would have closed off all areas for fishing *huachinango* that were close to Agua Verde; this would mean they would always have to make long journeys to fish for *hauchinango*. And so they selected the size based on what was a feasible size of

area to close. Fishers repeatedly emphasized social considerations in my interviews, telling us that they did not want to 'harm' specific groups of fishers unfairly, and that they wanted a place that was easy to monitor and enforce. The Agua Verde fishers picked San Marcial over other productive and ecologically diverse places because it was close enough to monitor easily. My interpretation of these interviews was that fishers used ecological criteria to identify a number of potential places for the Fish Refuge. Then, they used social criteria to select the best option. Finally, they used detailed, site-specific knowledge of the area from their fishing experience to fine-tune the parameters of their proposals. In all cases, it was fishers' knowledge that provided the data for these criteria, some of which (the ecological criteria) were provided by Niparajá based in science, and others which the fishers conceived of themselves. Part of this iterative consideration between ecological and social considerations can be seen in my conversation with one fisher, who is a leader in one of the fishing cooperatives:

> Interviewer: "Why San Marcial?"
> Fisher: "It is an area where fish gather. It was a good fishing area there, and if we wait a while [with the Fish Refuge], there will be a lot of fish there."
> Interviewer: "And why did you pick there and not another area?"
> Fisher: "Because it is easy to guard [*vigilar*]. You go out to fish, and you pass there. And on the other hand, if you don't go out, everyone else can guard there. If one boat goes out to fish, it passes there. And if you leave here, you pass there. And that is why we wanted that place: everyone passes there, you see a diver or someone fishing there, and you talk on radio to say, that a boat or diver is fishing here. That is why we picked that area." (Agua Verde fisher, December 2017)

The specific decision-making process to design the maps was facilitated by Niparajá but occurred mostly in their absence (Niparajá is based in the capital of the state, several hours from the nearest town in the Corredor). At the end of the workshops on designing MPAs, fishers who attended the workshops (n=55 across four workshops, about a third of the fishers in the Corredor) proposed initial ideas for the Fish Refuge sites, which they drew on large, poster-sized maps provided by Niparajá, and left in the towns. Over several weeks, fishers discussed, drew on, and edited the maps. By summer 2010, the fishers from the 13 towns of the Corredor had designed 11 Fish Refuges, each town selecting one or more sites within their habitual fishing grounds. In places where fishing areas overlapped between towns, as is the case in the southern Corredor, several towns agreed together to one or more Fish Refuge. The final map of locations was approved and signed by about two-thirds of the fishers of the Corredor. The other third did not sign for a mix of reasons, including apathy, disinterest, mistrust in legal processes, and disagreement with the final map.

The Corredor fishers designed the map but it was Niparajá who wrote the bulk of the proposal. Once a majority of fishers agreed on the final map for the Fish Refuges, Niparajá compiled this with a 41-page justificatory document to submit to CONAPESCA. The justificatory document explained the ecological-scientific rationale for establishing no-take zones to benefit fisheries and the legal context of Fish Refuges. It included descriptive biological, fisheries, and social information about the Corredor

based on Niparajá's census of fishing activity, socioeconomic survey of fishers in 2009, and official catch data, organized into maps and graphs. A Niparajá staff member involved in writing this document told us that it used some of the logic behind protected area feasibility studies, which they had experience writing. This same person told us that there were "huge holes" in the proposal because they did not have any data or analysis on size distributions of fish populations, catch per unit effort, or the status of the fisheries: "There were huge holes, so we said: we think this is a really big action needed to rebuild fisheries, because it looks like fisheries are going downhill, and the fishers perceive this, and they want this, and here's the proposal" (Niparajá staff, December 2017). Even after all their data collection efforts, Niparajá staff saw the proposal as lacking in information because of the lack of scientific fisheries information.

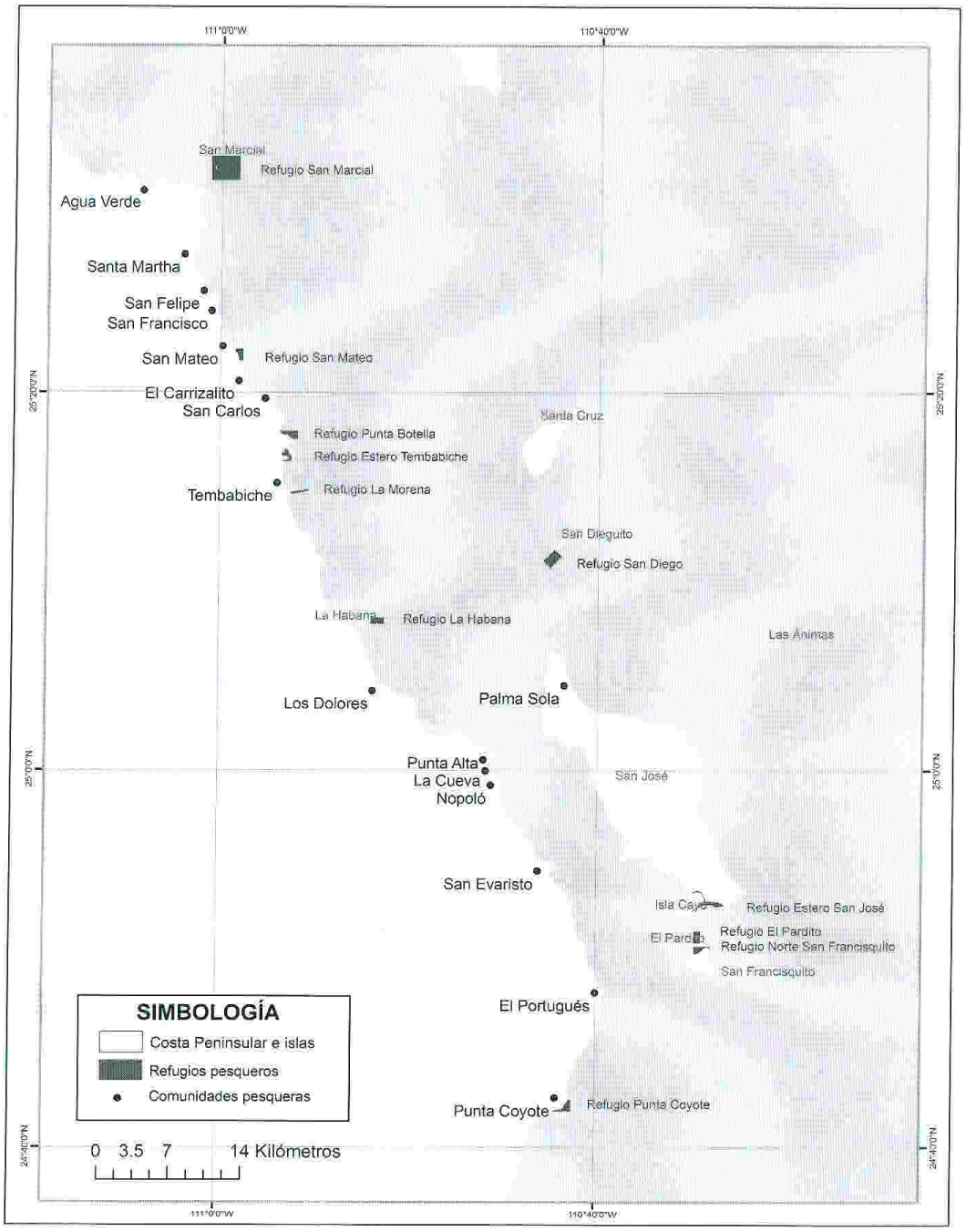

Figure 6: Map of the original Fish Refuges included in the original proposal assembled by Niparajá in 2010 (page 17 of the proposal).

3.4.3 The 2-year stalemate from knowledge illegibility

Knowledge legibility and power issues caused the proposal to languish in government offices for two years, from 2010-2012. In October 2010, Niparajá submitted the proposal for Fish Refuges (map and justificatory document) to CONAPESCA (the government fisheries agency) on behalf of over 100 fishers of the Corredor. CONAPESCA sent the proposal to INAPESCA (its research arm) for a technical evaluation. There the proposal stalled for nearly two years. In September 2012, INAPESCA sent their technical evaluation to CONAPESCA, stating that they had no technical objections to the proposed Fish Refuges. CONAPESCA then approved the Fish Refuge proposal and pushed it through the legal process; the first Fish Refuges were finally published as a secretarial agreement in the Diario Oficial de la Federacion, the legal registrar for all laws in Mexico, on November 16, 2012 (DOF 2012).

The reason INAPESCA struggled to write the technical evaluation is because the knowledge in the proposal was not legible to them. As mentioned above, the proposal contained mostly descriptive information about fishing activities and fishers' perceptions, without information like catch per unit effort or size distributions of fish stocks. This proposal was, in fact, based on Niparajá's extensive data collection using social science methods to collect and organize fishers' knowledge: focus groups in every Corredor town in 2008, a census of Corredor fishing effort in 2009, and a survey of fishers in 2010. Niparajá had distilled this knowledge to identify fishers' claims that

fishing was in decline and areas of key habitat for different species, a process much like Holm's FEK to FEK* transformation (Holm 2003).

However, INAPESCA is set up to use formal fisheries science alone. Their evaluation tools are primarily concerned with assessing fisheries based on standardized, statistical, and quantitative methods deemed as legitimate within the field of fisheries biology; they are not trained to accommodate or evaluate FEK* or fishers' knowledge. One INAPESCA official, who himself values the knowledge fishers have and interviews them as part of his fisheries assessments, told us that even he has never been able to integrate this knowledge formally:

> "Frankly, formally, I have never used information from fishers to make an evaluation or a recommendation. In an informal measure, when I interview them, I ask them, I try to get to know what they know, and as a function of this, I define areas and time periods to sample, things like that. But formally, I have never integrated that information. I use it to do the study. But I don't integrate it formally into the analysis" (INAPESCA staff, November 2017)

This all meant that INAPESCA did not have the tools to determine from the information given whether the Fish Refuges were optimally designed. An example is the number of Fish Refuges (11), which was a product of process where each town suggested their own Fish Refuge(s), unless they had overlapping fishing areas in which case they collaborated. Most towns suggested one Fish Refuge, although one suggested four, and several collaborated on a single area. INAPECA struggled to determine whether 11 was the optimal number: "One thing was the number. Why were there 11? Why not 15? Or why not 1?" (INAPESCA staff, November 2017). Another staff member

told us, “There were certain doubts, certain reservations, about how they defined the areas. The fishers just put them in…we didn’t have more information” (INAPESCA staff, November 2017). They said they did not have the capacity to analyze the information because it was descriptive and much of the information came directly from fishers rather than from fisheries scientists collecting data. They also said they did not have information on the status of the fishery, and that Fish Refuges were intended for fisheries in decline.

