Adaptive Capacity and Governance Effectiveness of Wetfish Fisheries

Stacy E. Aguilera
University of Miami, staceyaguilera@gmail.com

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ADAPTIVE CAPACITY AND GOVERNANCE EFFECTIVENESS OF WETFISH FISHERIES

By

Stacy Elizabeth Aguilera

A DISSERTATION

Submitted to the Faculty of the University of Miami in partial fulfillment of the requirements for the degree of Doctor of Philosophy

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Doctor of Philosophy

ADAPTIVE CAPACITY AND GOVERNANCE
EFFECTIVENESS OF WETFISH FISHERIES

Stacy Elizabeth Aguilera

Approved:

__________________________
Kenneth Broad, Ph.D.
Professor of Marine Ecosystems
and Society

__________________________
Gina Maranto, M.A.
Graduate Program Coordinator,
Environmental Science and
Policy

__________________________
Andrew Bakun, Ph.D.
Professor of Marine Ecosystems
and Society

__________________________
Guillermo Prado, Ph.D.
Dean of the Graduate School

__________________________
Larry Crowder, Ph.D.
Professor of Biology
Stanford University
Fisheries contribute a wide variety of ecosystem services, from food provisioning to shaping community identity to bolstering local economies. The sustainability of these benefits is under threat due to global and local stressors, including climate change, rising demand for animal protein, and habitat destruction. The dynamic climate, governance, and market drivers influencing fisheries present social and ecological challenges and opportunities that form the focus of this dissertation. Examining the adaptive capacity of a fishery offers insight into diverse aspects of the system that influence outcomes, such as trends in landings, social stability, and habitat condition. Additionally, academic theories, including Ostrom’s common pool resource theory, provide useful frameworks for an integrated understanding of the resource units, resource users, and governance systems, and in turn, for providing guidance for management approaches in the face of environmental uncertainty associated with dynamic ecological systems.

This dissertation analyzes wetfish fisheries due to their distinctive governance characteristics and increasing economic significance. As large finfish fisheries have declined due to overexploitation, management and industry have shifted their attention to the world’s wetfish fisheries, particularly squid fisheries. The emergence of squid fisheries in the global seafood market will require effective management strategies if they
are to remain viable. While the understanding of ecological dynamics and ecosystem functions are fairly advanced for squid fisheries, there is a pressing need to understand the social and governance dynamics of squid fisheries in order to design more effective policies in the face of increasing fishing pressure and climate variability and change. This dissertation details a series of distinct, but thematically linked case studies designed to examine the adaptive capacity and governance effectiveness of fisheries that are subject to cumulative fluctuating stressors, and addresses existing gaps in applying multi-method systems approaches to the study of wetfish fisheries over time. It presents a comprehensive analysis of adaptive capacity with a focus on three adaptive capacity determinants in each chapter: flexibility, early warning systems, and contextually based policies.

Chapter 1 introduces the dissertation by framing fisheries within the context of dynamic common pool resource systems, by reviewing key literature contributing to the study of fisheries as systems, and by introducing the wetfish fisheries complex as an ideal case study, particularly those within the Monterey Bay area (Pacific sardine (*Sardinops sagax*), northern anchovy (*Engraulis mordax*), and market squid (*Loligo opalescens*)). Chapter 2 explores multiple social and ecological drivers of change within the Monterey Bay wetfish fisheries over a 38-year time series, examining how the fisheries have survived economic and environmental disturbances and benefited from optimal market and ecological conditions. Chapter 3 focuses on one of those known disturbances to the Monterey Bay wetfish fisheries, El Niño Southern Oscillation, and investigates the social-ecological system’s adaptive capacity in relation to an impending El Niño event (the 2015-16 event). Chapter 4 assesses the efficacy of squid governance from a social-
ecological perspective in three fisheries, comparing the Monterey Bay market squid fishery to the Falkland Islands Patagonian squid fishery and the New Zealand arrow squid fishery. Chapter 5 synthesizes the findings in this dissertation and discusses management implications and areas for future research, particularly by emphasizing the value of systems-based, interdisciplinary, and participatory approaches to the study and management of fisheries.
DEDICATION

To my mom, Jackie, and my dad, Hector. Thank you for showing me the world, inspiring my curiosity, and for the freedom to explore and learn. Education is a gift, and I am forever grateful to you for supporting me at each new step with each new goal.

And to Matt. Thank you for your constant support and love.
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This dissertation is shaped by the many participants from the California, New Zealand, and Falkland Islands fisheries. Thank you to the many fishermen, processors, managers, community members, and others who participated in interviews and shared with me their knowledge and experience, without whose contribution this would not have been possible. I appreciate your time, honesty, and faith in the scientific method.

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<tr>
<td>CDFW</td>
<td>California Department of Fish and Wildlife</td>
</tr>
<tr>
<td>CPR</td>
<td>Common Pool Resource</td>
</tr>
<tr>
<td>CPS</td>
<td>Coastal Pelagic Species</td>
</tr>
<tr>
<td>CPUE</td>
<td>Catch Per Unit Effort</td>
</tr>
<tr>
<td>ENSO</td>
<td>El Niño Southern Oscillation</td>
</tr>
<tr>
<td>ITQ</td>
<td>Individual Transferable Quota</td>
</tr>
<tr>
<td>NGO</td>
<td>Non-Governmental Organization</td>
</tr>
<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
</tr>
<tr>
<td>PDO</td>
<td>Pacific Decadal Oscillation</td>
</tr>
<tr>
<td>PFMC</td>
<td>Pacific Fisheries Management Council</td>
</tr>
<tr>
<td>SES</td>
<td>Social Ecological System</td>
</tr>
<tr>
<td>SESMAD</td>
<td>Social-Ecological System MetaAnalysis Database</td>
</tr>
<tr>
<td>SSF</td>
<td>Small Scale Fishery</td>
</tr>
<tr>
<td>SST</td>
<td>Sea Surface Temperature</td>
</tr>
<tr>
<td>TA(C)C</td>
<td>Total Allowable (Commercial) Catch</td>
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<tr>
<td>TAE</td>
<td>Total Allowable Effort</td>
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Chapter 1

Introduction: The Case for Social-Ecological Systems Approaches to the Study and Management of Fisheries
1.1 The Core: The Human Relationship with the Ocean

*Exultation is the going*
*Of an inland soul to sea –*
*Past the houses, past the headlands,*
*Into deep Eternity!*

*Bred as we, among the mountains,*
*Can the sailor understand*
*The divine intoxication*
*Of the first league out of land?*
*(Emily Dickinson)*

The human relationship with the ocean has remained central to our growth and survival as a species for hundreds of thousands of years (Erlandson & Rick, 2010). Archeological evidence points to our use of aquatic resources, maritime adaptations, and seafaring as playing a fundamental role in human evolution for the past 200,000 years (Erlandson, 2001). Our relationship with the ocean extends further, as we have grown to value the ocean for spiritual, aesthetic, and cultural purposes (UNEP, 2006).

Fisheries embody the core of this connection between humanity and the ocean. Ocean fisheries have existed for 160,000 years, and now have a global reach (Ainley & Brooks, 2013; Marean et al., 2007). While at first glance fisheries may seem to represent a simple food provisioning extractive relationship with the ocean, upon closer inspection, fisheries exemplify the complex relationship human communities have with the ocean. Fishing is viewed as valuable for a number of reasons, including as a primary source of income, an avenue to experience freedom and independence, an essential cultural tenet of many coastal communities, and a way to connect humans to the ocean (Gatewood & McCay, 1990; McEvoy, 1986; Pollnac et al., 2006).

In today’s society, the desire to use marine resources is in direct conflict with the desire to protect marine ecosystems. Technological advances in finding, processing, and
marketing fish expand our ability to access resources, and unfortunately have led to
global declines in fish stocks (Postel, 1994; Thurstan, Brockington, & Roberts, 2010).
Innovative conservation strategies enhance our ability to protect natural systems, and
have proven to rebuild stocks and revive ecosystems (Worm et al., 2009). However,
sometimes ocean protection in the form of no-take marine reserves results in the end of
fishing livelihoods for coastal people (McClanahan, 2010). As such, fisheries pose as the
classic example of the dichotomies and conflicts in natural resource management, and a
model system for the relationship between people and ecosystems. Despite this close
relationship, the human dimension is often removed or minimized from the study and
management of marine resources.

In recent years, scholars and managers have integrated more systems-based
analysis and management approaches in an attempt to better understand the many drivers
within fisheries, to develop a more efficient and ecologically sustainable industry, and to
increase conservation benefits (Levin, Fogarty, Murawski, & Fluharty, 2000; Pikitch et
al., 2004). This chapter reviews pressing conflicts and challenges within today’s fisheries,
highlighting areas that require further human dimension and systems-based studies. It
argues that fisheries are best understood and managed through a full social-ecological
systems lens and presents developed theories useful for such systems analyses. It then
introduces the wetfish fisheries of Monterey Bay, California, which consist
predominately of Pacific sardine (Sardinops sagax, Clupeidae), northern anchovy
(Engraulis mordax, Engraulidae), and market squid (Loligo opalescens, Loliginidae), as
an ideal case study to test new methodologies and investigate conditions for high
adaptive capacity and governance effectiveness. This chapter will conclude by outlining the succeeding dissertation components and their respective research aims.

1.2 The Problem

Despite the decades-old adage that fisheries management is 10% biological resource management and 90% people management, the profession will likely stabilize with a mix of professionals that suggests the reverse proportion. (David Fulton and Ira Adelman)

Fisheries globally are subject to a multitude of threats, from climate change to habitat degradation and to the expansion of invasive species (Crain, Kroeker, & Halpern, 2008). Such threats differ in magnitude, time scale, and recognition. While overfishing is considered the greatest contributor, fisheries can collapse because of any one threat, or from a combination of threats (Mullon, Fréon, Cury, 2005; Roughgarden & Smith, 1996). Challenges that further threaten economically viable fisheries include global market expansions, rising costs from regulations, and low generational recruitment within the industry (Anderson, Flemming, Watson, & Lotze, 2011; Chen et al., 2012). Numerous estimates indicate that global fisheries are in unprecedented decline, with many species already on a trajectory towards extinction (Hutchings & Reynolds, 2004; Jackson et al., 2001; Lotze et al., 2006). Evidence from a number of studies shows that human impacts external to the fishing industry such as habitat destruction and pollution have proven to substantially disturb marine ecosystems, further deteriorating global fisheries (Lotze et al., 2006; Worm et al., 2006). While declines in fishery stocks threaten the survival of the fishing industry, other potential consequences include marine ecosystem degradation, food security concerns, coastal community health declines, and a loss of identity for many individuals and communities (Brunner, Jones, Friel, & Bartley, 2009; Jackson et
al., 2001; Srinivasan, Cheung, Watson, & Sumaila, 2010; van Ginkel, 2001). As such, effective fisheries management benefits many social and ecological agendas.

For most of the 19th and 20th centuries, natural resource management focused on maintaining stable states of species of interest (Holling & Meffe, 1996; National Research Council, 2006). For example, within fisheries management, policies fixated on a single-species population-based strategy concentrated on narrow metrics such as Maximum Sustainable Yield (MSY) (Crowder et al., 2008; Walker, Holling, Carpenter, & Kinzig, 2004). Such rigid control mechanisms have frequently fragmented social-ecological systems such as fisheries, reducing overall resilience (Folke et al., 2002). Reflecting the many U.S. federal and state fisheries policies that are based on single-species plans, many scientific analyses and reports are also focused on a single fished species. Studies employing ecosystem based management (EBM) concepts attempt to end this trend, and recognize the connections among species as well as with human dimensions (Crowder et al., 2008).

Human dimensions are intrinsic characteristics of the social-ecological resource system and should be actively recognized as such (Folke et al., 2002). Efforts to better incorporate human dimensions in fisheries science and management such as interdisciplinary collaborations with stakeholders have been shown to produce effective natural resource management effects (Johnson & van Densen, 2007; Stöhr, Lundholm, Crona, & Chabay, 2014). While some fishery management areas are just beginning to integrate participatory knowledge, in many cases stakeholder engagement is not a novel concept, but is a long-standing customary approach adopted to generate positive outcomes in a particular system (Dyer & McGoodwin, 1994). Co-management of marine
resources has often resulted in successful ecological outcomes such as increases in standing biomass (Friedlander, Shackeroff, & Kittinger, 2014; Pinkerton, 2011). Participatory research and participatory management have contributed to sustainable fisheries management at the local community level (Kittinger et al., 2013; Kittinger et al., 2015). Community-based initiatives have resulted in social benefits such as community empowerment and higher levels of compliance (Jentoft, 2005; Kaplan, 1998).

A continuous challenge in integrating human dimensions into fisheries management is that terms such as “human dimensions,” “interdisciplinary collaborations,” and “participatory management” often lack any operational meaning or definition, operating as buzzwords in studies and plans with no clear utility. Often, human dimensions are simplified and only expressed in common economic terms, ignoring other factors that strongly drive trends and outcomes in fisheries (Hall-Arber, Pomeroy, & Conway, 2009). Efforts to create useful metrics and indices such as community vulnerability indices, human well-being indices, sustainable development indices, personal disruption indices, population composition indices, poverty indices, and labor force structure indices have given concepts of human dimensions greater utility (Breslow et al., 2013; Jacob, Weeks, Blount, & Jepson, 2013; Jepson & Colburn, 2013). While numerous studies have operationalized such human dimension metrics (e.g., within NOAA’s fisheries social impact assessments (SIAs) (Jepson & Colburn, 2013), and as seen in Alaskan fishery managers assessing communities within their jurisdiction (Himes-Cornell & Kasperski, 2016)), there is still a substantial gap in integrating human dimensions within fisheries management. I argue that fishery management systems that do not incorporate human dimensions through stakeholder engagement, co-management,
participatory monitoring, and/or human dimension metrics are substantially at risk of falling to meet both social and ecological goals.

1.3 The Systems Lens Approach

Due to the repeated failures of management bodies in assuming control and trying to triage crises that the system was not prepared for, adaptive management strategies have been increasingly proposed and adopted. Adaptive management is a “plan that acknowledges the uncertainty of a managed system and therefore integrates design, management, and monitoring in order to allow managers to adapt and to learn” (National Resource Council, 2006). Adaptive management acknowledges and is shaped by inevitable uncertainties, which can stem from any corner of a system. Thus, fisheries adaptive management requires a systems lens.