The knowledge in the proposal was equally illegible to outside scientists, who attacked it retroactively because of a perceived lack of scientific information. A university scientist we interviewed in 2017 told us that, when the first Fish Refuges were established, there were no “studies”: “Those Fish Refuges were formed, were decreed, without a single study. I know the case perfectly well” (university marine scientist, November 2017).

Over the two years that INAPESCA resisted giving a technical evaluation, Niparajá put pressure on government officials to keep the process moving. As part of other ongoing projects, Niparajá staff met with high-level officials from CONAPESCA and INAPESCA from 2010-2012, and when they could, asked whether the proposal had been reviewed. At one point, they flew two fishers from the Corredor, who had never flown on a plane, to meet with top director of CONAPESCA at the national level. These fishers directly demanded to know what was going on with the Fish Refuges; they

explained why they wanted Fish Refuges and argued that they had done everything legally required to propose them. Finally, after two years of building pressure, CONAPESCA demanded the technical opinion from INAPESCA, who sent a technical evaluation in September 2012.

Ultimately, INAPESCA never recognized the legitimacy of the fishers' knowledge, but they supported fisher engagement in management. When INAPESCA issued what they called a "positive" technical evaluation, they did so on the basis of strong fisher support. Although INAPESCA never recognized the legitimacy of the fishers' knowledge that was in the proposal, they supported fishers getting engaged in management, and especially fishers agreeing to abide by a fisheries regulation. INAPESCA staff told us, "[The proposal] had a deficiency of technical information, but it had the backing of its own community, that it was something that was born from them" (INAPESCA staff, November 2017). INAPESCA was able to justify its technical opinion by invoking the precautionary principle: "We abide by the precautionary principle: not, for the lack of information, to do nothing" (INAPESCA staff, December 2017). In their opinion, INAPESCA wrote not that it seemed likely that the Fish Refuges would work, but rather that they did not have enough information to determine whether or not they would work. Thus, invoking the precautionary principle, they were able to support a 5-year period of implementing Fish Refuges in the Corredor.

3.4.4 Assessment and renewal: Fishers' knowledge and fisheries science interwoven

After 5 years, in 2017 the Fish Refuges were assessed and renewed. In this new process, fishers' knowledge was again integrated through their design of the renewed Fish Refuges, although in the renewal process there was much greater overlap of fishers' knowledge and science than in initial establishment. Scientific analyses of data largely collected by fishers played key roles in convincing scientists at INAPESCA and externally that the Fish Refuges were working, and should be renewed. However, for the fishers – the stakeholders whose opinion would be actually reflected in determining whether or not to renew or change the Fish Refuges – these scientific analyses were only convincing to some. These fishers drew on several sources of information, mostly based on their own knowledge or the knowledge of trusted fellow fishers, to determine if the Fish Refuges were working. The assessment and renewal of the Fish Refuges thus depended upon what we call the "ping-pong" hybridization of knowledge, depending upon fishers' experiential knowledge and scientific knowledge at different stages.

The process of renewal was essentially the same as establishment because there is no legal distinction between renewal and establishment. In 2016, in anticipation of the expiration of the Fish Refuges in 2017, Niparajá facilitated the process of determining if the fishers wanted to renew their Fish Refuges, and spearheaded a second process of decision-making, starting with a survey of fishers (n=95) including several questions on whether they wanted to keep, remove, or change each of the 11 Fish Refuges, and/or

propose new Fish Refuges. Niparajá hosted a workshop from February 23-24, 2017, to disseminate the results of the survey and other data collection efforts, and invited fishers, government fisheries staff, and academic scientists. Fishers then debated whether to renew or change the Fish Refuges at several meetings through the Corredor. They decided on a final proposal, signed by over 100 fishers, to renew the Fish Refuges for another 5 years, with some changes from the original design. Niparaja wrote another justificatory document and sent these to CONAPESCA, who sent them to INAPESCA. INAPESCA gave a favorable technical evaluation, and in November 2017, CONAPESCA approved the proposal for another 5 years.

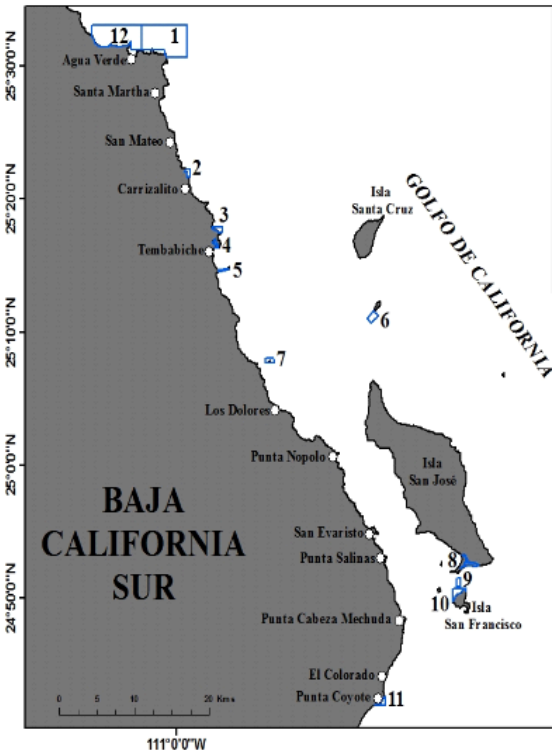

Figure 7: Map of renewed Fish Refuges in 2017 (DOF 2017); changes from 2012 are: one area (San Marcial) expanded 5x; another (La Brecha) added; both at top.

However, several important changes occurred between 2012 and 2017 when the Fish Refuges were being renewed. The legal structure had gotten more rigid; Norma-049 had been published with its 25 categories of data to be included in a Fish Refuge proposal. Some of these overlapped with the original criteria that Corredor fishers used (habitat types; productivity) but they did not include some of the important social considerations (ease of monitoring; not prejudicing against any one group of fishers; not closing the most economically important areas). The new legal structure meant that the proposal for CONAPESCA had to be justified with extensive fisheries, biological, and socioeconomic information. Also during this time, Niparajá started two data collection programs involving fishers. One was an annual underwater ecological survey conducted by a handful of fishers (the "Buzos Monitores"), whom Niparajá trained to conduct transects and identify; their goal was to compare biodiversity and abundance inside and outside the Fish Refuges. The other program was the "Técnicos Pesqueros" ("fisheries technicians"), fishers paid a small stipend to collect length, weight, and reproductive information on the fish they caught throughout the year; their goal was to estimate changes in fish catch composition. These programs meant that, by 2017, there was much more quantitative data available about the Fish Refuges.

The summary of the ecological information analyzed by Niparajá and presented in the February 2017 results workshop was that the Fish Refuges were leading to small but detectable increases in fish biomass. Some of the most salient conclusions were that

there was a 30% increase in biomass inside the Fish Refuges compared to control sites, and that several of the Fish Refuges overlapped important larval export sites for the entire Corredor region. The recommendations summarized by Niparajá in a document they released following the meeting were to renew all the Fish Refuges for another 5 years; to expand all to 3-5 km length on each side (at the time, almost all had less than 1km length on each side) based on results on scientific literature; and to continue monitoring (socioeconomic and ecological) (Niparajá 2017). In presenting the results to the fishers and government agency staff, Niparajá emphasized quantitative analyses like comparing fish and invertebrate biomass, diversity, and species richness between Fish Refuges and control sites, collected through the Buzos Monitores program.

University scientists agreed with Niparajá's interpretations of the outcomes of the Fish Refuges: non-optimal yet producing positive ecological results. One of the aspects that most scientists disagreed with was the size: "The Refugia are very tiny, as I said. The minimum size, the ideal one, should be at least a few kilometers" (university scientist, November 2017). And yet, this same scientist asserted that the Fish Refuges are increasing the fish biomass, pointing to data from ecological surveys: "They have been very successful. In the data that we have, we have seen that the size of the animals has increased, as much inside the Refuges as outside the Refuges, which is the idea… In parrotfish, the changes can be seen quickest. We have seen a 25% increase in the biomass" (university scientist, November 2017). Nearly all of these biologists (university

and INAPESCA) that we talked with explicitly attributed the positive outcomes to the fact that the Fish Refuges serve as an ecological "network", citing studies that networks (i.e., groups of ecologically connected areas) can improve no-take zone effectiveness. This, they attested, made up for what they saw as the small size of the Fish Refuges. They also pointed as evidence of ecological effectiveness to the multiple streams of data: that the trends in biomass and diversity could be seen in both underwater monitoring data from the Buzos Monitores and, more slowly, in the fisheries data from the Técnicos Pesqueros.

Both the 2016 survey and the final decision to renew the Fish Refuges suggest that most fishers think that the Fish Refuges are providing benefits. In response to the 2016 survey question asking how fishing would be if they had never put in Fish Refuges (n=95), about 2/3 of fishers thought that it would be worse without Refuges (6% said it would be better; 31% said it would be the same; 41% said it would be worse; and 22% said it would be much worse). Only one third (34%) of fishers in the survey (n=95) noticed changes in the abundance and size of specific species in catch after the implementation of the Fish Refuges. Of 156 changes noted (each fisher could identify multiple species that had changed in abundance or size), 100 (64%) were inside the Fish Refuges and 56 (36%) were outside. Most of these changes were increases, with 86% reporting increases in abundance (14% decrease) and 89% reporting increases in size (11% decrease). Most fishers who saw changes were supportive of keeping or expanding

the Fish Refuges, while those who did not notice changes were more likely to advocate for removing the Fish Refuges.

When we asked fishers in interviews what knowledge they used to assess whether the Fish Refuges were working or not, they mentioned two main sources of information: their own experience, and the Buzos Monitores. Fishers gathered information through their own experience by directly observing the Fish Refuges, sometimes chumming the water with bait to see how many fish came to the surface. They also informally monitored their own catch, noting whether the number and size of fish (especially the most important species, *huachinango*) had increased measurably, and whether their incomes had increased. Many fishers also mentioned the Buzos Monitores, the fishers who had been trained to monitor the Fish Refuges using underwater transects, as their information source to determine renewal. They emphasized that the Buzos Monitores had seen results with their eyes, while under the water: "the Buzos Monitores that just did the monitoring, they found large grouper, snapper, parrotfish" (fisher, November 2017) and "There are four Buzos [Monitores] here who said, this year, they saw a lot of fish" (fisher, November 2017).

While the Buzos Monitores produced the information that both fishers and scientists used to demonstrate that the Fish Refuges were working, the way this information was interpreted and used was very different. The scientists we interviewed focused on the analyses of the transect data, and the trends that could be extracted from

these. My fisher respondents, on the other hand, emphasized the findings that the Buzos Monitores directly noted and reported immediately upon return: the size of fish they saw, the quantity, and the location. Fishers also emphasized personal trust in the Buzos Monitores; trust in the person was tightly linked to trust in the information.

Conversely, many of my fisher respondents expressed distrust of scientists' ability to monitor fishing areas, citing conflicts of interest and a lack of practical sea knowledge. One of the Buzos Monitores, who has been trained in ecological transect methods and has worked extensively alongside scientists, explained that he does not trust the data scientists produce unless he knows they do the methods well:

> "Many scientists study without knowing reality. They know letters, but a fisher knows more than them. They know the methods better, but they don't know how to work under the water…. For people from outside, you can't trust them, because you don't know them. So I don't trust anyone from outside until I get to know them. They're all the same. For example, they might know the scientific names, but under the water a fish might look one size, but it's really very different. But the scientists don't know that. The only thing I trust them in is the scientific name and the methods. But the majority that have been under the water with us are not trustworthy." (Buzo Monitor, July 2016)

Another respondent told us, "I wouldn't trust much in the scientists because they have other ideas…I trust more in the Buzos Monitores because they are from this community and I know them" (fisher, July 2016). Another told us, "Scientists say things that aren't true. They say that whales used to have legs like dogs" (fisher's wife, August 2016). Given this mistrust in science, it is not surprising that most of my respondents did

not point to scientific results to indicate whether they thought the Fish Refuges were working after 5 years, or not.

Niparajá staff that we talked to lamented the lack of science in the process of designing and evaluating the Fish Refuges. One staff member from Niparajá told us that in design of both the original Fish Refuges and the renewal, "what we really hoped was that the original proposal by the fishermen would be improved by INAPESCA" (Niparajá staff, December 2017). Instead, this stakeholder told us, it was a "process to redesign them based only on fishermen's desires, with hardly any science involved in it". This stakeholder connects this lack of science to poor predictions of performance: "Do we have expectations of the Fish Refuges doing more? I don't really. Because, why would they get more? They didn't make them bigger. They didn't make them last longer" (December 2017).

In this case of the first Fish Refuges, government scientists never had to recognize the legitimacy of fisher knowledge because Niparajá assembled and cleaned the fishers' knowledge in the proposal, combining it with ecological and fisheries data. INAPESCA was able to use the precautionary principle to justify its "positive opinion". A scientist told us, "The data that CONAPESCA recognizes is scientific data… And the people from CONAPESCA know that data comes from the scientists. You know that the people of CONAPESCA, the only people they heed are scientists" (academic scientist,

November 2017). Similarly, INAPESCA discredits the knowledge of fishers without confirmation by science. A previous INAPESCA director told us:

> "The zones they selected, the fishers said, here is where the fish reproduce. And my question was always, how do you know that they reproduce? It is that there are many fish? Fish come together to do many things, not just reproduce. They make aggregations to eat, for protection - without the goal of reproduction. That is to say, just because the fish are aggregated, doesn't mean that they are reproducing… we have to make sure that if the fisher says that the huacho reproduces there, we confirm with eggs" (previous INAPESCA director, November 2017).

Whatever knowledge the fishers used to make their decision, they ultimately decided to renew the Fish Refuges. The only change was that the largest Fish Refuge, the San Marcial Refuge decided upon by fishers of Agua Verde, was quintupled in size (from 6km^2 to 33km^2). Additionally, the fishers of Agua Verde proposed a second Fish Refuge (27km^2) that was limited-take rather than no-take, where fishers could fish for bait only. 146 people signed the map proposal, which was accompanied by another justificatory document with the 25 categories of information requested by Norma-049. INAPESCA issued its technical opinion – in 101 days after receiving the proposal rather than the 60-day limit imposed by Norma-049, but much faster than 2 years as had been the case for initial establishment. The opinion said that INAPESCA had "no technical objection to validating the establishment or renovation of the Fish Refuges in the Corredor," which was enough for CONAPESCA to approve the areas. Finally, on November 15, 2017, the secretarial agreement for the renewed and larger Fish Refuges

(now, there were 12 of them) of the Corredor was published in the Diario Oficial de la Federacion, to be legalized for another 5 years (DOF 2017).

3.5 Discussion

3.5.1 Ping-pong hybridization

In this process of establishing and renewing the Fish Refuges, it seems that hybridization has taken a peculiar form to navigate these barriers of legibility and power. Rather than a blended hybridization including some elements of each fishers' knowledge and standardized scientific methods (such as knowledge co-production promoted for co-management (Armitage et al. 2011; Campbell et al. 2016; Dale and Armitage 2011)), hybridization here was iterative, with different steps integrating different types of knowledge. The process started from ecological-scientific design principles for MPAs, but fishers adapted and complimented these using their own knowledge. Niparajá then repackaged their design with science in the proposal that they submitted to CONAPESCA. In renewal, fishers referenced the Buzos Monitores (fishers trained in scientific data collection) to support their design, but they primarily referenced the Buzos Monitores' personal observations under the water in the Fish Refuges, rather than the data they collected there. Again, Niparajá packaged the fishers' design with science, which was legible and legitimate to INAPESCA. Because this dynamic hybridization occurred as back-and-forth bouncing between science and LEK

through the process driven by knowledge used in decision-making by different actors, we call this "ping-pong hybridization".

This idealization depends on a conceptual dichotomy between LEK and science, which reflects many parts of this process but not all. Fishers did use LEK and managers and scientists did use science in their decision-making throughout, but there was certainly crossover, and this distinction is getting blurrier over time. To design the original Fish Refuges in 2010 and again for the re-design in 2017, fishers from the Corredor primarily drew on their experiential information gathered from fishing and living in the Corredor. However, the idea to make Fish Refuges in the first place came from Niparajá, informed by the scientific literature, and some of the principles the fishers considered were scientific design principles from the workshops put on by Niparajá (e.g., selecting a productive fishing ground). Managers (INAPESCA and CONAPESCA) at first struggled with the proposal due to the perceived lack of rigorous science, but eventually found a way to accept the proposal (i.e., the precautionary principle) in response to political pressure from Niparajá and interest in fisher participation in management. Niparajá has a foot in both camps; it funds expensive and extensive scientific data collection and analysis about the Fish Refuges, but its staff have also repeatedly indicated that they respect the knowledge fishers have, and from the beginning reflected this in their actions; the workshops from 2010 featured discussions where fishers drew food webs and contributed their knowledge about local ecology. The

line between LEK and science is particularly blurry for the Buzos Monitores program, which at first looks much like the co-production discussed in the literature on co-management (Armitage et al. 2011; Campbell et al. 2016; Dale and Armitage 2011). However, for now, the Buzos Monitores are perhaps more like data technicians (Murray et al. 2005); while many fishers used information from the Buzos Monitores to evaluate whether the Fish Refuges were effective, they did not draw on the statistically analyzed data, but rather on personal accounts directly from trusted Buzos Monitores.

Enforcing the dichotomy between LEK and science as many LEK researchers intentionally or inadvertently do (including this paper) is boundary work that stabilizes these two concepts in opposition to one another (Gray 2016). In many cases, this dichotomy has not served resource users. There are published cases where their knowledge has been ignored when it does not conform to idealizations of LEK (Agrawal 1995; Tuhiwai-Smith 1999), where their knowledge is respectfully described and acknowledged but sidelined in favor of scientists' recommendations (Gray 2016), and where their knowledge is used against them (Silver and Campbell 2005). What we hope to achieve with the concept of ping-pong hybridization is an emphasis on the dynamism (i.e., decision-making power moving between actors using different knowledge systems) rather than further stabilize the concepts of LEK and science.

Our findings align with others who advocate for hybrid knowledge in fisheries management (Callon et al. 2002; Holm 2003; Nowotny et al. 2001). Stephenson and

colleagues (2016) argue that most fisheries management already uses hybrid knowledge, even though it may not be recognized as such given the enforced dichotomy of science and LEK; for example, they argue that fisheries-dependent data (e.g. catch data) is a form of local knowledge provided by fishers analyzed using scientific procedures (Stephenson et al. 2016). Hybridization may be especially important if LEK is indeed declining, as suggested by a recent meta-analysis that reported generational loss in 77% of 80 published papers about changes in LEK globally (Aswani et al. 2018). In the 15% of cases from their meta-analysis where LEK was not in decline, one of the principal reasons LEK was maintained was hybridization with science (Aswani et al. 2018). Still, the project of hybridization, like integration, seems likely to run into barriers of legibility and power. Below we address how ping-pong hybridization specifically addressed the barriers of each legibility and power.

3.5.2 Overcoming legibility barriers: LEK is legible to fishers

This case featured similar legibility barriers to integrating LEK similar to those documented in other cases of fisheries management, viz., that fisheries management cannot integrate LEK in its raw form (Gray 2016; Holm 2003). Government fisheries scientists in my case reported being unable to integrate fishers' knowledge in their research projects, even when they wanted to, as one official described to us. The two-year delay to implementation was evidently a direct outcome of government scientists'

inability to assess a proposal based on knowledge from fishers. Government scientists throughout the process expressed a preference for science-based management.