Many natural resource managers and scientists have gained an appreciation for managing natural resources from a systems approach, as studies have increasingly shown that social and natural systems are often strongly coupled and behave nonlinearly (Folke et al., 2002; McClanahan & Cinner, 2008; Ostrom, 2009). Natural resource managers have increasingly incorporated more ecology-based ideas, such as food web theory and interactions of keystone species and functional groups, and ecosystem-based management approaches have become widely accepted (Crowder et al., 2008; McLeod, Lubchenco, Palumbi, & Rosenberg, 2005). To account for this, resource management science and practice has turned to systems thinking, where approaches account for the particular role of each level that influences and is influenced by that system, allow for analysis of multiple spatial and temporal scales, take into account intra- and inter-generation
dynamics, and incorporate the perspectives and relationships of multiple actors (Gallopín, 2003; Holling, Gunderson, & Peterson, 2002).

Common pool resource (CPR) theory best encapsulates fisheries systems thinking and is useful for developing systems approaches to management. The commons, which are resources that have the potential to be owned by many individuals or groups of people, represent most natural resource systems (e.g., forests, fisheries, coal, water). The notion of the “tragedy of the commons” has been used to explain failures in management of common pool resource systems (e.g., Gordon, 1954; Hardin, 1968). Collective action challenges this idea that groups of individuals will behave in self-interested ways and will not cooperate or act to achieve group interests when using or managing a commons (Olson, 1965). Assumptions of noncooperation have been dispelled by a number of cases proving that common pool resources can be managed for sustainability through user-led mechanisms (Berkes, Feeny, McCay, & Acheson, 1989; Ostrom, 1990). Self-governing institutions can result in sustainable outcomes, sometimes more effectively than larger-government led procedures (Dietz, Ostrom, & Stern, 2003; Ostrom, 2009). People can create their own rules, norms, and institutions to regulate resource use and sustain resources for future purposes (Tengö & von Heland, 2011).

Foundational to much CPR related research is the Institutional Analysis and Development (IAD) framework (Ostrom, 2011). IAD is used for policy research to accurately reflect the complexity of dynamic policies, and to incorporate multiple participants (Polski & Ostrom, 1999). The IAD framework is meta-theoretical, using multiple theories primarily from political science and economics to provide a usable analysis of formal policies (Kiser & Ostrom, 1982). Matching institutions to the physical
environment, social context, and broader institutional context is central to the IAD framework, as every CPR and every community influences—and is influenced by—external bodies (McGinnis & Walker, 2010). The IAD framework helps to focus policy analysis on rules-in-use versus paper rules, with both the biophysical and community context integrated. The action situation is central to IAD. McGinnis (2011) summarizes the action situation as, “in which individuals (acting on their own or as agents of organizations) observe information, select actions, engage in patterns of interaction, and realize outcomes from their interaction.” Ostrom (2011) further describes these social spaces as interactions that include problem solving, individuals dominating over others, exchanging goods and services, and engaging in disagreements. The acknowledgement of such interactions is key to systems thinking in fisheries.

The concept of institutions is central to in depth analysis of fisheries systems. Institutions can be informal, such as the habitual behavior, rules, and norms in which humans interact and thus shape a society (Adger, 2000; Tengö & von Heland, 2011). They can also be formal, such as organizations with memberships, constituencies, and stakeholders (Adger, 2000). Institutions may naturally evolve, or may be proactively implemented (Tengö & von Heland, 2011). Institutions are responsible for the social distribution of vulnerability, management success of social-ecological systems, the provision of resources, the social and political acceptability of policies, and individual and regional worldviews (Næss, Bang, Eriksen, & Vevatne, 2005; Tompkins & Adger, 2005). Institutional arrangements can be identified at all levels of a system. Institutional linkages connect different scales and occur when processes at one level influence
institutional arrangements at another level (e.g., national policies influencing local economies) (Robinson & Berkes, 2011).

Areas of study like ecological economics contribute to the reconceptualization of resource systems in terms of structures and processes rather than in terms of single elements (Berkes, Colding, & Folke, 2003). Thus, focusing on complementarity patterns of social and ecological characteristics rather than on one-dimensional environmental conditions can improve resource management efforts (Berkes et al., 2003). Another major contributor to systems thinking regarding fisheries is panarchy: the conceptual framework of cross-scale dynamics between institutions and ecosystems, where interactions of multiple nested adaptive cycles lead to both stability and change (Gallopín, 2006; Gunderson & Holling, 2012; Walker et al., 2004). Social and ecological systems are subject to multi-scalar complex dynamics that interact with each other; local conditions are subject to large-scale factors such as policies, climate change, market changes, and economy, and such large-scale factors are subject to smaller-scale factors such as individual ideologies and ecosystem timescales. The overwhelming complexity by which panarchy operates in a particular system can be somewhat simplified when viewing the system through a derivative of the IAD framework, the Social-Ecological System (SES) framework (Ostrom, 2007; Ostrom, 2009). In this SES framework, four subsystems (resource system, resource unit, governance system, and users), each of which is individually composed of many complex characteristics, interact with one another while also being influenced by and influencing related ecosystems and the broader social, economic, and political settings (Ostrom, 2009) (Figure 1.1). Each of the subsystems is subject to institutional arrangements, and each has the ability to enhance or threaten the
whole system’s sustainability (Nelson, Adger, & Brown, 2007). The SES framework is built off of SES assumptions that human and biophysical subsystems are inherently interactive and that one cannot be removed from the other when deliberating on approaches to resource management (Gallopín, 2006; Tengö & von Heland, 2011). As is central to the panarchy framework, the SES framework incorporates system feedbacks, highlighting both positive and negative feedback processes that lead to outcomes in the various subsystems. This dissertation adopts the SES framework and uses it to frame the methodologies in each chapter, building upon previous theoretical and practical studies of the framework to apply new approaches to addressing natural resource system research questions.

Figure 1.1. The four subsystems of the Social-Ecological System, with inter- and intra-system relationships. Figure from Ostrom, 2009, Science
1.4 Adaptive Capacity

The development of natural resource management strategies and policies through a systems approach has not only highlighted the need to incorporate human dimensions into resource management, but also emphasized the need to include interdisciplinary variables of system properties, such as renewal capability and resilience (rather than solely variables that focus on short-term conditions) (Gunderson, 2003; Janssen, Schoon, Ke, & Börner, 2006). Adaptive capacity is an example of such human-centric and interdisciplinary elements that can be used to study long-term resource system sustainability (Robinson & Berkes, 2011). Adaptive capacity stems from human ecology, the science of human-environment interactions that characterizes institutional arrangements as encouraging or impeding sustainable resource use (Dietz et al., 2003). Adaptive management acknowledges and is shaped by inevitable uncertainties; as fluctuations and threats are known to be inevitable in fisheries as previously discussed, often a proposed solution is for fishery managers to manage for adaptive capacity (Armitage, 2005; Folke et al., 2002).

Despite the adoption of systems-based thinking, the recognition of the value of self-governance, and increased evidence linking adaptive capacity with sustainable resource systems, adaptive capacity in general has been declining in many management systems (Folke et al., 2002). In order to reverse this trend and rebuild adaptive capacity, there must be a clear definition of adaptive capacity as well as clear routes for operationalization (Walker et al., 2002). While many scholars have defined adaptive capacity in different ways, there is no unified definition (Adger, 2003; Berkes & Ross, 2013; Folke et al., 2010; Walker et al., 2002). Here I build upon the literature and
propose a new and comprehensive definition of adaptive capacity: ‘Adaptive capacity’ is the latent ability of a social-ecological system and its components to rely on, or design and implement, effective adaptation strategies to cope with current or future disturbances. Key to such coping is that it occurs in a way that the system either retains its critical functions and structures or transforms into a system with equal or improved social and/or ecological benefits. Another central feature is that the system retains its management, conservation, market, and resource-use options during a disturbance. Adaptive capacity is best realized through one or many of the following natural and social determinants, including but not limited to:

(1) Social Capital (e.g., trust, collaboration, defined property rights, recognized norms)

(2) Diversity (e.g., multiple species with same function, multiple predators/prey, multiple management options, multiple resource types, occupational multiplicity)

(3) Learning (e.g., sharing knowledge, learning from mistakes, integrating new information)

(4) Innovation (e.g., species accommodation/evolution, new technology, new communication strategies)

(5) Mobility (e.g., occupational mobility, species geographic mobility)

(6) Infrastructure (e.g., robust habitats, social infrastructure such as health facilities and education structures, physical infrastructure e.g., functional roads and bridges)

(7) Linked Networks (e.g., strong community ties, nested guilds of both generalist and specialist species, multiple population clusters (groups surrounding a keystone species), multilevel decision-making processes)
Social mechanisms such as building adaptive capacity have allowed communities to persist through challenging conditions, assert rights to land and resources, transform mis- or unmanaged systems, improve access to ecosystem services, create contextually appropriate management rules, and implement a wide spectrum of adaptation options (Dietz et al., 2003; Fabricius, Folke, Cundill, & Schultz, 2007; Robinson & Berkes, 2011; Tompkins & Adger, 2005). Building adaptive capacity is often more effective for sustainable systems than concentrating on specific adaptation strategies that target specific risks (Smit & Pilifosova, 2003). In one example, building adaptive capacity, in the form of strengthening local knowledge of tsunamis and investing in institutional preparedness for disasters, helped fishing communities on Simeulue Island (Sumatra) and Surin Island (Thailand) withstand tsunamis (Adger, Hughes, Folke, Carpenter, & Rockström, 2005). Adopting adaptive capacity building strategies has also been shown to allow communities to withstand climate change impacts, such as temperature changes impacts on Kenyan coral reef fisheries (Cinner et al., 2015). Fisheries stressed by shorter climate fluctuations, such as small-scale fisheries in Baja California Sur, Mexico that experience stress from El Niño Southern Oscillation events, are able to withstand such periodic events by integrating adaptive capacity strategies (Finkbeiner, 2015). While other examples exist, there is clear consensus within the literature that building and enhancing adaptive capacity contributes to social and ecological benefits in fisheries, and thus should be further investigated.

Studies on adaptive capacity and strategies on how to manage and augment a system’s adaptive capacity are especially important considering the variety of factors that can weaken a system’s adaptive capacity, thereby threatening the social-ecological
resource system. Threats to adaptive capacity can be identified at all levels and subsystems within a resource system. Economic changes, such as market liberalization and resource privatization, threaten both the social and ecological elements of adaptive capacity (Adger, 2000). Declining diversity (of any resource unit, actor group, or institutional support) also threatens the adaptive capacity of a system’s social and ecological components (Brooks & Adger, 2005; Carpenter & Brock, 2008). Another social-ecological threat is any weakening of network relationships, such as food-web networks (ecological component) or conservation coalitions with non-governmental, stakeholder, and manager representatives (social component). Adaptive capacity is threatened when opportunities are limited, such that a resource in a geographically constrained setting is likely to have lower adaptive capacity because options for migration have been removed (Brooks & Adger, 2005). Adaptive capacity can also be threatened by many contextual factors including dense populations, unequal socio-economic societies (including instable and unequal income distribution), political stability, and an inability to keep up with rapid globalization patterns (Finkbeiner, 2015; Smit & Pilifosova, 2003; Yohe & Tol, 2002; Young et al., 2006). Climate change poses a threat to adaptive capacity as it will lead to unprecedented conditions at uncertain rates, likely producing traps (Gunderson & Holling, 2002). Climate change is expected to threaten natural resource system’s adaptive capacity from multiple angles by complicating multiple system components such as sensitivity, acceptance of risk, including new relevant actors, and readiness of decision-makers (Allison et al., 2009; Yohe et al., 2006). These threats and complications should be recognized in any analysis of a resource system’s adaptive capacity as their potential impact on the system can have
long-term negative social and ecological consequences. This dissertation is a comprehensive analysis of adaptive capacity, applying a broad scope while also narrowing the focus onto three adaptive capacity determinants in the next three chapters: flexibility, early warning systems, and contextually based policies.

1.5 The Case of Monterey Bay

To best address pressing knowledge gaps within fisheries systems science and test new adaptive capacity and common pool resource system analysis methodologies, I sought a case that presented the following qualities: 1) culturally significant resource, 2) influenced by climate fluctuations, 3) a data-rich setting in terms of fisheries data, and 4) a community with excellent access to scientific knowledge. The wetfish fisheries in Monterey Bay, California satisfied each of these criteria.

Monterey Bay is located along the central coast of California, about 100 miles south of San Francisco. Three main municipalities mark the Bay: Santa Cruz to the north, Moss Landing at its center (the most eastern point of the bay), and Monterey/Pacific Grove to the south (Figure 1.2). While the Bay comprises about 449 square miles of ocean, the wetfish fisheries extend beyond the Bay along the majority of the California coast (Pomeroy, Hunter, & Los Huertos, 2002). The California Department of Fish and Wildlife (CDFW) manages those fisheries that are found within state waters, and the Pacific Fisheries Management Council (PFMC) manages those that typically extend beyond state waters. Market squid is monitored by PFMC but is actively managed by CDFW, and Pacific sardine and northern anchovy are actively managed by PFMC.

The first criteria for which this site was selected, the historical reliance on marine resources, focuses on the wetfish fisheries but embraces the broader marine ecosystem.
Fishing has been a dominant industry in Monterey Bay for its entire documented history, with accounts describing the use of marine resources by the Ohlone people who inhabited the region prior to Spanish colonization in the mid 18th century (Margolin, 1978; Palumbi & Sotka, 2010). Since Spanish explorer Captain Gaspar de Portolà arrived in 1769 and established Monterey as California’s capital, a number of immigrants from various origins have settled within the region and partaken in marine activities. The Chinese community historically targeted market squid (since about 1850), and the more recently immigrated Sicilian community fished primarily sardines and anchovies (since the early 1900s) (Pomeroy et al., 2002). Present day California wetfish fisheries have strong connections to the bustling Monterey fishing industry famously chronicled in John Steinbeck’s Cannery Row, which crashed in the 1950s (Radovich, 1982). Most fishermen and buyers have a long personal and family history in the fisheries. Relationships among them are social, cultural, as well as economic and have enabled many people to withstand the challenges of variable and uncertain environmental, regulatory, and economic conditions.

In particular, climate fluctuations have long been documented in the Monterey Bay wetfish fisheries. High frequency events such as El Niño Southern Oscillation (ENSO) events, and low frequency shifts such as Pacific Decadal Oscillation (PDO) and the North Pacific Gyre Oscillation (NPGO) have substantial influence in marine species dynamics at the regional and local level (Dalton, 2001; Chavez et al., 2002; Chenillat, Riviere, Capet, Di Lorenzo, & Blanke, 2012; Mantua, Hare, Zhang, Wallace, & Francis, 1997). In the Northern region of the Pacific Ocean, climate variability is most often
measured according to changes in the Aleutian low-pressure system, wind-patterns, water temperatures, and ecological productivity (Peterson & Schwing, 2003).