We argue that the process of establishing Fish Refuges was able to overcome legibility barriers to integrating LEK because of several key features. First, although Niparajá had a heavy hand in facilitating the process, the fishers had decision-making power to actually design the Fish Refuges. This meant that they were able to draw on their own LEK directly, without having to transform it. This aligns with Stephenson et al. (2016)'s prediction that LEK is likely to be integrated in management processes designed to use and receive it, such as co-management where fishers have a central role. This challenges some assumptions about what Petter Holm describes as FEK*, Fishers Ecological Knowledge that has been separated from its context, summarized, and distilled into the "useful" parts. Here, instead of translating fishers' knowledge to FEK* in order to use in management, a pathway that Holm (2003) discusses, translation in this case occurred after fishers' knowledge had already been integrated in management. This *ex poste* transformation by Niparajá served to justify the design the fishers had created and make it legible enough for government scientists to approve – and thus facilitate the integration of 'raw' fishers' knowledge in management, a very different picture than typical in the integration of fishers' knowledge in management (Carr and Heyman 2012; Hind 2015; Silvano and Valbo-Jørgensen 2008). Davis and Wagner have argued that documenting LEK must precede the role of local people in natural resource

management: "While acknowledging that LEK potentially offers much with regard to developing alternative proposals for effective approaches in natural resource management that include and empower local people, certainly few would dispute the view that this potential is only realizable through *a process that will, first, carefully and thoroughly document LEK systems*" (Davis and Wagner 2003, p. 466, emphasis added. However, this case suggests that knowledge integration may come from a process that involves local people first, with the documentation of their knowledge after. LEK is legible to the resource users – so if they design regulations, LEK is reflected in regulations, even if it is not legible to the state.

Another key feature for overcoming legibility barriers was the vagueness of the law. This meant that there were no a priori criteria, knowledge, or data requirements when the first Fish Refuges were being established, so that fishers were able to set their own criteria. Government fisheries scientists did not have precise objectives or procedures to evaluate the Fish Refuges, which led to delay, but also ultimately meant that the proposal could be approved as it was written. However, since the first Fish Refuges were established, new legal guidelines have emerged (Norma-049) specifying categories of information that must be included in a Fish Refuge proposal. This has not affected the fishers' ability to use their own knowledge to determine renewal, probably because of the extensive social, ecological, and fisheries data available by 2017, which could be strategically drawn upon by different actors. However, the new policy could be

a barrier to fishers using their knowledge to establish new Fish Refuges in other parts of Mexico, especially if they do not have an NGO partner to provide all the categories of data required by the new law. The stipulation of particular categories of data to provide could also lead to a process where fishers' knowledge is used to design proposals, but that this is 'checked' by scientific studies. Using LEK as a hypothesis to be checked by science is used in fisheries management (Hind 2014), and can serve to disempower and marginalize LEK (Holm 2003).

A final key feature for overcoming legibility barriers in this case was interest from the government in promoting fishers' engagement in fisheries management. Government officials emphasized their eagerness to enact a type of fisheries management that fishers could agree to. These officials never suggested that their institution thought the fishers' knowledge to be a legitimate and legally defensible source of information, although as stated above, one official does use fishers' knowledge to design his fisheries research. However, there has been increasing interest in fishers' participation in management, and thus in enacting legislation that the fishers supported. A government fisheries scientist from INAPESCA discussed this with us:

> INAPESCA official: "Since the beginning, the fishers agreed with having them [the Fish Refuges]. And this influenced INAPESCA's decision a lot, to give a positive decision."
> Interviewer: "And why, if INAPESCA is the research branch of CONAPESCA?"
> INAPESCA official: "Because when you put a restriction on them, it has always been top-down. They see it like this. We have always studied restrictions of closed seasons, minimum sizes, quotas. You study and see where you can pull the reins, or limit them. And the fishers never agree with these

> things. The fishers always scream and they see it as a punishment. And in this occasion, we saw that the community was interested. Ultimately, you are restricting their fishing area for 5 years. So when you see that they say, "we want it" – "ah, good". Let's go ahead. Because our mission ultimately is to care for the resource. (0020, Nov 2017)

3.5.3 Overcoming power asymmetries: Dynamic decision-making using different knowledge systems

Ping-pong hybridization has meant that different actors could appeal to different sources of information and different systems of knowledge to defend their claims about the Fish Refuges. In other cases, the power asymmetry between fishers' knowledge and formal fisheries science has meant that fishers' knowledge is co-opted or subsumed into fisheries science, often for management envisioned as necessary by scientists (Nadasdy 1999; Nadasdy 2005). In this case, the process of establishing Fish Refuges avoided these issues because the resource users directly designed the Fish Refuges, albeit within a process shaped and facilitated by the NGO, Niparajá. For the resource users, their own knowledge was the most legitimate for both designing and assessing the Fish Refuges, and certainly more trustworthy than science. Because the decision-making locus moved back and forth between fishers and managers, each could draw on their own knowledge system; in this way, LEK did not have to overcome power asymmetries.

An important part of the process was political pressure from Niparajá on the Mexican government to keep the process moving. The fishers' knowledge, having been formalized in the proposals to establish and renew the Fish Refuges, survived the

process of legalization (i.e., technical evaluation and approval by the fisheries agency) because of political support from the NGO, Niparajá, which was relentless in following the progress of the proposal. In other cases, NGOs have served as gatekeepers that mediate how fishers' knowledge is used in management (Gray 2016). In my case, the NGO has played an important role in supporting fishers' knowledge being directly reflected in local management. While they have lamented some of the decisions the fishers made, and wish they had incorporated more science, they ultimately supported and defended the fishers' active role in their own management by putting pressure on CONAPESCA to demand the technical opinion from INAPESCA.

Ping-pong hybridization has also meant that the process did not depend on actors trusting in each other's knowledge systems. Indeed, scientists are still doubtful about the fishers' knowledge, and fishers are skeptical of much of the science they receive, which they perceive as biased or lacking in know-how. Yet because of knowledge hybridization through the process, fishers were able to use their own sources of knowledge and scientists could point to scientific findings.

There is reason to believe that fishers from the Corredor find scientific evidence increasingly legitimate. A fisher from Agua Verde who had participated in the Tecnicos Pesqueros program told us,

> "A year ago Niparajá came to present on all the data that was collected. They presented on how they had measured, how they collected all the data. It is something that the community had never done. Before, we just got my money, and now we are seeing the reality of how the species really behaves, what size,

> where it migrates, what genes it has, in what months it is reproducing, in what months it is not reproducing. Now people are good for knowing all this. And it is something interesting because it is the reality of this fishing zone" (Agua Verde fisher, December 2017).

As the process of assessing and renewing the Fish Refuges continues, it seems possible that fishers will draw more and more on scientific assessments – at least the ones conducted by people they trust, like the Buzos Monitores and the Técnicos Pesqueros.

The creation of the first Fish Refuges has been one step in the changing role of fishers' knowledge in fisheries management in Mexico, and thus potentially challenging the power asymmetry. There is some evidence that the government is starting to recognize fishers' knowledge as legitimate. Norma-049 explicitly states that fishers' knowledge may be used as evidence for various categories of the data. For example, for the category of "flora and fauna species list associated with the objective species in the proposed area," (section 4.3.7), Norma-049 states that "This information can be obtained from previous studies, bibliographical information, fisheries reports, or information provided by fishers of the area". Several other categories of data explicitly mention fishers as potential legitimate sources of information for a Fish Refuge proposal. Still, there is not to say that INAPESCA values fisher knowledge outright. What we observed on the monitoring vessel of the Buzos Monitores was that scientists from INAPESCA value the data that the Buzos Monitores produce, but they give, as their reason, that the

Buzos Monitores are well-trained in scientific methods. Scientists talk about the value of having fishers conduct monitoring, because of the skills that fishers bring to conduct science 'better'. These opinions still reflect a preference for scientific knowledge over fishers' knowledge. It was mostly Niparajá staff who said things like, "we learn more from the fishers as they learn from us", indicating that they value the fishers' knowledge directly.

3.6 Conclusion

Scholars of local ecological knowledge (LEK) have questioned the capacity of LEK to inform resource management because of issues of legibility, power, and other institutional barriers (Soto 2006), particularly in the case of fisheries management (Hind 2014). This is a problem because science-based fisheries management has not been a unilateral success (Worm et al. 2009), and it seems likely that including fishers' knowledge could improve the performance of fisheries management (Murray et al. 2006; Neis et al. 1999). We present data gleaned from interviews with government, NGOs and fishers, as well as legal documents to suggest one approach for integration of LEK in fisheries management. Themes emerging from this research paint a complex story of fishers' knowledge integration in these Zonas de Refugio through a process we term "ping-pong" hybridization, where the knowledge used in different steps of the process alternated between traditionally-conceptualized fishers' knowledge and formally

conducted science, rather than consisting of a unification of both approaches. Key factors that emerged as enabling knowledge integration were the ability of local fishers to contribute to the choice of evaluation criteria, as in this case a priori requirements were not clearly specified, which avoided power asymmetries, and the extensive knowledge translation actively conducted by the NGO, which increased legibility. Additional factors of importance were the openness of the government that supported input from local fishers and ongoing engagement by fishers through the multi-year process, increasing power to LEK. My findings have direct policy implications: for example, new legislation in Mexico in 2014 has sought to define evaluation criteria for the Fish Refuges. My results indicate the potential for over-specification of evaluation criteria to stifle local knowledge and input, and possibly jeopardize its legitimacy to fishers involved in the process. Careful study of the factors and processes that overcome barriers to integration of LEK in fisheries management is one step towards increasing the voice of local people in environmental governance.