Climate drivers are especially apparent when productivity manifests into ecosystem changes and declines throughout various trophic levels, since the area is well known to be a hot spot for observing marine life and is often referred to as the "Blue Serengeti" to reflect the high diversity and productivity. Physical features of note within the Bay including the nearshore yet 2-mile deep Monterey Submarine Canyon, the upwelling California current, and the various seamounts and banks off the coast (e.g., Davidson Seamount, Cordell Bank), all contribute to this region being highlighted as one of the most productive marine ecosystems in the United States (Lisa Wise Consulting, 2013).

The high richness in available data on regional climate variation and local fisheries is due to the abundance of research institutions in the area. Monterey Bay is a heavily studied region, with a number of thriving higher education, private, state, and federal research institutions, including over 50 marine focused research institutions (NOAA, 2014). While CDFW and PFMC are the most involved with Monterey Bay fisheries, a number of other agencies and organizations play substantial roles in the fishery system, including but not limited to the National Marine Fisheries Service, Monterey U.S. Naval Research Laboratory, National Marine Sanctuary, U.S. Coast Guard, National Park Service, and California Resource Agency. Many contribute environmental, biological, and social data, as well as interpretation of data and dissemination of scientific knowledge to the public. This multi-scale research assortment positions this case to be well equipped for adaptive capacity analyses, which often take
into consideration multiple levels and the role of multiple actors. The large amount of available data and information in this case is ideal for systems based analyses as they often require insight into the many drivers and factors in the full SES over time, which if independently collected for one study would be costly, slow, and demand a large team of experts from multiple disciplines.

Many of the science and marine resource management institutions and organizations in the area actively and/or passively involve fisheries stakeholders and the general public in their activities. Often, such involvement is to share knowledge, which includes climate dynamics and local impacts. Key science centers in the region have contributed to higher awareness of environmental concerns and enhanced ecological citizenship (Katz-Kimchi & Atkinson, 2014; Kemmerly & Macfarlane, 2008). This area fosters a community with a strong understanding of environmental issues and strong attitudes of conserving natural systems and adapting to environmental change (Moser, 2013). Such a base of high awareness within the public positions this case as highly suitable for studies examining users’ decision-making according to available climate information, and to engage in detailed participatory methodologies (e.g., interviews) within the community to better understand the system and consider multiple perspectives.
1.6 Why Wetfish

This dissertation examines three wetfish fisheries of Monterey Bay, California: Pacific sardine, northern anchovy, and market squid. ‘Wetfish’ is a term referring to species that are processed whole (rather than having entrails removed) directly from the vessel, and are thus ‘wet from the sea’. While species other than the three studied in this case are considered wetfish (e.g., Pacific mackerel (*Scomber japonicas*, Scombridae) and jack mackerel (*Trachurus symmetricus*, Carangidae)), these three are the most targeted species in the Monterey Bay area. Product from these fisheries is exported to many countries, connecting Monterey Bay to the global seafood industry.

Wetfish is an industrial term used by fishery participants in Monterey Bay, but these species are also commonly referred to as coastal pelagic species, reflecting their occurrence above the thermocline in the upper mixed layer, and forage fish, reflecting their substantial contribution in the food web. These species serve critical roles in the
transfer of energy and control the dynamics of higher and lower trophic levels, as “wasp-waist” populations (described as such to represent the few dominant species at the middle trophic level, such that the trophic system appears reminiscent of a wasp’s body form) (Bakun, 2006). Many marine mammals and seabirds rely on forage fish for energy, particularly in upwelling ecosystems such as Monterey Bay (Alder, Campbell, Karpouzi, Kaschner, & Pauly, 2008; Cury et al., 2000).

These fisheries play a major role in the seafood industry. Estimates for small pelagic species contribution to annual global marine landings range from 37% to 50% (Alder et al., 2008; Fréon, Cury, Shannon, & Roy, 2005). A significant portion – 90% of total small pelagic catches globally – is used to produce fishmeal or fish oil (Alder et al., 2008; Jackson, 2007). The rise in aquaculture has increased demand for such products and in turn raised the price of these fish, threatening the food security of many of the world’s poorest communities that rely on these typically less expensive protein options (Tacon & Metian, 2009). Coastal pelagic species fisheries exist all around the globe, some of which are among the world’s largest fisheries (Food and Agriculture Organization, 2014). The largest ever single-species fishery, the Peruvian anchovetta, is an ecological analog with the northern anchovy species in this case study (Chavez, Ryan, Lluch-Cota, & Ñiquen, 2003; Fiedler, Methot, & Hewitt, 1986). The wetfish studied here are closely connected to a wider global food market for animal protein and other essential nutrients (Food and Agriculture Organization, 2015). As such, the study of the Monterey Bay wetfish fisheries is an opportunity to test theories and methodologies with global relevance.
As global fisheries continue to “fish down the food web” and deplete large, long-lived species, pressure on shorter-lived species such as the wetfish in this case study will become increasingly important to the seafood industry (Pauly, Christensen, Dalsgaard, Froese, & Torres, 1998). Considering their vital role in marine ecosystems, and in wild seafood, aquaculture, and livestock industries, applying novel systems based approaches to better understand and manage these fisheries is imperative for ecological sustainability and global food security. While there is an advanced understanding of their ecological dynamics and ecosystem functions, there is a pressing need to understand the social dynamics and role of these fisheries and how their management can better incorporate systems thinking. Such efforts will better position these fisheries to withstand cumulative stressors as these fisheries experience increased fishing pressure, are subject to new threats such as anthropogenic climate change, and provide support to increasingly stressed ecosystems.

1.7 Dissertation Synopsis

* A part of us has to die to transform; and a part of us dies if we don’t. (Jett Psa*

Transformations are inevitable in natural resource systems. While stable fisheries inspire confidence, investment, and technological development, stability is a temporary condition. Systems based approaches such as adaptive ecosystem-based fisheries management internalize system fluctuations and changes, and incorporate often ignored human dimensions. Such strategies help managers and resource users in guiding system transformations to retain social and ecological benefits. Climate change threatens to rapidly transform our natural systems, further stimulating the interdisciplinary study of system dynamics, community dependency on resources, interactions of actors, and
institutional networks. Characteristics that contribute to the historical success of fisheries may or may not hold true in the future, but the study of such characteristics increases the likelihood that they can be purposefully retained to encourage positive outcomes in future conditions.

The research presented in this dissertation attempts to understand the factors contributing to social and ecological outcomes in contemporary fisheries when faced with fluctuating conditions and disturbances. It uses the Monterey Bay wetfish fishing community to exemplify a fishing community with access to scientific information, a multi-level governance system, and a close network of actors. This dissertation applies a systems lens to adaptive capacity and governance effectiveness, providing evidence for the value of inclusive approaches to the study of common pool resource systems. The following chapters consider the multiple levels of actors and institutions that influence these fisheries, concluding with a global comparison of squid fisheries. This dissertation builds upon previous common pool resource theory and adaptive management literature to apply novel approaches in examining a natural resource system’s adaptive capacity and to assessing fishery governance effectiveness through a social-ecological systems lens. Chapter 2 explores the variety of social and ecological drivers of change within the Monterey Bay wetfish fisheries, specifically focusing on fishery flexibility as a key determinant of adaptive capacity. Chapter 3 focuses on one of the key drivers of environmental change, El Niño Southern Oscillation, and explores strategies contributing to the adaptive capacity of the Monterey Bay wetfish fishing community in relation to an impending event (2015-16 El Niño). Chapter 4 explores the social-ecological system variables that contribute to governance effectiveness of the Monterey Bay squid fishery.
To examine the Monterey Bay squid fishery’s similarity to others in the greater global seafood industry, this chapter compares the governance system of Monterey Bay market squid with the governance system of two other squid fisheries, the Falkland Islands Patagonian squid fishery (*Loligo gahi*, Loliginidae) and New Zealand Arrow squid (*Nototodarus spp.*, Ommastrephidae), of which market squid directly competes with in the market. Chapter 5 integrates the key findings of the first four chapters by discussing the value of social-ecological systems approaches to the study and management of fisheries, and proposes future directions for studies to build upon the work presented here. In the next chapter, I use a wide lens to examine the Monterey Bay wetfish fisheries through a time series analysis of trends, identifying the many drivers of change to take into consideration in the remainder of this dissertation.
Chapter 2

Managing for Flexibility:
Insights from Dynamic Social-Ecological Drivers of Change
2.1 Motivation for Study

Among fishing communities, fisheries diversification and occupational multiplicity are critical strategies fishermen use to respond to environmental, regulatory, and economic variability and change, and contribute to the viability and welfare of a fishery and associated communities (Allison & Ellis, 2001; Cinner & Bodin, 2010; Comitas, 1964; Salmi, 2005). It is common for fishermen to engage in many different fisheries, using a “portfolio approach,” shifting focus among fisheries in response to various social and ecological drivers (Anderson, Flemming, Watson, & Lotze, 2011; Badjeck, Allison, Halls, & Dulvy, 2010; Holland & Sutinen, 1999; Schindler et al., 2010). Historically, fishermen have shifted effort among fisheries because of (1) management strategies that limit or promote particular gear types (Degnbol & McCay, 2007), (2) the availability of more valued or abundant species (Anderson et al., 2011), (3) climate variability (Badjeck, 2008), and (4) ease of adapting one’s vessel, gear, or location (Vestergaard, 1997). However, because of regulatory and economic factors, fisheries diversification is declining in the U.S. (Hilborn, Maguire, Parma, & Rosenberg, 2001; Kasperki & Holland, 2013; Norman & Holland, 2012). Recent changes in fisheries policy in the U.S., such as the implementation of limited access privilege programs (LAPPs, limited entry, catch shares) have been shown in some cases to reduce fisheries diversity and produce inequitable outcomes (Brewer, 2011; Kasperski & Holland, 2013; National Research Council, 1999). Such programs, often marketed as the professionalization of fisheries, can increase the cost of entry, such as permits, and thereby reduce the number of different fisheries a single fisherman might be able to access. Moreover, traditional management plans rarely specifically address interactions
among fisheries, further hindering adaptive capacity (Essington, Beaudreau, Wiedenmann, 2006). This presents problems for sustaining fisheries in the face of stochastic disturbances such as disease outbreaks, market fluctuations, or long-term shifts in climate (Steneck et al., 2011).

The ability to participate in a diversity (or portfolio) of fisheries is especially vital for small-scale fisheries (SSFs) (Allison & Ellis, 2001; Berkes, Mahon, McConney, Pollnac, & Pomeroy, 2001). Globally, SSFs can be defined in many ways, but generally these fisheries target multiple species, are carried out by individuals, families, or small firms rather than by larger corporate entities, and typically have a lower environmental impact and less financial investment than industrial fisheries (Berkes et al., 2001; Chuenpagdee, Liguori, Palomares, & Pauly, 2006; Jacquet & Pauly, 2008; Kittinger, 2013). While often overlooked in national policies and statistics, SSFs contribute more than 120 million jobs (direct and indirect) that support more than 500 million people globally (Food and Agriculture Organization, 2012). Possible compounding factors such as environmental fluctuations and human system dynamics can make it difficult to predict future conditions that affect SSFs, especially given the long temporal scales and large areas in which many fisheries function (Travis et al., 2014). In systems that encourage flexibility, fishery participants are better positioned to take advantage of opportunities such as resource abundance and strong markets, and avoid or buffer themselves against challenges (Cinner et al., 2013; Pradhan & Leung, 2004). Common fisheries management approaches such as catch shares and other rights-based approaches can, however, make it more difficult to adapt (Kasperski & Holland, 2013; National Research Council, 1999).
Additionally, failure to account for important social factors that influence adaptive
capacity has made many SSFs more vulnerable to external drivers (Andrew et al., 2007).

2.1.1 Adaptability in Small-Scale Fisheries

The Monterey Bay commercial SSFs for Pacific sardine (Sardinops sagax),
northern anchovy (Engraulis mordax), and market squid (Loligo opalescens) comprise an
interdependent system known as the “wetfish fisheries,” in which fishermen and buyers
shift effort among the three individual species-specific fisheries in response to several
drivers (Table 2.1). ‘Wetfish’ refers to species that are canned fresh or ‘wet’ and are then
cooked inside the cans. We study the history of Monterey Bay wetfish fisheries as a case
study in order to (1) explore an approach for analyzing adaptability in SSFs from a
social-ecological perspective in a data-rich location, and (2) summarize lessons from this
case study for other SSFs.

Table 2.1. Key Features of the Commercial Fisheries that Comprise the Interconnected
Monterey Bay Wetfish Fisheries System

<table>
<thead>
<tr>
<th>Fishery</th>
<th>Market Squid</th>
<th>Northern Anchovy</th>
<th>Pacific Sardine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary management authority</td>
<td>State</td>
<td>Federal</td>
<td>Federal</td>
</tr>
<tr>
<td>FMP implementation</td>
<td>2005</td>
<td>1978</td>
<td>2000</td>
</tr>
<tr>
<td>Limited entry implementation</td>
<td>1998</td>
<td>2000</td>
<td>2000</td>
</tr>
<tr>
<td>Limited entry permit type</td>
<td>Squid</td>
<td>CPS Finfish</td>
<td>CPS Finfish</td>
</tr>
<tr>
<td>Number of permits, 2013*</td>
<td>76</td>
<td>61</td>
<td>61</td>
</tr>
<tr>
<td>Number of resident vessels in area†</td>
<td>~10</td>
<td>~10</td>
<td>~10</td>
</tr>
<tr>
<td>Number of resident seafood buyers in area†</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Primary gear</td>
<td>Round haul net</td>
<td>Round haul net</td>
<td>Round haul net</td>
</tr>
<tr>
<td>Peak season</td>
<td>Spring/Summer</td>
<td>Fall</td>
<td>Fall</td>
</tr>
<tr>
<td>Preferred oceanographic regime</td>
<td>Cooler</td>
<td>Cooler</td>
<td>Warmer</td>
</tr>
<tr>
<td>Spawning habitat</td>
<td>Nearshore</td>
<td>Nearshore</td>
<td>Offshore</td>
</tr>
<tr>
<td>Primary market destination</td>
<td>China</td>
<td>Domestic U.S.</td>
<td>Japan/Australia</td>
</tr>
<tr>
<td>Average ex-vessel price, 1974-2012 ($/lb)</td>
<td>0.245</td>
<td>0.062</td>
<td>0.148</td>
</tr>
</tbody>
</table>
Available permits does not indicate the number of vessels with landings as some permitted vessels may not participate in a given year. The number of market squid permits applies only to round haul (seine) vessels; light boat and brail vessel permits are issued separately.

†Same vessels and buyers in all three fisheries.

The social and ecological complexities of fisheries viewed as common pool resource systems call for an interdisciplinary approach to addressing these aims (Bodin & Tengö, 2012; Ostrom, 2009). To do so, we identify key climate, governance, and market drivers that are associated with focus shifting among target species and we contextualize the social and ecological conditions that existed when system flexibility was utilized. We also identify the role of drivers associated with long-term fishery trends. By exemplifying time periods when fishermen have relied on the flexibility to adapt to reduce social and ecological vulnerability, we not only reinforce literature on the importance of flexibility in fishery systems, but also present an analysis applicable to other SSFs.