4. Community-based strategies to end open access in small-scale fisheries

4.1 Introduction

Developing climate change sensitive policies for marine ecosystems constitutes one of the biggest challenges currently facing marine policymakers for the long-term attainment of UN Sustainable Development Goals (IPCC 2019). As the most globally widespread area-based conservation measures, protected areas are sure to play a prominent role (Pendleton et al. 2017; Tittensor et al. 2014). Yet, by being spatially delimited, protected areas offer an inherent tension between providing secure property rights over biologically significant marine areas, and being flexible and adaptable to the anticipated shifts in species ranges and their associated habitats (Maxwell et al. 2020; Roberts et al. 2017; Sumaila et al. 2017). The Mexican case of Fish Refuges might offer insights as area-based tools adaptable to climate change (CONAPESCA 2017). These temporary no-take zones aimed at rebuilding fish stocks in nearby fisheries can be renewed every 5 years during which it is possible for communities to propose changes in size or location. A crucial challenge remains as dominant theory predicts that the temporary nature of their property rights would create uncertainty about future benefits to stakeholders, leading to precarious incentives for costly management and long-term sustainability (Ostrom 2003). However, this does not seem to be the case in Baja California Sur, Mexico. In this paper I study how fishers and their civil society advocates seem to have harnessed an opportunity for collaborative governance that has given

them more control over their fishing areas, despite holding limited property rights over the resource. These fishers' behavior increasingly reflects a long-term vision of resource harvest. My analysis, based on interviews, observation, social-science surveys, and ecological data, and draws initial policy lessons of Fish Refuges' potential for locally-driven climate change adaptation. I contribute to a developing research agenda on emergent sustainability in systems with weakly-defined property rights, like open access pastoral systems (Moritz et al. 2018; Querou et al. 2017) and systems with temporary property rights (Maxwell et al. 2020).

4.2 Theoretical positioning: Self-governance, institutions, and property rights in community-based conservation

Community-based conservation has gained attention in recent years for its potential to avoid the failures of equity, legitimacy, and long-term social-ecological outcomes that have pervaded traditional approaches to conservation including command-and-control, but also increasingly market-based approaches (Armitage et al. 2009; Berkes 2007). Critiques of community-based conservation point to its failure to really empower or include the interests of local resource users, who are often heterogeneous, as well as the manipulation of local "communities" for an agenda that is not their own (Blaikie 2006; West et al. 2006). One theoretical approach that places resource users and communities at the center of decision-making is self-governance, which emphasizes how users build and sustain institutions and property rights in

management of the commons (McCay and Acheson 1987; Ostrom 1990). Scholarship on self-governance of the commons has developed insights about how communities and resource users can develop incentives for the long-term success of conservation initiatives (Ostrom 2002). Some of the best-known insights are related to characteristics of the users and the resource that are important for the emergence of new rules structuring collective behavior, as well as design principles important for the sustainability of governance arrangements (Ostrom 1990). While there is ongoing debate about their applicability and generalizability (Cox et al. 2010; Fleischman et al. 2014), there is general agreement that property rights play an important role in long-term sustainable use (see (Schlager 2002) for a good summary). This literature associates well-defined, secure bundles of property rights with long-term sustainable outcomes (Ostrom 2000; Schlager and Ostrom 1992). The importance of property rights derives from their role in defining who captures which benefits from a resource, which structures the incentives resource users face for long-term sustainability (Commons 1968; Demsetz 1974).

While there is general agreement on the importance of property rights for sustainable use, there is disagreement about the particular "bundle" of rights that leads to long-term sustainable outcomes. There are arguments that resource users possessing a complete bundle (i.e., full privatization) will lead to efficient and optimal outcomes (Demsetz 1974). However, evidence from the self-governance literature has found that

certain incomplete bundles of property rights, if secure and recognized by the state, can lead to sustainable behavior (Schlager and Ostrom 1992). Schlager and Ostrom (1992) developed a conceptual schema of five types of rights (access, withdrawal, management, exclusion, and alienation) to systematically analyze institutional change in property rights regimes. They argue that incentives for sustainability shift predictably with the accumulation of each new right, with three important jumps:

Table 4: Shifts in incentives for long-term sustainable management by cumulatively gaining collective-choice rights on top of access and withdrawal rights

+ Management	Without management rights, users must follow rules that they did not make. Gaining management rights can lead to greater legitimacy of rules, better fit of rules to local context, and greater compliance.
+ Exclusion	Gaining exclusion rights assures users that they will capture the benefits of the management actions they undertake, which may be costly in terms of time, direct costs, or lost potential income.
+ Alienation	Gaining alienation rights completes the bundle. Alienation rights, associated with private property, may lead to sustainable behavior for some goods (Demsetz 1974), but may lead to unsustainable behavior for commons, e.g., when a forest is sold and cut down (Schlager and Ostrom, 1992)

In the nearly 30 years since this schema was published, it has extensively used to analyze property rights regimes and sustainability (Poteete et al. 2010; Ribot and Peluso 2003) with strong interest in the mechanisms that drive changes in property rights regimes (Galik and Jagger 2015; Ostrom 2005). Yet it has not been sufficiently documented how or whether those who possess a limited bundle of rights are able to

find incentives for sustainability. In this paper, I use the conceptual schema of Schlager and Ostrom (1992) to support my analysis of the evolution of engagement between fishers and their civil society allies, in which they have developed incentives to invest in resource maintenance despite not having the full bundle of property rights, effectively shifting the regime at play.

4.3 Methods

4.3.1 Study site: Fish Refuges of "El Corredor" San Cosme to Punta Coyote, Baja California Sur

Mexico's Fish Refuges (Zonas de Refugio Pesquero) are area-based tools (limited take or no-take zones) intended to protect or rebuild fisheries (DOF 2014). Unlike most protected areas in Mexico, Fish Refuges are not governed by the ministry of conservation but by the Commission on Fisheries (Comisión Nacional de Acuacultura y Pesca, CONAPESCA). Most Fish Refuges have been designed and proposed by fishers, typically for 5 years at a time before they expire with the option of renewal. Since the first ones were established in 2012, 41 Fish Refuges have been established across Mexico covering 20,185 km^2 (CONAPESCA 2017).

Fish Refuges were pioneered in Baja California Sur where fishing is of central economic importance (Leslie et al. 2015). Its hugely productive Gulf of California produces 71% of Mexico's total fisheries volume (OECD 2006), yet there is evidence of decline (Saenz-Arroyo et al. 2005; Sala et al. 2004). Such is the case in the "Corredor" San

Cosme to Punta Coyote, a region with 150km of coastline, 13 permanent towns, 659 residents, and 104 fishing vessels (Niparajá 2016). Most livelihoods depend on fishing, with some ranching and tourism. Fishers in the region have noticed and been affected by fisheries decline (Niparajá 2009).

Mexico's first Fish Refuges were established in the Corredor because of the confluence of declining fisheries and strong promotion by a civil society organization dedicated to regional conservation, Sociedad de Historia Natural Niparajá A.C. (hereafter, Niparajá). Niparajá's Sustainable Fishing program (Pesca Sustentable) is dedicated to fomenting social structures that create and maintain rules to support long-term fishing livelihoods. Much of their work is concentrated in the Corredor region. In 2009, Niparajá started systematic data collection on problems and proposed solutions within fisheries of the Corredor. Through a process which spanned 3 years, described below, a network of 11 Fish Refuges were finally established in 2012 in the Corredor, with a 5-year duration. In 2017, the Fish Refuges were reinstituted and expanded for another 5 years.

4.3.2 Data collection and analysis

I conducted six months of ethnographic research between May 2016 and July 2018 (IRB permit #2018-0130) to understand the outcomes of changes in fisheries governance and property rights institutions. Data collection activities included a ten-day

ecological cruise along the entire Corredor region, short field visits to three of the thirteen towns in the Corredor, two months of fieldwork in the state capital (La Paz), and three months of fieldwork in Agua Verde, the largest town in the Corredor. In order to learn about fishing traditions and local history before and after the Fish Refuges, I conducted 68 interviews, of which I recorded and transcribed 54 with consent (average length 58 minutes). My respondents included fishers and their family members, fishing sector leaders, professionals (policemen, teachers), academic scientists, the State Secretary of Fishing (SEPADA), CONAPESCA staff, scientists from the National Institute of Fishing (Instituto Nacional de la Pesca, INAPESCA), and Niparajá staff. I coded interviews and all field notes for emergent themes like 'informal rules', 'relationship to Niparaja', and 'status of fishery', iterating between data, theory, and conclusions (Charmaz 2006). I also analyzed eight legal documents relevant to the Fish Refuges of the Corredor: the national fisheries law (DOF 2007), the legal agreement that established the Fish Refuges in 2012 (DOF 2012) and renewed them in 2017 (DOF 2017), and the protocol for establishing Fish Refuges (DOF 2014). In addition, I analyzed internal regulatory documents for each of the above regulations (Manifestación de Impacto Regulatorio, MIR). I also gained access to two socioeconomic surveys conducted in 2010 and 2016 (before and after the Fish Refuges) with 51% (2009) and 57% (2016) of the fishers of the corridor region, and continuous underwater monitoring data of all Fish Refuges in the study area from 2012-2017. The second author was involved in

the design of the 2016 socioeconomic survey and the training of the enumerators that deployed it.

Our approach invites two sources of bias. First, Niparajá participated in all survey and ecological data collection. I credit and thank them for sharing this data, and also acknowledge that this influences my analysis. Second, my ethnographic fieldwork was concentrated in the Corredor's largest town, Puerto de Agua Verde ("Agua Verde"), with 42% of Corredor's residents. Agua Verde has the largest fishing cooperatives and the longest relationship with Niparajá; its fishers proposed the largest Fish Refuge in 2012, and in 2017 were the only ones to expand their Fish Refuge. This study best reflects Agua Verde's opinions and experiences, although my interviews with government officials, university scientists, and Niparajá staff represent the entire Corredor region.

4.4 Results

4.4.1 Few incentives for long-term sustainability before the Fish Refuges

In summary, before the Fish Refuges, fishing in the Corredor was poorly enforced and *de facto* open access. Fishers lacked fishing permits and experienced confusion about who could fish and where. Management and exclusion rights legally rested with the state, but in practice were nonexistent; a common complaint of Corredor fishers was that they were powerless to stop the illegal spearfishers ("pistoleros") from outside from "taking everything". Local fishers in the region blamed the decline in

fishing on overharvest from poor management and inability to exclude outsiders. The situation created weak incentives for long-term management, visible in the property rights structure (see Table 4), although I acknowledge that property rights are only one factor affecting fishers' behavior.