We focus on Monterey Bay’s SSFs because the flexibility to adapt appears to be central to the persistence of these fisheries in the past four decades. These fisheries are considered fully recovered from the 1950s industrial sardine fishery collapse, and since the passage of the Magnuson Stevens Fisheries Conservation and Management Act (MSA) of 1976, have sustained relative ecological and economic stability and multi-generational participation.

This study aims to answer three major questions applied to the Monterey Bay case study as examples that can be applied to other SSF cases: (1) What drivers are associated with fishery participants shifting focus among strongly interconnected small-scale fisheries? (2) What drivers best explain disproportionate representation (low evenness)
among species in fishery landings? (3) What drivers are associated with the total and relative contribution of the different target species landings over time?

2.1.2 The Monterey Bay Wetfish Fisheries System

The sardine, anchovy, and squid small-scale fisheries share several key characteristics that contribute to the flexibility and connectivity of the Monterey Bay social-ecological system. First, in most cases, the same fishermen, crew, vessels, buyers, and shoreside receivers and processors participate in all three fisheries. Fishermen use similar fishing gear, methods, and practices in the three fisheries, making it relatively easy to shift effort among target species. All of these fisheries occur within three miles of the coast, and are carried out as day fisheries (as opposed to multi-day or ‘trip’ fisheries). Moreover, the seasonal availability of these species varies, with anchovy and sardine most abundant in the fall and squid available primarily in the spring and summer. Lastly, most fishery participants hold both a federal coastal pelagic species (CPS) permit and a state market squid limited entry permit, affording them the flexibility to participate in – and shift effort among – these fisheries (California Wetfish Producers Association, 2013).

This flexibility allows for the persistence of one of the most significant fisheries in California. In 2012, landings of Pacific sardine, northern anchovy, and market squid accounted for 91.3 percent of landings and 48.3 percent of ex-vessel revenue at the three major Monterey Bay ports (Monterey, Moss Landing, and Santa Cruz), and 77 percent of the total statewide commercial fishery landings by volume and 30 percent of total state ex-vessel value (California Department of Fish and Wildlife, 2013). In 2011, 80.4 percent of total California seafood exports were wetfish, and totaled 195 million U.S. dollars (California Wetfish Producers Association, 2013). In 2011, approximately 31 vessel
owners (defined as an individual with commercial fishery landings data associated with a commercial fishing license number) participated in the Central Coast region CPS fishery, 14 of whom were identified by CDFW as primarily participating at the Monterey port (Chen et al., 2012).

Despite the high volume of landings and ex-vessel revenue generated by these fisheries compared to other Monterey Bay area fisheries, we consider the Monterey Bay wetfish fisheries to be small-scale because of the individual ownership, targeting of multiple species, and involvement of family members. Vessels range between 30 and 90 feet in length, and between 20 and 140 gross registered tons (California Wetfish Producers Association, 2013). Vessels are operated by 3 to 7 crewmembers (Pomeroy, Hunter, & Los Huertos, 2002).

2.1.3 Fishery Management Structure

The Monterey Bay small-scale fisheries operate under the auspices of a complex state and federal management regime that includes consideration of fishing effort, stock abundance, environmental change, and the role of these species as prey items. Pacific sardine, northern anchovy, and market squid all fall under the Federal Coastal Pelagic Species (CPS) Fisheries Management Plan (FMP) (Pacific Fishery Management Council, 2011a). The market squid fishery is managed by the state, and regulations are consistent with the federal CPS FMP as squid is a “monitored” species under the federal plan (State of California Resources Agency, 2005). The Market Squid Fishery Management Plan (MSFMP) limited entry program reduced the fleet to 77 transferable purse seine vessel permits in 2005 (CalCOFI, 2005). About 45 to 50 seiners also carry the CPS finfish permits (California Wetfish Producers Association, 2013). As of 2013, the federal CPS
limited entry fleet consisted of 61 permittees, 33 of which landed sardine and 11 of which
landed anchovy in California (California Department of Fish and Wildlife, 2014) (see
Appendix A.1.1 for additional information on the structure of the fisheries and their
management).

2.2 Methods

2.2.1 Study Design

This study addresses its aims using mixed methods, which are outlined in Figure
2.1. In order to understand the level and role of adaptability in this case study, we first
had to identify when focus shifted among fisheries, and then had to contextualize the
status of the fisheries and conditions at the time of transitions between dominance modes.
A cluster analysis and Simpson’s diversity index were used to identify modes of
dominance. Model selection, literature review, use of expert knowledge, and time series
plots of fishery information were used to contextualize the social and ecological
conditions and identify drivers associated with landings trends. We use these methods to
show quantitatively and qualitatively how the flexibility to adapt has led to the
persistence of these fisheries through changing conditions.
We used annual time series data for the period 1974-2012 to assess trends in the Monterey Bay CPS finfish and squid fisheries. Our data series begins two years prior to the passage of the MSA to help contextualize the period that followed. We used landings (weight) to characterize the status of the fishery and determine fishery dominance, defined as a given species accounting for the plurality of landings in any given year. These data were extracted from the California Department of Fish and Wildlife (CDFW) commercial fisheries information system (CFIS), Table 18PUB, Poundage and Value of Monterey Bay Area Commercial Fishing, and summed across the region’s three major ports: Monterey, Moss Landing, and Santa Cruz.
2.2.2 Determining Dominance Transition Points

To identify modes of dominance, or time periods when a given species accounted for the plurality of landings, we performed a cluster analysis of the log of annual landings for all three species together and identified groups based on the Bray-Curtis Similarity index, choosing 40 percent similarity as a cut off point (Primer-E v. 6, United Kingdom). To better view which years were within any one dominance mode, we created multidimensional scaling (MDS) ordination plots to map the years based on similarity in a 2-dimensional space, where years closer to one another on the plot are more similar in terms of pounds landed. We used the Many Eyes visualization software (IBM, 2007) to create bubble-plots showing proportional changes in landings during identified transition points from one dominant fishery mode to another. We then used a Simpson’s diversity index comprised of landings to identify years of relatively equal catches and years focused primarily on a single species. To support the identification of dominance modes, we consulted with nine Monterey Bay wetfish fishery experts, from academia to NGOs and industry representatives (Martin et al., 2012). With their guidance, an extensive literature review provided additional insight into characterizing the transitions between dominance modes.

2.2.3 Variables Associated with Long-Term Fishery Trends

We applied model fitting with forward variable selection using a set of variables to examine the extent to which landings for each species are associated with various drivers. Here we refer to the large-scale sectors that influence the fisheries, such as markets and climate as ‘drivers’, and the metrics by which to measure or identify the drivers as ‘variables’, such as local market price and Pacific Decadal Oscillation (PDO).
indices. To guide the identification of possible drivers of variability and change in the fisheries, we used the four subsystems defined in Ostrom’s social-ecological system framework for common pool resources (Ostrom, 2009). This general framework uses a common set of subsystems and variables to illuminate the complexities and external factors within any common pool resource system. Drivers we expected to be associated with long-term trends in landings include: climate dynamics (in Ostrom’s resource units subsystem), governance phase changes (in the governance subsystem), market forces (in the resource system subsystem), and participation trends (in the users subsystem). Although potentially important, we did not include technology (in the resource system subsystem) and community identity (in the resource user subsystem) drivers in the models due to lack of time series data at our geographic scale (see Appendix A.1.2 for examples of how each subsystem has influenced fisheries).

We selected variables that relate to each of these drivers based on data availability and significance to this case study. We list and describe the variables used in the next section. We explored potential carry-over effects of these variables from year to year using lagged data (with one-, two-, and three-year lags) for each variable when a sufficient number of years of data was available. For each fishery, we used factor analysis including all possible independent variables and excluding the landings of the fishery in question to generate a set of factors used to test for explanatory relationships with landings of the target species. Many of these potential explanatory variables were highly correlated (e.g., ENSO and PDO, the number of fishing vessels and fishing trips), preventing detailed conclusions about the role of individual predictors. Therefore our approach (factor analysis with orthogonal axis rotation; VARIMAX, SAS 9.4 software)
generated a smaller set of non-correlated factors that retain the predictive relationships of the original variables. We identified explanatory variables with significant loadings (P<0.05) on each of these factors in our analysis. To determine which of these variables were associated with factors that could explain significant portions of the variance in the landings for each fishery, we entered all factors with eigenvalues greater than one, along with categorical variables to code for the governance phases of all three species fisheries, into an ANCOVA model using forward variable selection. We retained those factors entering the model with a P-value less than 0.15 in our final model (a commonly used criteria; e.g., Nislow & Lowe, 2006; Randall, Minns, Cairns, & Moore, 1996) and calculated effect sizes (semi-partial Eta-squared) to determine the portion of variance accounted for by each selected factor. Model results produced an assembly of factors, representing combinations of independent variables (e.g., market price) that are significantly correlated with the dependent variable, landings.

2.2.4 Details on Independent Variables Used in Model Selection

2.2.4.1 Resource Unit Subsystem Variables

Several oceanographic variables known to affect the biology of the three study species included annual mean values for the El Niño Southern Oscillation (ENSO) and PDO indices, and seasonal averages of the Bakun upwelling index (Bakun, 1990; Breaker & Broenkow, 1994; Chavez, Ryan, Lluch-Cota, & Niquen, 2003; Dalton, 2001). We calculated PDO values as the annual average of the standardized values for the PDO index, derived as the leading principal component of monthly sea surface temperature anomalies in the North Pacific Ocean, poleward of 20° North, from the University of Washington Joint Institute for the Study of the Atmosphere and Ocean (JISAO). We
calculated ENSO values as the annual average Multivariate ENSO Index (MEI), obtained from the NOAA Earth Systems Research Laboratory. We included upwelling trends as the seasonal averages of the Bakun index of the 36°N 122°W observations (NOAA Pacific Fisheries Environmental Laboratory).

We used sardine biomass (Pacific Fishery Management Council, 2013b) as an indicator of that species’ ecological status. We were not able to incorporate quantitative data for the other species, as anchovy and squid biomass data were not available. However, we included qualitative observations from the literature of anchovy and squid abundance to explain trends in those fisheries.

2.2.4.2 Governance Subsystem Variables

We identified governance phase changes through an extensive literature search and use of expert knowledge. We focused on restricted access measures, which we believe play a vital role in effort shifts among fisheries, and divided each fishery into distinct phases marked by particular formal and informal governance events and circumstances (Table 2.2).
### Table 2.2. Governance Phases

<table>
<thead>
<tr>
<th>Fishery</th>
<th>Phases</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Squid</td>
<td>A 1976-1993</td>
<td>Fishery managed by the California Legislature</td>
</tr>
<tr>
<td></td>
<td>B 1994-1997</td>
<td>Discussion and efforts to restrict access</td>
</tr>
<tr>
<td></td>
<td>C 1998-2004</td>
<td>California SB 364 passed and implemented, with moratorium on entry and other measures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>California Fish and Game Commission (CFGC) assumes management of the fishery (2001)</td>
</tr>
<tr>
<td></td>
<td>D 2005-2012</td>
<td>State implements Market Squid FMP, with permanent restricted access and other measures</td>
</tr>
<tr>
<td>Anchovy</td>
<td>A 1976-1977</td>
<td>CFGC manages fishery based on a reduction quota</td>
</tr>
<tr>
<td></td>
<td>B 1978-1999</td>
<td>Pacific Fishery Management Council (PFMC) adopts and implements Northern Anchovy FMP (NAFMP)</td>
</tr>
<tr>
<td></td>
<td>C 2000-2012</td>
<td>PFMC amends NAFMP, adds other CPS species to establish the CPS FMP</td>
</tr>
<tr>
<td>Sardine</td>
<td>A 1976-1985</td>
<td>CDFW manages fishery, with moratorium on directed fishery, incidental catch allowed</td>
</tr>
<tr>
<td></td>
<td>B 1986-1990</td>
<td>State re-opens directed fishery with 1,000-ton annual quota</td>
</tr>
<tr>
<td></td>
<td>C 1991-1999</td>
<td>State increases quota as stocks recover</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Quota geographically divided between two regions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Discussion of limited entry and inclusion in a federal FMP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fishery declared rebuilt</td>
</tr>
<tr>
<td></td>
<td>D 2000-2012</td>
<td>Sardine (and other wetfish species) added to CPS FMP, with limited entry south of Point Arena</td>
</tr>
</tbody>
</table>

#### 2.2.4.3 Resource Subsystem Variables

We calculated market price from the same tables and at the same scale as landings (CDFW Table 18PUB) and present the data in U.S. dollars, adjusted for inflation (using the 2014 consumer price index inflation calculator from the U.S. Department of Labor). To estimate Monterey Bay area exports of each species and enable assessment of trends therein, we used landings at the three Monterey Bay area ports combined as a proportion of statewide landings, and multiplied the result by the amount exported from California. We extracted export data from the NOAA National Marine Fisheries Service database of foreign trade annual data, compiled by specific U.S. customs districts since 1975.
2.2.4.4 Resource User Subsystem Variables

We evaluated trends in the number of trips and number of vessels as indicators of fishery activity for Monterey and Santa Cruz counties. We extracted these data from the Pacific Fisheries Information Network (PacFIN) database (from data originating from CDFW’s CFIS), retrieved in August 2013, from the Pacific States Marine Fisheries Commission, Portland, Oregon (www.psmfc.org). Using the CDFW landings data and PacFIN number of trips data, we also used catch per unit effort as a variable, calculated as average landings per trip for each fishery.

2.3 Results

2.3.1 Identifying and Characterizing Dominance Transition Modes


An extensive literature review guided by the cluster analysis results indicated that over all, climate and market played the biggest role in determining dominance of a given fishery, (i.e., when one fishery accounted for a plurality of landings), or when effort

Figure 2.2. Timeline of dominance modes and transition points. Identified drivers most associated with each transition are listed accordingly.

<table>
<thead>
<tr>
<th>Years</th>
<th>Mode</th>
<th>Transition</th>
<th>Driver Attributed to Dominance Transition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985 - 1994</td>
<td>Squid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002 - 2003</td>
<td>Squid</td>
<td>2001 - 2002</td>
<td>Market (domoic acid/VHS concerns)</td>
</tr>
<tr>
<td>2010 - 2012</td>
<td>Squid</td>
<td>2009 - 2010</td>
<td>Climate (La Niña) Market (squid market expanded)</td>
</tr>
</tbody>
</table>

The time series plots of the landings, estimated proportion of landings exported, local market price, number of vessels fishing, and number of trips (Figure 2.3 a-e) provide further evidence of differing fishery dominance phases, highlighting the
dominance of the market squid fishery throughout the time series. In recent years, when
the squid fishery did not dominate, the sardine fishery did. Anchovy played a dominant
role in landings at the very beginning of the time series, but dropped to the least dominant
fishery in 1978 after demand for squid increased and the sardine fishery re-opened.

Figure 2.3. Selected variables in time series plots. The a. landings, b. estimated
proportion of exports, and c. market price are values for the Monterey, Santa Cruz, and
Moss Landing ports combined for the period 1974-2012, while the d. number of vessels
and e. number of trips are specific to all Monterey and Santa Cruz county sites combined
from 1981-2012.
The Simpson Diversity Index, calculated for landings, identified a dominant species in 1978, 1980, 1982, 1985-1989, 1993, 1998, and 2007 (Figure 2.4). The difference among landings for these fisheries is highest in these years, with one fishery dominating the system. In 1978, 1980, 1982, 1985-1989, and 1993, squid dominated the
landings, and then in 1998 and 2007, the sardine fishery yielded the highest catches. Squid dominated the system after El Niño events and during La Niña events, and sardine landings were greatest during high export years. Generally, the species perceived to be most abundant corresponded to the dominant fishery. The Simpson index also identified the three years of relative evenness - 1994, 1996, and 2000 - during which fishery participants clearly depended on all three fisheries combined rather than any single fishery in particular. The transition points from 1994-1995, 2003-2004, and 2009-2010 best visually display the shift from one fishery dominance mode to another (Figure 2.5).

Figure 2.4. Simpson Diversity Index of landings. Higher values indicate more evenness (less dominance) among fisheries landings, lower values indicate less evenness (greater dominance of a single fishery), based on pounds landed (CDFW Table 18PUB) at the three study ports combined. Dotted line represents average.
Figure 2.5. Dominance mode transition points. Proportional landings bubble plots showing dominance mode transition points for three of the seven transition years identified by the cluster analysis. Circle size is scaled to relative volume of landings (Data from Table18PUB CDFW). Darkest purple circles are sardine landings, lightest purple are anchovy landings. Gray arrows represent the movement of focus shifting from one fishery to the next.

2.3.2 Model Selection: Drivers for Long-Term Fishery Trends

Model fitting with forward variable selection resulted in optimized models for each species (Table 2.3). Changes in sardine landings were most explained by sardine governance phases and squid landings were most explained by squid governance phases. Sardine landings and sardine biomass, followed by sardine exports best explained
anchovy landings. As management decisions are driven by evidence of environmental conditions and estimated abundance (Pacific Fishery Management Council, 2011a; Pacific Fishery Management Council, 2011b), the governance phases appear to be a response to perceived changes in abundance. These abundance-guided governance phases explained long-term fishing trends more than any other variables. Other important variables that explained long-term fishing trends include fishing effort metrics (i.e., CPUE and number of anchovy vessels) and climatic drivers of availability.

Table 2.3. ANCOVA Results
Factors are listed in order of highest contribution to explaining landings to lowest contribution to explaining landings. All significant variables are included in this table.

<table>
<thead>
<tr>
<th>Fishery</th>
<th>Explanatory Variable</th>
<th>Variation Accounted For</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Squid</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R² = 0.842</td>
<td>Squid Governance Phases</td>
<td>0.8048</td>
</tr>
<tr>
<td>p-value = 0.0003</td>
<td>Factor 1: spring upwelling, no. of anchovy vessels</td>
<td>0.0375</td>
</tr>
<tr>
<td><strong>Anchovy</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R² = 0.959</td>
<td>Factor 1: sardine landings, sardine biomass, sardine exports, anchovy CPUE, sardine CPUE, fall upwelling lagged 0, 1, 2 years</td>
<td>0.5416</td>
</tr>
<tr>
<td>p-value = 0.0002</td>
<td>Factor 2: no. of anchovy vessels</td>
<td>0.1939</td>
</tr>
<tr>
<td></td>
<td>Squid Governance Phases</td>
<td>0.1560</td>
</tr>
<tr>
<td></td>
<td>Factor 3: negative correlation with summer upwelling lagged 0 and 1 year and squid landings</td>
<td>0.0399</td>
</tr>
<tr>
<td></td>
<td>Sardine Governance Phases</td>
<td>0.0275</td>
</tr>
<tr>
<td><strong>Sardine</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R² = 0.854</td>
<td>Sardine Governance Phases</td>
<td>0.4467</td>
</tr>
<tr>
<td>p-value = 0.0002</td>
<td>Factor 1: anchovy landings, fall upwelling, sardine biomass, sardine CPUE, anchovy CPUE</td>
<td>0.3248</td>
</tr>
<tr>
<td></td>
<td>Factor 2: anchovy landings lagged 3 years</td>
<td>0.0420</td>
</tr>
<tr>
<td></td>
<td>Factor 3: squid landings lagged 1 and 2 years</td>
<td>0.0389</td>
</tr>
<tr>
<td></td>
<td>Factor 4: negative correlations with no. of anchovy vessels and spring upwelling</td>
<td>0.0016</td>
</tr>
</tbody>
</table>
2.4 Discussion

Traditional fisheries, especially small-scale fisheries, have relied on interconnected systems to maintain market and community stability, and such systems can enhance the overall sustainability and resilience of fisheries. This case study of Monterey Bay wetfish serves as an example of a modern interconnected system, and is an illustration of how flexibility supports social and ecological aspects of fisheries. Fisheries are subject to a number of possible drivers that can and do affect fishery trends. The ability to adapt to the resulting variability and change enables fishermen and buyers to support themselves and the local fishery system, particularly in economically marginal years that otherwise may lead to spatial displacement or drive participants to seek other livelihoods. Adaptation also allows for the pressure on one fishery to be reduced when conditions make it vulnerable. Other fisheries that might benefit from such an interconnected system can adopt a number of strategies to encourage the ease of shifting effort among fisheries. In fisheries that are strongly driven by factors such as climate and markets, governance systems may enable or hinder adaptability (i.e., the ability to be flexible and shift focus among fisheries). Thus, to enable the flexibility to adapt, fishery managers should understand the social-ecological dynamics and actively acknowledge possible external drivers as inherent aspects of the system as opposed to external shocks or ‘surprises’ and encourage flexibility. Promoting access through less expensive permits or less stringent regulation to multiple fisheries of an interconnected system, stimulating investment in diversifying gear types, and establishing multi-species processing at local facilities can all lead to stronger interconnected and adaptive fishing systems. While the Monterey Bay case may be a fortuitous outcome of unplanned responses by various
actors, we highlight aspects that may be codified and applied elsewhere. Below we explore the details and plausible explanations for the dominance mode transitions and model selection results, followed by an overview of understanding the vitality of the Monterey Bay wetfish SSFs and more general lessons on the applicability of interconnected flexibility to other fisheries.

2.4.1 Contextualizing Fishery Modes and Dominance Transition Points

In this case study, anchovy dominated the system from 1975 to 1977, or only when the sardine fishery was closed, the squid fishery was relatively underdeveloped, and squid landings were significantly lower than average. When the sardine fishery collapsed in 1952, fishermen turned to anchovy because they had the necessary vessels, expertise, and infrastructure to support activity in the fishery. The end of this anchovy dominated mode is most attributed to fishermen shifting their focus to increasingly abundant and higher priced squid (Figure 2.2). Of the three fisheries, market squid sells for the highest price and thus it is assumed that fishermen and buyers would generally prefer to target squid when they are available in marketable quantity. From the early 1900s until around the 1970s, Northern anchovy was primarily a reduction industry, producing oil and fish meal. When prices plummeted, so did the desirability to catch anchovy. Today, anchovy is primarily used for animal food, most notable the local Monterey chicken industry, but a proportion also goes for live bait and human consumption purposes. Squid dominated from 1978 until 1982 and then dropped significantly in 1983 and 1984 in the wake of the 1982-1983 El Niño event. Because these species have a short life cycle (~ 9 months), their population abundance and distribution depends mainly upon climate variation (Bakun, 1990; Koslow & Allen, 2011).
From 1983 to 1984, all fisheries had significantly lower landings, attributed primarily to the 1982-1983 El Niño event, which resulted in low abundance for all wetfish fisheries (Figure 2.2). Large-scale warming occurred along the North American west coast in January 1983 and had major ecological impacts, especially on the squid and anchovy populations (Butler, 1989; Lynn, 1983). The 1983-1984 period is an example when the interconnected social-ecological system was at high risk, despite the flexibility of fishermen to move among wetfish species. Fortunately for Monterey Bay wetfish fishermen, some were able to participate in the San Francisco Bay herring and Alaska salmon fisheries (CalCOFI, 1984). Sardine populations were rebounding and increasingly were observed and caught more in 1983 and 1984 than at any other time since the moratorium began. Although the regulations were flexible in allowing incidental catch, they did not allow the fishermen to target this resource, and therefore sardine catch could not support the wetfish fisheries system.

With a poor anchovy market, and strictly limited quotas for sardines since the fishery was re-opened in 1986, squid again dominated from 1986 until the 1994 El Niño (Figure 2.2). For the first time since the 1974 moratorium, the 1995 sardine quota, dictated by biomass, was large enough that the sardine fishery remained open through the end of the season and sardine dominated the system from 1995 until 2001 (Pacific Fishery Management Council, 2013b). The international market for California sardine fully opened in 1995 (CalCOFI, 1996), and the amount and value of exports increased nearly tenfold relative to the previous decade (Figure 2.3b). The sardine dominance mode ended in 2002 due to health advisories and concerns related to domoic acid toxins and viral hemorrhagic septicemia (VHS), which resulted in temporary prohibitions on the sale
of sardine and anchovy for human and animal consumption, and temporary bans on exporting California sardines (CalCOFI, 2002; CalCOFI, 2003).

Squid dominated the system for the period 2002-2003. However, this phase of squid fishery dominance ended in 2004 as health concerns about sardines subsided and biomass as well as the market for sardine grew (Figure 2.2). Additionally, the market squid fishery suffered from warmer waters attributed to a PDO fluctuation, prompting fishermen to once again target sardines (CalCOFI, 2005). Strong markets likely contributed to sardine’s dominance during this time. However, the expansion of the Chinese market demand for squid in 2009 helped mark the end of this sardine dominant mode (CalCOFI, 2010). In 2010, a strong La Niña stimulated strong squid resource conditions, and fishermen who participated in the sardine fishery in 2009 shifted their attention to the squid fishery. During all squid-dominated years, sardine biomass was relatively low (Pacific Fishery Management Council, 2013b).

2.4.2 Contextualization of Simpson Index Results

One hypothesis is that according to the CalCOFI reports from these three years, all three species experienced improvements in biomass or markets during this time. Thus, it is likely that since all three fisheries were in positive states, fishery participants were able to access all three and choose to do so. The five most extreme years of fishery dominance identified by the Simpson Diversity Index identified the years when this system relied the most on the flexibility available to them.

2.4.3 Contextualization of Model Selection Results

While dominance mode transitions are linked to conditions at the time, model selection indicated which variables played the most significant roles for long-term trends
in landings of each fishery. The squid governance phases, which were the most significant in explaining squid landings, are largely products of fluctuations in squid resource availability, as sardine governance phases are products of sardine resource availability. The state and federal management systems monitor resource availability and determine strategies based on perceived abundance, such that landings were primarily dependent on availability. Thus, identified governance phases in each fishery are tightly linked to perceived or estimated abundance and best viewed as a response to changes therein. Years with both governance phase changes and fishery dominance transitions (1978, 1985, 2004) were all associated with significant shifts in abundance of one species or another.

Anchovies had the lowest market price per pound, and thus were generally the least desirable to catch. Participation in this fishery was thus affected by trends in the squid and sardine fisheries. The squid and sardine governance phases were the most significant when abundance of these two species was high; anchovies were targeted less since fishermen could access higher-value products. These species respond to climatic changes and upwelling intensity, and the significance of the upwelling variables is an indicator of how the fisheries are environmentally driven.

2.4.4 Flexibility in the Monterey Bay Interconnected System

In the sardine, anchovy, and squid fisheries of Monterey Bay, we have three species fished largely by the same fleet. Fishermen and buyers generally have a choice of which fishery to participate in, and we assume that this choice largely depends on availability of the product (which depends on climate conditions), and markets (domestic and international). Most fishermen can readily change nets, and can use the same
equipment, vessels, personnel, and receiving and processing infrastructure for all three species.

This multi-species network is highly variable from year to year, suggesting a need for flexible management. The interconnected system has persisted because of a number of factors including ease of gear-switching, possibility of buying operations with or qualifying for permits in all fisheries, spatial similarities, and temporal complementarity in species availability. Fishery dominance in this system changes as a result of climate, market, and limited access regulations, as well as from the interaction among these factors.

The Monterey Bay wetfish fisheries, like the majority of the world’s fisheries, do not exist in a vacuum, but are influenced by external fisheries and external users. The stocks are not restricted to the bay’s waters, and neither are the fishermen. Thus the issue of scale is critical to consider when analyzing these fisheries as well as when comparing attributes and outcomes of management strategies according to differently sized fisheries. For example, the Monterey Bay squid fleet and squid processors include actors from Monterey Bay, Port Hueneme and Ventura, and San Pedro Terminal Island (Pomeroy, FitzSimmons, & Los Huertos, 2005). In addition, Oregon and Washington fishermen, stocks, and management plans all influence Monterey Bay fisheries. This expanded view of the Monterey Bay wetfish fisheries in a broader context further reveals the complexities of a modern U.S. fishery, as a multitude of drivers can lead fishermen to shift effort from one target species or one geographic area to a variety of other options, and highlights the need to consider the flexibility to adapt as a key element to fishery resilience and sustainability. As is the case for many fisheries, the development of this
system was gradual and a result of key events and conditions. In the mid 20th century, sardines were the primary target species and were the foundation of one of the largest industrial fishing systems in the world. Today’s wetfish fisheries were built on the ruins of this large industry, and its collapse allowed for this interconnected set of fisheries to emerge. With a closed sardine fishery, and before the demand for market squid grew, the focus shifted to anchovy, with fishermen and processors readily adapting fishing and receiving/processing equipment, infrastructure, and practices from the sardine fishery. Later, fishermen and buyers opportunistically responded to the opening of the Chinese market for squid, which became a major driver of fishery participation and increased emphasis on squid. Climate changes and larger market factors have altered the dynamics of the fisheries since, changing conditions and further prompting focus to shift among fisheries. Today, all three fisheries are active and the proportion of participation in each changes as environmental and market conditions vary (Figure 2.5).