In the Corredor, like other rural coasts of Mexico, subsistence and small-scale commercial fishing preceded fishing regulations. The legal implementation of a permit system placed traditional fishers outside the law until they could attain permits, a challenging process rendered more difficult by geographic, social, and political isolation. Fishers still struggle to keep up with fishing regulations created by the Mexican state. On one hand, there are high barriers to attain permits (costs, paperwork, uncertainty), and on the other, there is little enforcement of a poorly coordinated system with overlapping and conflicting access and withdrawal rights. Before the Fish Refuges, only half of active fishing boats in the Corredor (47 of 104) had legal permits for finfish (Niparajá 2009). Fishers without permits from states like Sinaloa and Sonora fished from temporary camps in the region, landing catch with permit-holding patrons (Niparajá 2009). Some fishers from La Paz claimed to have permits that provided access to the southern half of the Corredor. Industrial shrimping boats were frequent in the Corredor with an overlapping permit to the entire state. Fishers from a town to the north, Ensenada Blanca, exercised an independent permit called an "UMA" (Unidad de Conservación, Manejo y Aprovechamiento Sustentable de Vida Silvestre) with exclusive

rights to sea cucumbers in a large area overlapping the Corredor. Fishers from the Corredor complained that, rather than constrain themselves to sea cucumber, these fishers opportunistically fished all species using highly efficient dive gear.

In contrast to the widespread access and withdrawal rights described above, management and exclusion rights were weakly exercised in practice. The nation's fisheries law gives CONAPESCA all management rights, with the duty of "regulating, fomenting, and administering the exploitation of fisheries and aquaculture resources" (DOF 2007). Most fisheries are seemingly managed at the desks of CONAPESCA through fishing permits, which stakeholders view as insufficient: "In Mexico, there are very few fisheries that are managed… I don't believe that CONAPESCA is in the business of managing fisheries" (NGO leader, 2017). In the absence of government-led fisheries management in the Corredor, there was some evidence of self-governance practices before the Fish Refuges. Local fishers had developed norms regarding fishing areas, baiting, and gear restrictions, which are locally articulated as "fishing well" ("pescar bien"). The understanding of these practices varied across the 13 communities, but generally included a tacit agreement to respect one another's baited zones ("zonas cebadas"), primarily use handlines (a low-efficiency fishing gear), and never use nets over rocky areas or with a compressor (Niparajá 2009). Outsiders tended not to respect these norms, often leading to conflict. The informal nature of these practices meant that authorities would not uphold them, frustrating the fishers in the Corredor, who felt that

the authorities unfairly punished local fishers rather than 'badly behaved' outsiders (Niparajá 2009).

CONAPESCA also holds exclusion rights, determining who can legally access and withdraw from the fishery, although my respondents accused this process of being opaque, random, or corrupt. In practice, there was little exclusion before the Fish Refuges. Occasionally, fishers from the Corredor would chase out fishers they perceived to be fishing wrongfully, but this exclusion was itself illegal, especially since many outsiders had some legal claims from the overlapping and complex permit system. Fishers from the Corredor described 'caring for' the fish by limiting gear and letting areas 'rest', while outsiders benefitted by 'taking it all'.

Table 5: Possession of fisheries property rights in the Corredor before the establishment of the Fish Refuges, as *de facto* (in practice) and *de jure* (legal)

Property rights	Actors with *de jure* rights	Actors with *de facto* rights
Access and Withdrawal	Half of Corredor fishers Ensenada Blanca fishers (UMA) La Paz fishers Industrial shrimp boats	All Corredor fishers Many outsiders, including fishers from Ensenada Blanca, La Paz Many shrimp boats, including from other states
Management	CONAPESCA	Corredor fishers, who developed norms about bait and gear types, although not respected by outsiders
Exclusion	CONAPESCA	Nonexistent
Alienation	The Mexican Federal Government on behalf of all Mexican citizens	

4.4.2 Motivations for change: How to curb fisheries decline?

Overlapping and unclear access and withdrawal rights coupled with lack of management and enforcement likely contributed to fisheries decline and conflict in the study area. In the 2010 survey (n=86 of 182 total fishers), the fishers of the Corredor expressed deep dissatisfaction with the property rights structure outlined above. 86% of fishers said that resources had declined, implicating overexploitation, harmful fishing techniques, and lack of fishing regulations. They wanted to restrict general access and withdrawal: 62% agreed with prohibiting nets across the Corredor and 92% agreed with prohibiting nets and compressors together to target finfish. They were willing to engage in management: 79% said they would follow, monitor, and enforce no-fishing zones if they existed. They wanted to exclude outsiders: 67% thought that each community should have an exclusive fishing area and 95% of fishers wanted to exclude shrimp boats from the region. Also, Corredor fishers wanted to legalize their own withdrawal rights; even without enforcement, they feared prosecution and wanted to fish legally. Residents of one town, Ensenada de Cortes, partly blamed a 50% population decline on lack of permits. Fishers from the town of El Pardito expressed feeling like "delinquents" even though they had been fishing locally since 1916, before the first fisheries law in Mexico was established. In the entire study area 95% of fishers called for more legal permits. However, applying for permits was expensive and could take 40 days to 2

years, and often resulting in no permit. Furthermore, there were almost no mechanisms for fishers to gain management and exclusion rights.

Historically, fishers' role in management was to keep up with regulations that CONAPESCA imposed. A government staff member told us, "Restrictions on [the fishers] have always been top-down; they see it like this. We do scientific studies and see where we can pull the reins in or limit them, and the fishers never agree with these things. The fishers always scream and see it as a punishment." The only legal pathway for fishers to gain management and exclusion rights was a fishing concession, itself an extremely expensive and cumbersome process. However, in 2007, the new national fisheries law defined Fish Refuges as a newly available fisheries management tool: "[a]reas delimited in federal waters, with the primary aim of conserving and contributing, naturally or artificially, to the development of fishing resources through reproduction, growth, or recruitment, as well as preserving and protecting the surrounding environment" (page 6) (DOF 2007). Little direction was given on the role of fishers in management, but Niparajá saw an opportunity and presented the possibility of Fish Refuges to the fishers of the Corredor, ultimately precipitating a shift in the perception of ownership, de facto property rights, and behavior among local fishers.

4.4.3 The mechanism leading to change: A collaborative process of establishing Fish Refuges, 2009-2012

Fish Refuges provided the opportunity to curb open access in the Corredor, but Fish Refuges do not necessarily lead to this result. Rather, it was through the collaborative process of establishing Fish Refuges that fishers of the Corredor positioned themselves as responsible fisheries managers deserving expanded rights with incentives for long-term sustainability. From a legal standpoint, Fish Refuges should seemingly have little effect on property rights and incentives for sustainability. Fishers may propose an area, but the management and exclusion rights ultimately lay with CONAPESCA, which approves or denies proposals based on a technical evaluation from its scientific branch, INAPESCA (Instituto Nacional de Pesca). Any individual or legal entity may submit a proposal, but CONAPESCA's intention is that only fishers with permits to the proposed area submit Fish Refuge proposals: "The one who asks for a Fish Refuge should be a fisher from that zone that has a permit" (retired Director de Ordenamiento, CONAPESCA, interview 2017).

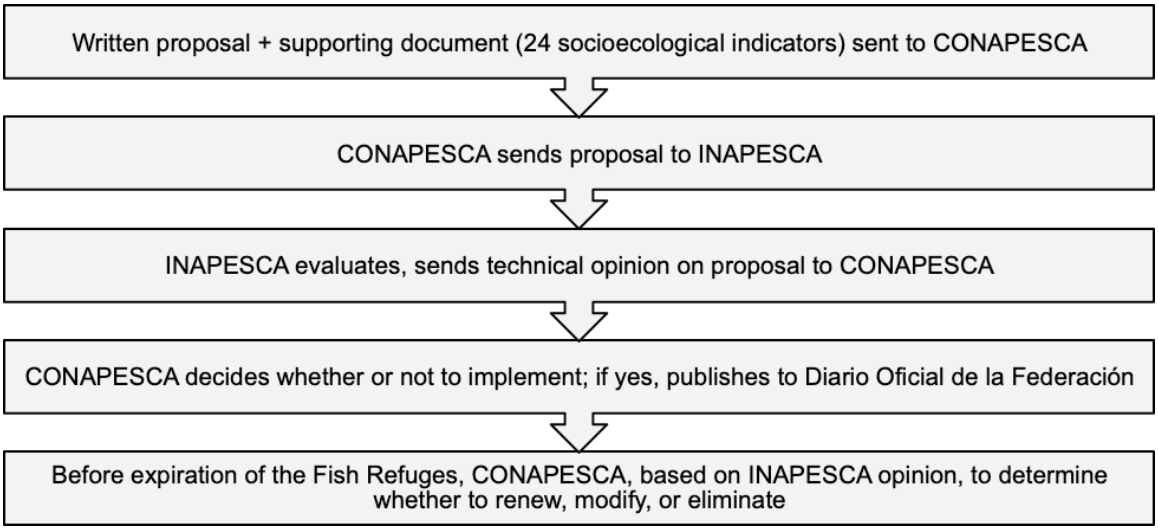

Figure 8: Legal process to establish a Fish Refuge in Mexico, assembled and streamlined by authors from (DOF 2014).

When Fish Refuges were first listed as an available tool in the fisheries law of 2007, CONAPESCA had strong political will to establish Fish Refuges. From 2008-2009, there were meetings between government officials, NGOs, and scientists about the ecological science of using marine reserves for fisheries management in Mexico, and how Fish Refuges could serve as such. Working groups coalesced around several sites for the first Fish Refuges, including the Corredor where Niparajá had been developing relationships for several years. One staff member of Niparajá's Sustainable Fishing team had lived intermittently in Agua Verde from 2007-2009, and was assisting their fishing cooperatives with paperwork and building leadership capacity. Seeing an opportunity to engage fishers with Fish Refuges, Niparajá decided to expand their geographic scope from Agua Verde to the whole Corredor; in 2009, they conducted a rapid appraisal of the needs, problems, and solutions across the Corredor, including interest in creating

Fish Refuges. They conducted a census of all fishing activities in 2009 and a socioeconomic survey of 86 fishers in 2010. Seeing strong interest in permits, Niparajá interceded with CONAPESCA on behalf of the fishers to discuss the possibility of distributing permits, and at the same time asked for guidance on establishing Fish Refuges. In February of 2010, a top official of CONAPESCA went to the Corredor and invited the fishers to apply for permits, and also to submit a proposal for Fish Refuges. Niparajá staff told us that getting permits were not contingent on making Fish Refuges ("It wasn't a trade for Refugia", Niparajá staff, 2017) but the two processes happened at the same time.