The Monterey Bay case study serves as a data-rich example in an industrialized country. However, many SSFs are data-poor and are in less industrialized regions. Additionally, many SSFs have different goals and structures than the Monterey Bay commercial fisheries, as many SSFs are directed for subsistence or local trade only. However, the role of adaptability in the persistence of Monterey Bay fisheries is not contingent on their commercialization or location in an industrialized country. Drivers of variability in conditions and responses are very relevant in other settings, and enabling the flexibility to adapt is still a key element for fisheries to survive such fluctuations in conditions. We were able to use the considerable amount of available information for this region to provide a concrete example of the role of flexibility in enabling adaptive
capacity and contributing to the persistence of a fishery system over several decades. This case study provides some ideas for managing multi-species SSFs in diverse contexts and also presents types of data that can be collected in other systems, in order to analyze the role and trends of adaptability in those systems. While Monterey Bay is relatively data-rich, a number of drivers and other information were not available, especially at our temporal and spatial scale (see Appendix A.1.3 for a more complete review of data limitations). Future collection and assimilation of such information could provide further insight into the dynamics of shifting effort among fisheries and how social-ecological multi-species SSFs adapt to fluctuating conditions.

2.4.5 The Role of Governance in Interconnected Systems

Participants in other SSFs have emphasized the need for more flexibility, and this study serves as an example of how to approach analyzing the opportunities for adaptation in a fishery system (Evans, Hicks, Fidelman, Tobin, & Perry, 2013). We show that market and climate factors more frequently drive the shifting of focus among fisheries than governance factors. However, governance can be a key factor in limiting or enabling shifting effort among fisheries. This is especially true in the first three years of the time series, as restrictions on directed sardine fishing hampered participation in this fishery and thus the least desirable species, anchovy, dominated. This again occurred during the low landings years of 1983-1984 when prohibitions on targeting sardine kept fishermen from participating in the fishery and El Niño conditions made squid and anchovy scarce, threatening the system.

Governance is a critical factor in affecting the flexibility to adapt in the fishery and in preventing the depletion of stocks, as occurred previously in the sardine fishery.
The 1950s sardine collapse destroyed the industry that depended on it (Radovich, 1982; Ueber & MacCall, 1992). However, through time, careful management, and a number of instrumental decisions made early on, such as implementing spatial and temporal closures, the ecosystem rebounded and the sardine fishery and many others now support the community (Palumbi & Sotka, 2010; Pomeroy et al., 2002). Since then, the federal government, the State of California, and the fishing community have managed the fisheries in an effort to prevent another collapse. Continued monitoring and assessment of environmental conditions, the resource, and its use are the foundations for maintaining a functioning system. Thus, formal governance is now structured to respond to and enable adaptation to drivers. These drivers primarily consist of climate and market factors that can change the status and attractiveness of a fishery from one year to the next. Governance still plays an important role as new regulatory actions can lead fishermen and buyers to seek economic opportunities elsewhere, but with governance allowing for the flexibility to adapt, now climate dynamics and market variability drive the shifting of focus among fisheries.

2.5 Management Implications

It is difficult to manage fisheries adaptively for fluctuating drivers such as climate and markets, except to maintain the ability of fishermen to shift effort among three strongly interacting fisheries. There are key management implications to consider in managing each species individually versus as a portfolio. This case study strongly suggests that optimizing the management of a single species may create lock-ins, or path dependencies, that constrain the flexibility to adapt and have unintended consequences to other fisheries that are strongly related via portfolio effects (Kittinger et al., 2013).
Additionally, future management decisions should avoid impairing the flexibility that has led to participant’s adaptability during fluctuating conditions. Such possible decisions include closed access policies such as TURFs (Territorial Use Rights for Fishing) that can impair access to multiple fisheries through spatial limitations, especially fisheries such as these where fishing grounds rapidly shift according to changing temperatures.

The movement of fishery participants among various fisheries is key to maintaining adaptability in these fisheries. Such flexibility provides a buffer against any one fishery becoming economically or ecologically unviable. This is a major concern, especially considering the recent scholarship on the effects of individual rights-based approaches such as catch shares. The trend in U.S. fisheries toward such approaches can reduce diversification and result in consolidation and overcapitalization, which hinders the capacity of fishery participants to shift to other alternatives (Kasperski & Holland, 2012; Steneck et al., 2011). An example of such a consolidation policy effect is seen in the British Columbia halibut fishery, where the efficiency and financial viability goals of the individual transferable quota (ITQ) system meant to benefit the fishery and community were not met and therefore distressed a number of actors in the system (Pinkerton & Edwards, 2009). Other similar situations include cases where consolidation has threatened fishermen’s safety (Windle, Neis, Bornstein, Binkley, & Navarro, 2008), innovation and debate within the fishery (Wallace, 1999), community equity (Phillips, Kriwoken, & Hay, 2002), generational recruitment (Le Gallic & Mongruel, 2006), and conservation efforts (Phillips et al., 2002; Wallace, 1999). Managing for flexibility can be used to avoid unintended consequences of fisheries management. Multi-species dedicated access systems such as multi-species catch shares have been proposed to mitigate such
concerns (Hilborn, 2007; Sanchirico, Holland, Quigley, & Fina, 2006). Such strategies seek to minimize spatial displacement, where if people cannot shift focus to other local fisheries, they may leave the area and enter fisheries further afield. This, in turn, can drain economic resources and livelihoods away from a community and increase pressure on resources and associated human systems elsewhere (Pomeroy, 2004). Limiting fishermen to a single fishery can make fishermen vulnerable, especially if that fishery becomes economically unviable.

The best method by which to manage fisheries for flexibility is debatable. An adaptable permitting system may be needed to integrate the management of strongly interacting fisheries. This applies to many fisheries globally, where fishermen shift focus seasonally and/or annually, or due to market or climate drivers. Managing for flexibility can be framed as managing portfolios of strongly interacting small-scale fisheries, and recognizing factors that may affect such portfolios. The CPS and squid permit systems in the Monterey Bay case provide the opportunity for fishermen to access all permits needed to catch each species, thus helping to ensure economic stability for participants.

Additionally, management that takes into account the conditions for success within the entire social-ecological system is benefited by shared knowledge between fishermen, scientists, and managers. In the case of the Juan Fernández lobster fishery, management practices restricted the relatively sustainable system in part because scientists and managers outside the local community were not aware of its informal tenure system (Ernst et al., 2013). This push for knowledge sharing and trust between different types of stakeholders is valuable especially for small-scale fisheries and has been a characteristic for improved fishery outcomes in some cases, such as in Chilean coastal fisheries.
Such participatory management strategies can further enhance implementing flexibility in a system as linkages and relationships may be more readily identified. One method that could further strengthen interconnected fisheries is expanding the lowest priced catch of a multi-species fishery to higher priced markets. In the case presented here, expanding the anchovy market to higher priced products would create more equal weight in desirability of the three species and may lead to more evenly distributed effort and more economic stability for participants.

The literature suggests that such systems may perform best if the interconnected system is at the same trophic level (Clark, 1990; Essington et al., 2006). In some cases, the exploitation of a broad range of species results in “opportunistic depletion” where high-value, low abundance species are collected since the low-value, high-abundance species are in the same area and caught with the same gear (Purcell et al., 2013). One area of caution is when interconnected fisheries are too similar and occupy the same niche, or are susceptible to the same risks. For example, the reason this interconnected system did not collapse during the 2002 domoic acid event was because fishermen could shift effort from the sardine fishery to the squid fishery. Thus, creating an interconnected system of species that occupy different niches or differ in their biological response to risks, such as vulnerability to toxins, may provide additional resilience. Interconnected systems would be beneficial in cases where coastal development and associated higher costs of living have led to economically nonviable single species fisheries. This has been seen in cases such as the Florida Keys where management failed to consider the broader socioeconomic context when creating a high cost of entry for the traditional fisheries, resulting in the majority of spiny lobster, shrimp, and stone crab fishery participants
exiting the industry as they could no longer make a living targeting one species (Shivlani, 2010). Other types of interconnected fisheries that depend on flexibility include nearshore tropical artisanal fisheries where participants integrate mangrove, reef, and semi-pelagic fisheries into a complex multi-species, multi-ecosystem network (Pratchett et al., 2011). The sectoralization of these fisheries or ecosystems could be harmful to participant's livelihoods and also may lead to ineffective management efforts. Another method for identifying potential interconnected fisheries for flexible management is in seasonal variation. In the case of the Piracicaba River fishery, the migrations of river fish are reflected in the usage of particular gear types according to seasonal patterns (Silvano & Begossi, 2001). The flexibility to shift gears with seasonal migrations is key to maintaining a steady fish production throughout the year for these fishermen. Additional flexibility may in some cases be the recognition of fishery participants shifting efforts between the fishery and other industrial sectors (Allison & Ellis, 2001; Bækgaard & Overballe, 1992; Johnson, 2005; McCay, 1978). The acknowledgement of such seasonal participation is critical to both fishery management and conservation initiatives, as well as for these participants who are often vulnerable and dependent on flexibility for their livelihoods.

Fishermen have historically fished the mean, knowing there will be big years and there will be lean years (McEvoy, 1986; Pradhan & Leung, 2004). Considering all the drivers that can induce fluctuations in one or more fisheries, we believe the key to management is to encourage flexible interconnected fishery systems. Managing fisheries as a coupled social-ecological multi-species system for flexibility provides extra
assurance that the fisheries and participants will remain viable within and across years,
even as conditions vary and change.
Chapter 3

3.1 Motivation for the Study

The concept of adaptive capacity is increasingly cited as critical to sustainable natural resource management (Folke et al., 2002; McClanahan & Cinner, 2008; Tengö & von Heland, 2011). Adaptive capacity is defined in this chapter as the latent ability of a social-ecological system and its components to rely on, or design and implement, effective adaptation strategies to cope with current or future disturbances. Key to such coping is that it occurs in a way that the system either retains its critical functions and structures, or transforms into a system with equal or improved social and/or ecological benefits. Another central feature is that the system retains its management, conservation, market, and resource-use options during a disturbance. The increasing emphasis on adaptive capacity in natural resource literature reflects calls for ecosystem-based adaptive management, as managers and scientists increasingly acknowledge that natural resource systems are complex and dynamic, and fluctuating conditions and crises are inevitable (Crowder et al., 2008; Gunderson, 2003; Pikitch et al., 2004; Young et al., 2006). While it has long been known that fisheries are subject to fluctuating conditions, fisheries management has only within the last few decades started to transition from managing for the steady state equilibrium of one-species to managing with more systems-based approaches (Smith, Fulton, Hobday, Smith, & Shoulder, 2007). As managers may attempt to account for the various social and environmental uncertainties and fluctuations that influence fisheries, ultimately it is the adaptive capacity of a particular system that determines how that system will respond to fluctuating stressors.

Adaptive capacity is an integrated feature of a natural resource social-ecological system and is directly related to the efficacy of resource management, as governance that
builds adaptive capacity is more likely to reach its management goals (Fabricius, Folke, Cundill, & Schultz, 2007; Gallopín, 2006). This case study examines adaptive capacity through a social-ecological lens, acknowledging that systems are integrated, interdependent, and coevolving. Many studies compare adaptive capacity at the national level due to the availability of better data and the fact that this is the level at which most policy formation occurs (Adger, Brooks, Bentham, Agnew & Eriksen, 2004; Adger & Vincent, 2005). This study instead focuses on the community level because adaptive capacity at this smaller scale often better reflects the specific resource system’s state. Studying a community’s capacity to adapt to a stressor potentially contributes insights into that community’s existing knowledge, experience, and institutional and organization capabilities. These insights could then be used to enhance the system’s overall adaptive capacity and management success (Fabricius et al., 2007). While various methods for measuring adaptive capacity have been proposed and tested, a simple yet effective approach is to document how a system or community experiences changing conditions and to analyze decision-making processes (Smit & Wandel, 2006). In addition to developing metrics to measure adaptive capacity, scholars have also developed and proven a number of strategies to build adaptive capacity in a system. Such strategies largely involve developing options for adaptive capacity within policy and within practice (e.g., resource use, market dynamics) (Armitage, 2005). This study builds upon previous work by exploring the potential of known adaptive capacity strategies within a specific system.

Any measurement of adaptive capacity is specific to a particular temporal and spatial context. We chose to focus on a system based on a resource with a known
relationship to a reoccurring climate perturbation that can be fairly well forecasted because we expect early warning systems to contribute to high adaptive capacity (Adger, Hughes, Folke, Carpenter, & Rockström, 2005). We analyze the adaptive capacity of the Monterey Bay wetfish fishing community (which targets Pacific sardine, \textit{(Sardinops sagax)}, northern anchovy \textit{(Engraulis mordax)}, and market squid \textit{(Loligo opalescens)}), in relation to a known significant stressor in the system: El Niño Southern Oscillation (ENSO). ENSO is a cyclical short-term climate fluctuation with global social and ecological consequences. However, effects vary from place to place, even within the same region or state (Diaz & Markgraf, 2000; Hewitson et al., 2014). Increasingly, scientific efforts aim to predict ENSO events and related consequences (Larson & Kirtman, 2015; McPhaden, Zebiak, & Glantz, 2006), and to better disseminate this information to communities that can use it to prepare for events and mitigate impacts (Broad, Pfaff, & Glantz, 2002; Goddard et al., 2010). It is well documented that the Monterey Bay fishing industry and wider community are influenced by ENSO events (Chavez, 1996; Dalton, 2001).

In Monterey Bay, El Niño events typically bring warm water species from Southern California, and some species that are usually abundant in Monterey waters, such as market squid, are significantly less available during events (Marinovic, Croll, Gong, Benson, & Chavez, 2002; Zeidberg, Hamner, Nezlin, & Henry, 2006). El Niño can also result in increased precipitation, storm activity, and flooding (Storlazzi & Griggs, 2000). This study focuses on how ENSO affects fish species but also considers how all ENSO-related consequences influence the fishing industry and greater community. While building adaptive capacity is often framed as the responsibility of managers or resource
users, all or most actors in a system can enhance or inhibit adaptive capacity, including but not limited to managers, scientists, resource users, community members, politicians, non-governmental organizations, national government agencies, and international trade groups. To reflect this, we take a broader look at the community rather than focusing on only fishing participants.

Monterey Bay serves as an ideal study site to investigate the role of ENSO in a community due to its history of ENSO-related impacts in the fishing industry, the close historical and community ties to the fishing industry, its relatively well-informed population, and its proximity to scientific resources. In March 2014, NOAA issued an El Niño Watch, indicating a strong event was likely to mature the following autumn and winter. We conducted interviews between August 2014 and December 2014. This was after the Watch was put in place, meaning ENSO information was publicly available in multiple outlets and users may have expected to observe evolving El Niño conditions.

This study builds upon the resource management/adaptive capacity literature by proposing a new three-part framework for studying a resource system’s adaptive capacity. These three parts are assessment, strategies, and activation. The first step, assessment, identifies the known and unknown stresses and hazards to the social-ecological system (e.g., the role of ENSO in the social-ecological system) and the institutional mechanisms that enable or constrain access to the resource. This step includes answering three questions that are essential to assessing a case: 1) “Who adapts to what?,” 2) “What is the adaptive capacity of?,” and 3) “What is adaptive capacity for?” (Brooks & Adger, 2005). The second step considers the wide variety of strategies a system can rely on for building adaptive capacity to a stressor. Many of these strategies
aim to mitigate risk, uncertainty, and contingencies, and widen the options for any resource system. Some of these strategies are short-term options (e.g., provide early warning signals, build physical infrastructure), while others demand a longer time scale (e.g., build a network of trust and reciprocity, stabilize national governments). While some argue that the concept of adaptive capacity should focus on a relatively medium-term timescale for a management system (e.g., Cinner et al., 2012), we argue that, at least in the case of Monterey wetfish, all strategies are valuable for enhancing adaptive capacity and can be applied at short, medium, and long-term temporal scales. Details on what strategies users recognize and rely on are best investigated during a disturbance and are most accessible through participant-based methodologies, such as interviews, especially considering how decision-making reflects adaptation strategies (Kates, 1971). The third step, activation, is necessary because while adaptive capacity is always within a system, it is not tested or realized until it is activated when a social or biophysical trigger occurs (Nelson, Adger, & Brown, 2007). The adaptive capacity of a system should already be present in the system when the stressor occurs. Observation of activation can include analysis of which strategies exist naturally, which strategies were proactively developed, which strategies were relied upon during a stressor, which strategies were ignored during a stressor, and which strategies users recognized.

With this framework, we test the hypothesis that the Monterey Bay wetfish fishery community’s adaptive capacity in relation to ENSO is high (indicating it is well equipped to cope with ENSO as a stressor). We speculate that such high adaptive capacity is a reflection of ENSO impacts being well understood and of the community being situated in an area that has easy access to forecasts. While we initially expect high
adaptive capacity (which we later analyze with the first step, assessment), we explore the contributing factors, guided by known adaptive capacity building strategies. We identify not only which strategies contribute to the system’s adaptive capacity, but also which strategies are absent or weak in this system. By examining a variety of social and ecological adaptive capacity strategies as an example of high adaptive capacity of a fishing community to El Niño events, this study may have implications for proactive enhancement of adaptive capacity for other common pool resource systems. This study contributes a new approach to analyzing a resource system’s adaptive capacity, adds further evidence for the validity of expected adaptive capacity building strategies, and provides insight into the use of ENSO-related information to make decisions within a fishing community.

3.2 Methods

We used a qualitative case study approach (Yin, 2013) to explore the adaptive capacity of the Monterey Bay wetfish fisheries to ENSO, collecting data primarily through semi-structured interviews and secondary gray literature sources. We conducted forty-nine semi-structured interviews, most of which were in person or by telephone, and lasted approximately one hour on average. Participants were chosen based on their active involvement in the Monterey Bay wetfish fisheries and/or in their role in providing ENSO information to fishery participants. Participant categories include captains and crew-members (8 participants); processors and buyers, many of whom play both roles (6 participants); state and federal fishery resource managers, who were divided into two categories based on whether their activities were primarily regulatory (12 participants) or primarily scientifically oriented (7 participants); harbor affiliates (4 participants); non-
governmental organization (NGO) representatives (5 participants); and official ENSO information providers from various agencies (7 participants). These subjects represent the range of individuals in these fisheries who have an actual or theoretical stake in the use of ENSO information. Participants were first identified through publicly available information, such as government websites, news articles, and NGO publications, and secondarily through the snowball method (Faugier & Sargeant, 1997). Interviews were structured to explore the participant’s activities in the fisheries, their views on how past ENSO processes and effects have influenced the local system, where they found ENSO related information, how they communicated about ENSO with others in the community, the trustworthiness of the information they saw, the usefulness of such information, and personal and professional decisions they made according to available information. The research protocol was reviewed and approved by the University of Miami Institutional Review Board (protocol #MOD00002686).

3.2.1 Analytic Approach: Thematic Coding with NVivo

Deductive coding of transcribed interviews was completed with the computer assisted qualitative data analysis software NVivo v.10 (Bazeley & Jackson, 2013). Thematic coding initially divided data among a framework we developed for analyzing adaptive capacity: assessment, strategies, and activation. The coded theme ‘strategies’ was coded into subcategories based on type of strategy. Sixty-seven strategies were coded after being identified through a literature review of natural resource management publications for strategies expected or known to build adaptive capacity.
3.3 Results

3.3.1 Assessment

The first step in assessing adaptive capacity is to evaluate participants’ perception of the role of ENSO in the community and fishing industry. While the physical impacts may differ from the participants’ perceptions of those impacts, the perceived severity and characteristics of a stressor on a system is likely reflective of the strength of the system’s adaptive capacity; whereas a stressor that is perceived to be detrimental to one system with lower adaptive capacity may be perceived to be harmless to a similar system with higher adaptive capacity.

Interviews indicate widespread acknowledgement of the potential negative impact an El Niño event can have on the wetfish fishing industry. ENSO events were associated with piers being destroyed, houses being damaged, floods, landslides, personal injury, and long periods of non-fishable days. The most significant potential negative impact was the obliteration of the squid fishery. As one fisherman noted: “El Niño is tragic for a squid. A mild one is not as devastating, a severe one is total disaster.”

However, participants also mentioned positive outcomes of El Niño events, including better surfing conditions, better sport fishing, and swimmable waters. Many participants welcomed the upcoming El Niño event, hoping it would end the prolonged drought on the West Coast. While recognizing potential fishery declines in their most valuable fishery (squid), many participants recognized ENSO could yield conditions that would enable them to target a new suite of fish species (rather than resulting in the destruction of the ecosystem). As one fisherman’s description illustrates:
Well when you get El Niños you get different fish. The waters get warmer, we get some strange fish that come up here sometimes. Fish stay out in the deeper waters, they don't like to come in, I mean there's fish like the mackerel that like the warmer water, they'll come in. Sardines like warmer water, they'll come in. Anchovies yeah they like warmer water, they'll come in sometimes. El Niño could hurt our squid. We've seen it hurt our squid a little bit, because it doesn't let the fish come in, and they spawn out in the deep. Not that it hurts it as a species of fish, but we've had real bad years with an El Niño, and then the next year will be the biggest year we've ever had. So it's kind of like a Mother Nature—they survive. They just don't come where we can catch them. We kind of are coastal fishermen.  

—Fisherman

Understanding how participants make decisions regarding a stressor also informs us of the adaptive capacity of the system. About half of participants responded that they would “do nothing” if they saw information about an upcoming El Niño event. The most significant behaviors – other than doing nothing – were integrating ENSO into new or current studies and projects (this was a common response for managers and NGO participants), and making financial changes (a response given mostly by fishermen, processors, and NGO participants). Many industry participants noted that while an El Niño event could be “devastating,” if one were to hit, they would be able to withstand it. For example:

You have a bunch of storms, and there's a bunch of run-off, you have problems fishing…I'm kind of set up for it, whatever happens happens. So like I said if we had to—I'm just worried about my crewmembers and people that work for me, but we'll survive.  

—Fisherman

Many participants who acknowledged the sometimes dramatic role ENSO could play on the system, also indicated ENSO was just one of many factors which must be considered by industry and management. As one participant explains:

Ultimately [ENSO] is one factor, so there’s nothing specifically deterministic, you know there’s lots of things going on in the large scale ocean atmosphere system and if there is an El Niño or a La Niña taking place then that’s one thing going on. No one thing kind of determines everything.  

—Information Provider
Participants perceived ENSO as being within the range of expected stressors on the system, with a number noting that ENSO does not pose any unique stress to the system and that each potential impact can be brought on by other stressors. Fishery managers were well aware of impacts on fishing trends, but no specific ENSO-related policy or regulation exists. Many in the community consider the Monterey Bay wetfish fisheries as fairly resilient; one NGO representative was confident in saying, The Monterey wetfish industry “will continue until the earth stops.” The acknowledgement of potentially drastic consequences from an El Niño event, combined with the most common response to an impending event as “do nothing” and “stay aware”, indicate high adaptive capacity in this system.

The second step in assessment is to identify institutional mechanisms that enable or constrain access to resource. The primary mechanisms in this system are governance (management body closes fishery or adjusts quota), market (lose buyers if supply is not steady, buyers fluctuate according to global seafood market dynamics), and infrastructure (vessels are not equipped for long days at sea or offshore, so if species migrate outside this zone, fish are inaccessible; trucking lowers quality of species, especially squid, and so if have to truck from/to new landing or processing sites, value decreases).

The third and final step in assessment is to answer a series of three questions about the system. In this case the question, “who adapts to what”, has three answers. One, fishermen and processors adapt to a new species portfolio as fish migrate to the bay from warmer temperatures and normal target species decline in availability, and to less biomass (ecosystem productivity decreases). Two, harbors and vessels adapt to increased frequency and severity of storms. Three, management adapts to a stressed ecosystem (less
productivity, less prey) and a stressed industry (economically viable industry is a goal of management). In this case, the answer to the question “What is the adaptive capacity of” is that adaptive capacity is of the local fishing industry persisting through an ENSO event that is typically 1-2 years long. Lastly, “what is adaptive capacity for” can be answered by identifying what participants would consider a system transformation. From interviews, we gathered that a system would be considered transformed if 1) the governance system closed the wetfish fisheries for multiple years and/or 2) the traditional fishing community exits the fisheries, sells vessels and processing plants, and “outsiders” control the industry. Thus, adaptive capacity can be considered to exist in order to prevent the system from reaching this perceived tipping point.

3.3.2 Strategies

Of the 67 adaptive capacity building strategies identified, 42 were present in relation to ENSO as a stressor, 13 were partially present with room for improvement, and 12 were not observed in this system in relation to ENSO. Table 3.1 lists all coded strategies, and identifies which were found present in the case, which were partially present, and which were absent. Table 3.2 presents the role and an example of the top five strategies that contribute the most to the adaptive capacity of the case in relation to ENSO: (1) access to early warning systems; (2) encourage social learning; (3) match rules (and change to match rules) to system dynamics; (4) diversify livelihoods; and (5) build economic safety nets. Table A.2.1 in Appendix B reviews the role of all coded strategies and provides supporting examples. Four strategies were found to be contrary or surprising to expectations and are further explained in the discussion. This includes three from the learning category (maintain collective memory, change policies and
management strategies according to new knowledge, and learn from mistakes in practice) and one from the participation category (involve stakeholders through active participation in decision-making processes). While collective memory was expected to contribute to higher adaptive capacity, coding results indicate this strategy rather inhibited adaptive capacity. The changing of fisheries policies to new knowledge was expected to be strongly present considering the high degree of scientific monitoring, frequent integration of scientific information, and common references supporting adaptive management in the case system, though was found absent. Learning from mistakes was found external to the system (another ecosystem) rather than learning from inter-system mistakes. We expected all participants to identify involving stakeholders through active participation as helpful, but this strategy was found to be helpful by some and absent by others.