Getting the permit applications in order was a Herculean task with layers of paperwork. Fish landings paperwork could only be filed with a unique identification number, which required a voter card and birth certificate. "And there were people in the Corredor who didn't have any of those things. They didn't have birth certificates. And so we had their parents, who were 70 years old, come and register their child, who was 40 years old" (Niparajá staff, 2017). In easier cases, fishing cooperatives already had permits, but these permits had to be expanded to include more boats. By July 2010, all permit requests were submitted CONAPESCA.

In 2010 Niparajá also facilitated the process of designing Fish Refuges in the Corredor. There was little legal direction on establishment from either the fisheries law or CONAPESCA, and so Niparajá based this process on other NGOs' experiences

facilitating community-based marine reserves in Mexico. Niparajá hosted workshops in the Corredor on optimal design of Fish Refuges for ecological outcomes, based on marine reserve biology. In each town, fishers held meetings to suggest and edit maps for possible sites. By September 2010, a map with 11 proposed sites for Fish Refuges had been finalized. Niparajá circulated the final map throughout the Corredor, and 109 fishers from the Corredor (of 182 total fishers in the zone) signed a letter of support for the final proposal. In October 2010, Niparajá submitted the full proposal and accompanying letter of support to CONAPESCA on behalf of the fishers of the Corredor.

CONAPESCA passed the proposal to INAPESCA for the technical opinion, creating a crisis because INAPESCA had no tools to evaluate the proposal. INAPESCA staff members told us, "There were certain doubts, certain reservations, about how they selected the areas… One thing was the quantity. Why 11? Why 11, and not 15? Why not 1?" and "The Institute doesn't have an official document with a methodology to use" (interviews with INAPESCA staff, 2017). INAPESCA held the proposal for 2 years, during which Niparajá staff members put political pressure on CONAPESCA and INAPESCA through meetings and personal connections. Niparaja also invited INAPESCA to workshops with internationally reknowned scientists in evaluating no-take zones. "What we really hoped as Niparajá was that the original proposal by the fishermen would be improved by INAPESCA" (Niparajá staff, 2017). At the end of 2011, the fishing permits were approved, doubling the number of permits (47 to 91). And

finally, in July 2012, nearly 2 years after the proposal was submitted, INAPESCA issued a technical opinion on the Fish Refuges of the Corredor.

According to INAPESCA staff, they issued a positive technical opinion for social and political reasons rather than ecological ones. They saw opportunity in working with fishers: "The proposal had a deficiency of technical information, but it had the backing of its own community; it was something that was born from them" (INAPESCA staff, 2017). Because the proposal was accepted on social grounds, the Corredor fishers' proposal was unaltered before it became law – contrary to the hopes of Niparajá (see above). Since it had been 2 years since the Fish Refuges were proposed, in August of 2012, CONAPESCA requested another signed letter from the fishers of the Corredor to make sure they still supported the proposal. 109 fishers had signed the letter in 2010; this time, 128 fishers signed the letter in support of the proposal for the Fish Refuges. Finally, on November 16, 2012, the Fish Refuges were published in the Diario Oficial de la Federación as a secretarial agreement, and thus became law.

4.4.4 Towards informal community-based management after the establishment of Fish Refuges

Although the process took 2 years, the locations and sizes of the fisher-designed Fish Refuges were directly translated into law. Corredor fishers agreed to respect the no-fishing zones, losing access and withdrawal rights but gaining *de facto* management and exclusion rights over their larger fishing area by having their management proposal

approved. Since the Fish Refuges are no-take zones, Corredor fishers lost *de jure* withdrawal rights in these areas for their 5-year duration, as have the shrimp trawlers and fishers from La Paz. In practice, some fishing still occurs inside the Fish Refuges. When asked in the 2016 survey about ongoing fishing inside the Fish Refuges, 45% reported some fishing by locals and 78% reported some fishing by outsiders. Confusion around overlapping rights continues. All activities outside CONAPESCA's purview are technically allowed inside Fish Refuges, including sea cucumber harvest under the UMA, frustrating fishers from the Corredor. "They say, no, if I am fishing for sea cucumber, I can fish in the Fish Refuge. You know that sea cucumber is more of a pretense… They pillage. They say they are fishing sea cucumber, and what a shame that they take everything there" (Corredor fisher, 2017). In the broader area around the Fish Refuges, Corredor fishers have gained *de jure* withdrawal rights through permits. Although permits were not contingent on Fish Refuges, CONAPESCA officials discussed them together and Niparajá facilitated both processes.

Management and exclusion rights also changed through the collaborative process of establishing Fish Refuges. Before, CONAPESCA had *de jure* management rights over resources in the area. *De facto*, there was no management. Fish Refuges have complicated these rights in a number of ways. The lack of a clear evaluation protocol for INAPESCA to assess proposals means that, in practice, Fish Refuge designs are not altered by INAPESCA. Because proposals in practice end up being accepted as long as

there is strong fisher support, fishers can use them to gain *de facto* management rights. Furthermore, the process of designing a proposal has given Corredor fishers the opportunity to exclude fishers from La Paz and other states, and shrimp boats from participating. Fishers in the Corredor strongly advocate for their exclusive rights to design Fish Refuges in their fishing areas: "The community has the right to say, we want a Refuge here, and if we don't want it, then we won't have it… You put your Refuge in your fishing area… The one with the right is the community, nobody else. People from outside, they don't have the right" (Corredor fisher, 2017). This exclusion was particularly visible from 2013-2014 when fishers from La Paz opposed the Fish Refuges in the Corredor through demonstrations, rallies and threats because they had not participated in their design. CONAPESCA quashed this opposition citing no legal records of catch landed in the Corredor by the La Paz fishers, irrespective that this was also true for many Corredor residents without permits who had never legally landed catch. However, in 2017 when Corredor fishers proposed a massive Fish Refuge permitting all gears except trawling (effectively a trawling ban across the Corredor), CONAPESCA denied the proposal because shrimp trawlers had not participated. CONAPESCA was not willing to legalize that level of exclusive management by Corredor fishers. Thus, the *de facto* management and exclusion rights that the Corredor fishers have gained are not secure or formalized, but through the process they have positioned themselves as partners with civil society and the government in managing

their resources sustainably. After the creation of the Fish Refuges, 53% of fishers said that government attention in the region increased (37% noticed no change). 68% of fishers said that fishing-related subsidies had increased.

Table 6: Actors with property rights to fisheries in the Corredor after the establishment of the Fish Refuges

Property rights	Inside Fish Refuges		Broader Corredor fishing area	
	De jure	*De facto*	*De jure*	*De facto*
Access and Withdrawal	None (except UMA)	Small amount of ongoing fishing	All Corredor fishers, some fishers from La Paz and other municipalities	For now, same as in 2009: All Corredor fishers Many outsiders, including Ensenada Blanca, La Paz, shrimp boats
Management	CONAPESCA	Fishers from Corredor	CONAPESCA	Increasingly, fishers from Corredor
Exclusion	CONAPESCA	Fishers from Corredor	CONAPESCA	Increasingly, fishers from Corredor
Alienation	The Mexican Federal Government on behalf of all Mexican citizens			

4.5 Discussion

4.5.1 From a top-heavy property rights structure towards a balanced one

Before the Fish Refuges were implemented, local fishers had developed local traditions of self-governance with a long-term sustainability orientation. Yet, they suffered from a classic "tragedy of the commons" with uncontrolled access, rampant overfishing, and fisheries decline, partly motivated by the lack of clarity in access and withdrawal, management, and exclusion property rights. Using Schlager and Ostrom's framework (1992), I classify this property rights structure as top-heavy: many actors exercised access and withdrawal rights, but few exercised any management or exclusion

rights, creating few incentives for long-term management. Local fishers expressed concern over "caring for" their resources by "fishing well" while fishers from outside would "take everything". Local fishers wanted to limit gear for others, but the government could not support them because it lacked any tool that allowed fisher proposals for management to become law.

The Fish Refuges, made legally available in a new fisheries law in 2007, provided a tool where fishers could propose management of their fishing areas. The process of engagement outlined above allowed fishers to reimagine their role in fisheries self-governance, taking on *de facto* management and exclusion rights reserved to the state, under the tacit and explicit authorization of the state. Niparajá internalized many of the costs of this process like organizing numerous meetings in the Corredor and political pressure on fisheries officials. All together, this has shifted the property rights structure from top heavy towards a balanced one; Corredor fishers have moved from *de facto* open access towards greater incentives for long-term management, albeit through informal and temporary management and exclusion rights. This presents a dilemma: the balance is tenuous because it is not official. However, it seems that this unofficial nature is precisely what allowed fishers to gain self-governance rights. On one hand, the lack of legal protocols meant that the fishers' proposal could not be technically evaluated, so was approved and translated to law without alteration. On the other hand, the small and informal attempt to exclude La Paz fishers from designing Fish Refuges was defended

by the Mexican state, while the larger and formal attempt to ban shrimp trawlers from the whole Corredor was rejected. Perhaps the seed of opportunistic unofficial rights, watered by support from civil society allies, is one pathway for resource users to build towards sustainable institutions. Fish Refuges in particular could provide a pathway that is adaptive to climate change, as they must be renegotiated upon their expiration, usually after five years.

Figure 3, below, is a conceptual diagram of the two types of property rights regimes. Levels correspond to Schlager and Ostrom (1992)'s property rights framework. Width of each level represents number of fishers exercising rights at that level within a given property rights system. The diagram on the left depicts a top-heavy property rights structure dominated by widespread access and withdrawal and less management or exclusion, as before the Fish Refuges were implemented. The diagram on the right depicts a balanced structure, as after the Fish Refuges were implemented.

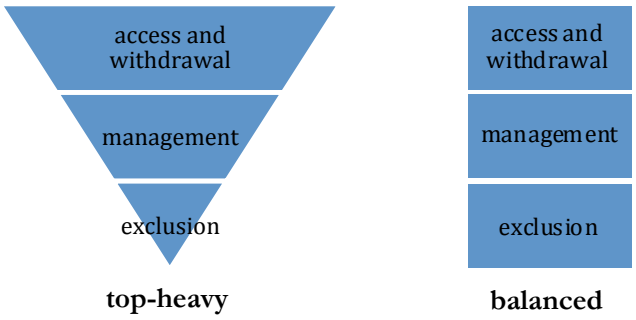

Figure 9: Conceptual diagram of two types of property rights regimes.

One aspect that has received less attention in the literature of property rights is who restructures property rights systems. Often, rights are "given" to resource users. Here, resource users demanded the evolution in property rights – and although the rights were largely informal, with legal rights retained by the state, fishers have received greater subsidies and attention from the government because of their participation in this project. Now, in 2019, these fishers are engaged in discussions of long-term and formal management and exclusion rights. Again facilitated by Niparajá, these fishers are creating Fisheries Management Plans and starting the process of applying for fishing concessions – 20-year exclusive management rights to a designated fishing area. There is evidence that CONAPESCA would support this self-governance: a retired director of CONAPESCA told us, "I am convinced that the scheme of concessions is a tool that will permit greater security to fishers, and more responsible fishing".

4.5.2 Property rights regime shifts as invisible but important outcomes of conservation policies

This case indicates that informal property rights may be invisible but important outcomes of conservation policies. The reason that fishers wanted to engage in the first place in a collaborative process to manage fisheries was centered on property rights: they wanted legal access to the fishery through more permits, gear restrictions that aligned with "fishing well", and limited access by outsiders. The promise of the first – when a CONAPESCA official asked them to apply for permits in 2010 – likely made

them more willing to engage in the costly and risky processes of the second and third. Engaging in community-based conservation is costly for communities of resource users in terms of time, energy, and money, with uncertain benefits. This is especially true for the creation of no-take zones or marine protected areas, which often fail to produce positive ecological outcomes (Gill et al. 2017) and may even attract poachers (Bergseth et al. 2015; Cudney-Bueno and Basurto 2009), yet which are costly for community groups to establish and maintain. Understanding property rights systematically using tools like Schlager and Ostrom's schema (1992) may explain why fishers would engage in a costly, risky endeavor to make protected areas that might not work. When no-take zones like Fish Refuges serve as focal points for a process of engagement that gives fishers or other resource users expanded rights to a resource, even informal ones, they may be more willing to try a suite of precautionary management tools. An advantage of area-based tools like protected areas is strong political support (e.g., Aichi Targets and Sustainable Development Goals), which was key in my case for the fishers' proposal to be legalized.

4.6 Conclusion

There is tension between adaptability and long-term sustainability in property rights theory, but temporary, informal property rights created by policies like Fish Refuges might be the key to serve both aims, although at the cost of security. Because informal rights may be easier to negotiate for than formal rights, these informal rights

may be easier for resource users to demand themselves. Informal rights may be especially powerful when part of a broader property rights regime change. In the case of the first Fish Refuges in Mexico, fishers used these temporary no-take areas to trigger a property rights regime change. An important conclusion of this work is that Fish Refuges, in this case, have provided a mechanism for fishers to actively restructure their own property rights to the resource they depend on, thus creating greater incentives for long-term sustainability.

5. Conclusions

With over 200 million people dependent on small-scale fisheries for their livelihoods (FAO 2016) and evidence of widespread overharvest and decline (Worm et al. 2009), there is urgent need to understand how failing fisheries can be flipped towards sustainable ones. One approach is through collective action by fishers themselves to manage their own fisheries sustainably. While the characteristics are well known for social-ecological systems where this collective action is predicted to spontaneously emerge, it is poorly known how collective action emerges when these characteristics are absent. What sparks collective action in declining small-scale fisheries?

Three objectives guided the research presented here. First, I aimed to understand how different types of actors conceptualized the management scheme through time, and how this related to the outcomes they perceived and their desire to engage in collective action. Second, I aimed to understand how the strategic use of different types of knowledge and information affected collaboration with diverse actors like rural fishers and government scientists. Finally, I aimed to understand how fishers were able to renegotiate their property rights in a process that transitioned from de facto open access in 2009 towards weakly defined but existent property rights in 2018.

This dissertation builds understanding towards answering this question through an in-depth study of a case from Baja California Sur, Mexico. In this case, fishers have voluntarily proposed no-fishing areas ("Fish Refuges" or, in original Spanish, "Zonas de

Refugio Pesquero") which have been implemented through an ongoing collaboration with a non-governmental organization (NGO), Niparajá, and the government fisheries agency. This work is based on an in-depth study of these Fish Refuges including 180 days in the field from 2016-2018, participant observation, informal interviews, journaling, and semi-structured interviews (n=66). Key informants were purposively sampled through snowball sampling. Recorded interviews were transcribed and coded in NVivo using a combination of inductive and deductive coding, and themes were assembled and analyzed in iterative memos.

In Chapter 2, "Blurry definitions help cooperation: Coexistence of three narratives accommodates competing stakeholder visions for coastal co-management in Mexico", I sought to understand how and whether different stakeholders (fishers, local leaders, government officials, government scientists, academic scientists, and NGO staff) perceived that the Fish Refuges were working. Once I arrived in the field, I realized that there were fundamental differences in how different stakeholders viewed the Fish Refuges. These visions coalesced around three narratives about what the Fish Refuges were for, how they were supposed to work, and how they could be assessed. The coexistence of these competing narratives actually seemed to facilitate collaboration between actors who had never previously collaborated to this extent, and with a relatively antagonistic history. An implication of this work is that policy flexibility to

accommodate competing goals and evaluation criteria could facilitate collaboration for fisheries management – and thus serve as one facet of a spark for collective action.

In Chapter 3, " 'Ping-pong hybridization' navigates barriers to local ecological knowledge (LEK) integration in fisheries co-management: lessons from Mexico", I sought to understand how the process of establishing Fish Refuges was able to accommodate different knowledge systems of fishers and government scientists. The paradox of knowledge in co-management is that the purported benefits of co-management are premised upon knowledge integration from both resource users and managers, but many cases of co-management have found local knowledge to be subsumed and co-opted into scientific managerial regimes because of power asymmetries and the illegibility of local knowledge to managers. In the case of the Fish Refuges, I found that multiple types of knowledge were integrated through a process I call "ping-pong hybridization" because the decision making locus moved between stakeholders who could draw on their own knowledge systems. This meant that the knowledge used in different steps of the process alternated between traditionally-conceptualized fishers' knowledge and formally conducted science. The implications of this work are that power asymmetries and issues of knowledge legibility can be countervailed by processes where fishers have decision-making power, and are able to use their own knowledge in these decisions.

In Chapter 4, "Community-based strategies to end open access in small-scale fisheries", I sought to understand how the property rights regime was able to evolve from *de facto* open access and declining fisheries towards greater incentives for sustainability. I found that fishers were able to trade *de jure* fishing rights for *de facto* management rights, closing a fishing area to gain government trust and partnership. There is tension between adaptability and long-term sustainability in property rights theory, but temporary, informal property rights created by policies like Fish Refuges might be the key to serve both aims. Because informal rights may be easier to negotiate for than formal rights, these informal rights may be easier for resource users to demand themselves. Informal rights may be especially powerful when part of a broader property rights regime change. This work implies that insecure and unofficial property rights may be a first step of property rights regime change to achieve sustainable fisheries.

In this case, collaboration to overcome mistrust and divergent goals in early stages was likely possible precisely because there was disagreement between actors about what the goals and mechanisms were for fisheries management. While diverse actors could not agree to implement the same thing, they could agree to implement their own interpretation of the process. Different actors similarly disagreed about what was legitimate knowledge for evaluating success – but flexibility in interpretation meant that most knowledge could be accommodated. While the transition from de facto open access towards empowered fishers is ongoing, this case suggests that 'baby steps' may

be key for building trust between fishers, civil society organizations, and governments. Short-term and imperfectly designed management measures, while not optimal for ecological outcomes, may actually facilitate long-term sustainability by facilitating trust building between actors who have never collaborated before.

The case of the Corredor is, in many aspects, a 'bright spot' for collective action. In the span of 10 years (2010-2020), their fishing has been transformed. Where half of Corredor fishers lacked permits and were thus illegal fishers in 2009, today they nearly all fish under permits. Where they had no recourse to stop outside fishers from exploiting their fishing areas in 2009, today they have the no-take Fish Refuges (although they are small). They now have leadership across the whole Corredor through a formal committee that discusses fishing regionally. Through these means, local fishers in collaboration with the NGO, Niparajá, have increased incentives for long-term sustainable management in the Corredor.

Challenges remain; and fishing is not decidedly sustainable as of 2020. Some fishers are very pessimistic about the future of fishing in the area, and many of my respondents emphasized that the future they see is in ecotourism (rather than fishing). In many other cases in Latin America and elsewhere, ecotourism has failed to meet its purportedly non-consumptive promise. When I asked my respondents at the end of my interviews how they saw the future of their towns, they responded with mixed answers, but many were hopeful; I conclude my dissertation with their voices.

"I see the future of Agua Verde in fishing. All the fishers see the future of Agua Verde in the fishing. For us, the Fish Refuges are the future that comes for Agua Verde."

"Now that there is a Refuge, the fishers are doing really well, they are fishing at night. Now that there is a Refuge, they fish at night because the product leaves to explore at night."

"I see in the future more tourism than commercial fishing."

"Hopefully in the future we will have a very big Refuge, and we will leave fishing completely, so nobody kills the fish. Why? Because we will have a large source of income from tourism… It is all about caring, while there is conservation, I think it is good for everyone."

"The future of fishing, I see it, how do I say it. Really, in past years, we saw more of what was good fishing. But there have been some years in which the production of fishing has been diminishing, and I see the future of fishing, well, that it won't be very profitable, that you'll go, and you won't catch the same amount. In the future, I see fishing going down, there won't be growth. And that is why there are Fish Refuges, so that the day of tomorrow, that there will be benefits. In fishing, I see that the future is the Fish Refuge. Why? Because we are leaving fishing, we are protecting for a future that is more, with more options. But fishing, what is really fishing, is going down. And it's not just here: it is in all parts of the world. Why? Because there are more fishers, more fishing effort, there are many things that have come so that everyone is taking out… How would I see the future of Agua Verde? The future of Agua Verde I see as not just in fishing, but closer to tourism."

"The future is looking up, right?"

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