Table 3.1. Strategies for Building Adaptive Capacity

<table>
<thead>
<tr>
<th>Category</th>
<th>Strategy</th>
<th>Study Identified In</th>
<th>In Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diversity</td>
<td>Increase institutional diversity and redundancy</td>
<td>Armitage, 2005</td>
<td>Present</td>
</tr>
<tr>
<td></td>
<td>Provide diversity of management options</td>
<td>Folke et al., 2002</td>
<td>Present</td>
</tr>
<tr>
<td></td>
<td>Ecological memory: diversity of species within and between functional groups</td>
<td>Folke et al., 2002</td>
<td>Present</td>
</tr>
<tr>
<td>Empowerment</td>
<td>Recognize community heterogeneity; consider respective norms, values, and world views</td>
<td>Armitage, 2005</td>
<td>Present</td>
</tr>
<tr>
<td></td>
<td>Foster policies aimed at empowering communities</td>
<td>Fabricius et al., 2007</td>
<td>Partial</td>
</tr>
<tr>
<td></td>
<td>Create policies for institutional frameworks to self-organize and autonomously respond to change</td>
<td>Fabricius et al., 2007</td>
<td>Partial</td>
</tr>
<tr>
<td>Flexibility</td>
<td>Resource</td>
<td>Author</td>
<td>Status</td>
</tr>
<tr>
<td>---------------------</td>
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</tr>
<tr>
<td>Mobilize marginalized groups</td>
<td>Robinson &amp; Berkes, 2011</td>
<td>Absent</td>
<td></td>
</tr>
<tr>
<td>Promote access of grassroots voices to higher level participation opportunities</td>
<td>Robinson &amp; Berkes, 2011</td>
<td>Partial</td>
<td></td>
</tr>
<tr>
<td>Support local people’s creativity and determination</td>
<td>Eriksen, Brown, &amp; Kelly, 2005</td>
<td>Present</td>
<td></td>
</tr>
<tr>
<td>Inspire motivation in all actors</td>
<td>Fabricius et al., 2007</td>
<td>Absent</td>
<td></td>
</tr>
<tr>
<td>Flexible collaboration</td>
<td>Folke et al., 2002</td>
<td>Partial</td>
<td></td>
</tr>
<tr>
<td>Flexible management</td>
<td>Folke et al., 2002</td>
<td>Partial</td>
<td></td>
</tr>
<tr>
<td>Flexible multi-level governance aiming to learn and handle change</td>
<td>Folke et al., 2002</td>
<td>Present</td>
<td></td>
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<tr>
<td>Institutional flexibility in problem solving</td>
<td>Folke et al., 2002</td>
<td>Present</td>
<td></td>
</tr>
<tr>
<td>Keep options open</td>
<td>Nelson et al., 2007</td>
<td>Present</td>
<td></td>
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<tr>
<td>Ecological flexibility</td>
<td>Turner et al., 2003</td>
<td>Present</td>
<td></td>
</tr>
<tr>
<td>Build social and physical infrastructure</td>
<td>McClanahan et al., 2008</td>
<td>Partial</td>
<td></td>
</tr>
<tr>
<td>Provide access to early warning systems</td>
<td>Cinner et al., 2012</td>
<td>Present</td>
<td></td>
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<tr>
<td>Inspire innovation</td>
<td>Armitage, 2005</td>
<td>Partial</td>
<td></td>
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<tr>
<td>Minimize corruption</td>
<td>Cinner et al., 2012</td>
<td>Absent</td>
<td></td>
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<tr>
<td>Increase political transparency</td>
<td>Cinner et al., 2012</td>
<td>Absent</td>
<td></td>
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<tr>
<td>Strengthen personal leadership skills and promote vision</td>
<td>Fabricius et al., 2007</td>
<td>Present</td>
<td></td>
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<tr>
<td>Promote learning through uncertainty and through crises</td>
<td>Armitage, 2005</td>
<td>Present</td>
<td></td>
</tr>
<tr>
<td>Learn from mistakes in practice</td>
<td>Armitage, 2005</td>
<td>Present</td>
<td></td>
</tr>
<tr>
<td>Encourage social / participatory learning</td>
<td>Berkes &amp; Ross 2013</td>
<td>Present</td>
<td></td>
</tr>
<tr>
<td>Stimulate institutional learning</td>
<td>Folke et al., 2002</td>
<td>Present</td>
<td></td>
</tr>
<tr>
<td>Test various management policies</td>
<td>Folke et al., 2002</td>
<td>Partial</td>
<td></td>
</tr>
<tr>
<td>Monitor ecosystems</td>
<td>Brooks &amp; Adger,</td>
<td>Present</td>
<td></td>
</tr>
<tr>
<td>Category</td>
<td>Action</td>
<td>Reference</td>
<td>Year</td>
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<tr>
<td>Accumulate new knowledge</td>
<td>Folke et al., 2002</td>
<td>2005</td>
<td></td>
</tr>
<tr>
<td>Match rules (and change to match) to system dynamics</td>
<td>Folke et al., 2002</td>
<td>2005</td>
<td></td>
</tr>
<tr>
<td>Change policies and management strategies according to new knowledge</td>
<td>Folke et al., 2002</td>
<td>2005</td>
<td></td>
</tr>
<tr>
<td>Foster institutions that aim to learn and store knowledge and experience</td>
<td>Folke et al., 2002</td>
<td>2005</td>
<td></td>
</tr>
<tr>
<td>Continuously evaluate and review the system and management interactions</td>
<td>Brooks &amp; Adger, 2005</td>
<td>2005</td>
<td></td>
</tr>
<tr>
<td>Maintain a collective memory of experiences</td>
<td>Armitage, 2005</td>
<td>2005</td>
<td></td>
</tr>
<tr>
<td>Linking</td>
<td>Link different knowledge networks (to support learning and adaptation)</td>
<td>Armitage, 2005; Fabricius et al., 2007</td>
<td>2005</td>
</tr>
<tr>
<td>Nest institutional arrangements across scales</td>
<td>Fabricius et al., 2007; Robinson &amp; Berkes, 2011</td>
<td>2011</td>
<td></td>
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<tr>
<td>Link management with culture</td>
<td>Fabricius et al., 2007</td>
<td>2007</td>
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<tr>
<td>Livelihoods</td>
<td>Invest in economic alternatives to resource dependent livelihoods</td>
<td>McClanahan et al., 2008</td>
<td>2008</td>
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<tr>
<td>Diversify livelihoods</td>
<td>Eriksen et al., 2005</td>
<td>2005</td>
<td></td>
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<tr>
<td>Participation</td>
<td>Facilitate actors at multiple levels to interact with each other</td>
<td>Folke et al., 2002</td>
<td>2005</td>
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<tr>
<td>Improve stakeholder relationships</td>
<td>Leslie et al., 2015</td>
<td>2015</td>
<td></td>
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<tr>
<td>Involve stakeholders through consultation</td>
<td>McClanahan et al., 2008</td>
<td>2008</td>
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<tr>
<td>Involve stakeholders through active participation in decision-making processes</td>
<td>Robinson &amp; Berkes, 2011; McClanahan et al., 2008</td>
<td>2011; 2008</td>
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<tr>
<td>Involve stakeholders through compensation</td>
<td>McClanahan et al., 2008</td>
<td>2008</td>
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<tr>
<td>Encourage deliberation, and create</td>
<td>Robinson &amp; Berkes, 2008</td>
<td>2008</td>
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<tr>
<td>Policy Formation</td>
<td>Create policies which enable options</td>
<td>Fabricius et al., 2007</td>
<td>Partial</td>
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<td></td>
<td>Write policies with clear directions for purposefully building adaptive capacity</td>
<td>Folke et al., 2002</td>
<td>Absent</td>
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<td></td>
<td>Include active platforms for adaptive management processes in policies</td>
<td>Folke et al., 2002</td>
<td>Present</td>
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<td></td>
<td>Close loopholes which promote illegal participation</td>
<td>Leslie et al., 2015</td>
<td>Absent</td>
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<tr>
<td>Safety Nets</td>
<td>Stimulate social safety nets to prevent poverty traps</td>
<td>Cinner et al., 2012; Eriksen et al., 2005</td>
<td>Present</td>
</tr>
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<td></td>
<td>Increase stability of national government</td>
<td>Cinner et al., 2012</td>
<td>Absent</td>
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<td>Build safety nets to endure political shifts</td>
<td>Eriksen et al., 2005</td>
<td>Absent</td>
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<td></td>
<td>Build economic safety nets</td>
<td>Eriksen et al., 2005</td>
<td>Present</td>
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<tr>
<td>Social Capital</td>
<td>Enhance collaboration</td>
<td>Armitage, 2005</td>
<td>Present</td>
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<tr>
<td></td>
<td>Stimulate power sharing</td>
<td>Armitage, 2005</td>
<td>Absent</td>
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<td></td>
<td>Build social trust</td>
<td>Eriksen et al., 2005</td>
<td>Present</td>
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<tr>
<td></td>
<td>Enhance reciprocity among actors</td>
<td>Eriksen et al., 2005</td>
<td>Present</td>
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<td></td>
<td>Encourage cohesion among networks</td>
<td>Armitage, 2005</td>
<td>Present</td>
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<tr>
<td></td>
<td>Consider various norms/perspectives in policy development</td>
<td>Armitage, 2005</td>
<td>Partial</td>
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<td></td>
<td>Strengthen community relationships</td>
<td>Berkes &amp; Ross, 2013</td>
<td>Present</td>
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<td></td>
<td>Enhance cooperation among groups through social learning</td>
<td>Robinson &amp; Berkes, 2011</td>
<td>Present</td>
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<td></td>
<td>Develop partnerships through social learning</td>
<td>Robinson &amp; Berkes, 2011</td>
<td>Present</td>
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<tr>
<td>Strategy</td>
<td>Role in Case</td>
<td>Illustrative Example(s)</td>
<td></td>
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<tr>
<td>Provide access to early warning systems (EWSs)</td>
<td>ENSO EWSs are produced at a global/national level (primarily Climate Prediction Center), &amp; then distributed through the community by multiple sources (e.g., National Weather Service, Coast Watch website, community leaders) through face to face communication, phone, email, social media, mainstream media, or public posting. All participants were confident they would hear/see an ENSO warning in plenty of time to prepare. Fishermen &amp; processors recognize observations in sea surface temperature &amp; biological shifts as local early warnings; they subscribe to services to track changing oceanic conditions &amp; buoy data. Forecasts were used by participants ranging for purposes from general awareness to planning monitoring activities to conserving funds. Challenges include lack of warning specifically for Monterey area, abundance of potentially helpful information, &amp; lack of confidence for direct use of</td>
<td>1) “El Niño is tragic for a squid. Evidently I read in the paper just the other day that the prediction of El Niño is waning and there is only 65% prediction now compared to 85% and that actually they claim it may be a mild one. A mild one is not as devastating; a severe one is total disaster. I read where it was 4 degrees warmer earlier in the year and now I think it's set at one point, it's a half degree colder than normal.” – Fisherman 2) “I think probably the challenge is though there's a lot of information, it's often not clear—at least speaking for myself—how to use that information, and what information is meaningful to the coastal pelagic species. Because what I might need to pay attention to is different than say what salmon fishery biologists would look at. Or sometimes there seems to be a lot of information, but how to actually utilize that and translate it into management is difficult. It's hard to keep up with all that's coming out.” – Manager (regulatory)</td>
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<td>Diversify livelihoods</td>
<td>A diverse portfolio is recognized as a key strategy to industry survival during El Niño events. Sardines &amp; anchovies were primarily targeted during ENSO events, followed by mackerel, tuna, &amp; other warm water species. Otherwise, fishermen would travel to San Francisco or Alaska &amp; work on fishing vessels there (though not as captains &amp; not on their own vessels), or go into another industry (e.g., construction, taxi services). Processors &amp; buyers can rely on other species (e.g., opal, mackerel) or buy squid from other locations (e.g., Falkland Islands) to satisfy customer base, or even access new products (e.g., strawberries). “So if you're a commercial fishermen now, you've got to sort of diversify a little bit, to where you're gonna fish squid, sardines, mackerel, maybe have a chance to go to Alaska. So if you're going to depend on that to make a living, you're going to want to be able to jump around, have the opportunity. A lot of guys got into construction, because most guys that were fishing were pretty outdoors type of people right. There's carpentry or plumbing or general construction, and a lot of guys did that. Some guys got out.” – Fisherman</td>
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<td>Encourage social learning / participatory learning</td>
<td>Participants from all roles identified a key person or group of people they communicate about ENSO to, many of which depend on that person for all or most information about ENSO (including but not limited to local impacts, forecast likelihood, oceanic condition changes). Those on the water share observational information. Managers &amp; scientists engage in formal conference calls regarding ENSO, &amp; partake in informal conversations regarding ENSO with local community members &amp; the global research community. Since ENSO potentially can lead to multiple impacts (weather, storm damage, marine biological, terrestrial biological changes), there are 1) “I just kind of go by what I see. Like I'll see something on the news, says &quot;oh the El Niño&quot;, then I look it up, call up the guys say &quot;hey what are you seeing up in there?&quot; You know call a guy in Monterey, call a guy in San Diego, wherever, whoever’s out, and just try to see what the conditions are. That's my best way to do it.” – Fisherman 2) “We'll also contact scientists and researchers locally, and sort of, get them on the phone and have conference calls and say okay what are you seeing, what are your thoughts on this. We'll be at a group of folks going on so we can sort of get a wide pulse of both like you know, what sort of animals people are seeing, in terms of, it's not an El Niño direct sort of thing but you</td>
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<td>EWSs in fishery management activities.</td>
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<tr>
<td>Build economic safety nets</td>
<td>Actors are financially conservative for times such as these, &amp; especially conserve funds if they see an ENSO forecast. Options for fishermen include tying up vessels &amp; going on a new insurance plan (Port Risk), relying on unemployment, &amp; collecting disaster loans from government (only if ENSO is proven disastrous). Options for processors include saving product for key buyers when expecting next year to be lean &amp; processor/vessel companies increasing use of spotter planes (save time &amp; money).</td>
<td>“I'm saving my money. I'm not buying any real expensive new stuff. I'm not going into debt, just taking it easy, because if it does hit, I'll be able to get through the times. So my decision would be not to upgrade my business, not to spend a bunch of money right now into a fishing business that I can't recoup. So right now I'm in save mode and planning for when it hits, or if it hits, to have everything as low an expense as possible, where I can just get by for a couple years until it's over with.” — Fisherman</td>
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<td>Match rules (&amp; change to match) to system dynamics</td>
<td>Fishery management seeks to ensure rules align with social interests &amp; ecological conditions. In sardine management, the SST parameter aims to match the harvest guideline to system changes through temperature as a proxy. Rules for ENSO matches system dynamics; ENSO impacts</td>
<td>“I think with respect to sardine and anchovy, just recognizing to the extent that these regional shifts are predictable. Just recognizing how those might affect fishers’ behavior. But the way those fisheries are managed, or at least the way the sardine fishery is managed, is based on stock assessment models that—</td>
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are not the same with each event, & so management stays aware & increases monitoring without engaging in any specific regulatory trigger. Researchers consider a continuum of ENSO events, & this trickles down through the system so that management is cautionary & not focused on the forecast. While El Niño events have an immediate impact on squid, sardine & anchovy often experience lags in impacts. As such, management aims for long-term stability (thus matching rules to system dynamics, e.g., lags).

they already account for this. One bad recruitment year is not going to destroy the stock unless the stock is at a very low level. If the stock's at a very low level, the harvest rate should already be low, or nothing, or basically to trivial or nuisance levels. So in theory, if we had a better sense of how the population really responded to both high frequency and low frequency climate, we could improve management. And we do have some sense of that, and that's actually in the management plan. It's the temperature control that drives the harvest rate. So climate's kind of recognized in there, but we don't have perfect understanding just of how climate is driving productivity.” – Manager (science)

### 3.3.3 Activation

The activation of a system’s adaptive capacity to ENSO was observed in a two-step fashion: first, through the NOAA forecast of an El Niño event, and second, through the observation of biological changes. Key strategies that were activated after the forecast include: create policies for institutional frameworks to self-organize and autonomously respond to change, provide access to early warning systems, inspire innovation, strengthen personal leadership skills and promote vision, promote learning through uncertainty and through crises, encourage social learning / participatory learning, stimulate institutional learning, monitor ecosystems, encourage deliberation and create new processes for multilevel nested deliberation processes, build economic safety nets, build social trust, enhance cooperation among groups through social learning, and advance technology and access (Table 3.1).
However, as an NGO representative stated, “El Niño doesn’t happen until it happens. Kind of like crying wolf sometimes.” As such, most participants were hesitant to make changes until they were certain ENSO was a present factor. During the time of interviews, Monterey was experiencing unusually high sea surface temperatures and participants were well aware of the El Niño forecast (sea surface temperatures (SSTs) were reaching 18°C, far above the average temperatures of recent years of 13-15°C (NDBC Station 46042)). Despite this context, key system adaptive capacity strategies were not yet activated or relied upon. The following strategies were mentioned, or would be expected once biological changes were experienced: flexible management, change policies and management strategies according to new knowledge, continuously evaluate and review the system and management interactions, invest in economic alternatives to resource dependent livelihoods, diversify livelihoods, create policies which enable options, include active platforms for adaptive management processes in policies, stimulate social safety nets to prevent poverty traps, and willingness and availability of resources to be allocated for adaptation.

### 3.4 Discussion

This case study uses the Monterey Bay wetfish fisheries to exemplify a new approach to examining adaptive capacity within a resource system. We first assess the level of adaptive capacity of the fisheries system in relation to a specific known stressor, ENSO. We consider users’ decision-making as an appropriate reflection of the high level of adaptive capacity within the social-ecological system. At first, participants indicated no preparation or plan including specific decisions to be made given the forecast of an ENSO event, despite their acknowledgement of the sometimes drastic consequences the
community and industry might experience during an event. Upon deeper investigation - illustrating one advantage of ethnographically oriented methods - however, ENSO does play a role in making decisions. These decisions largely reflect the adaptive capacity strategies that exist within the system. This study considers the whole fishery social-ecological system beyond primary extractors, who are in this case fishermen. By doing so, we are able to more fully understand the dynamics of the system and are able to engage with the community members who enhance or constrain the adaptive capacity of these fisheries.

3.4.1 Assessment

We consider the Monterey Bay wetfish fishing community to have high adaptive capacity to the stressor of an El Niño Southern Oscillation event. While ENSO may result in dramatic consequences, the most severe and likely of which would be to completely shut down the most economically lucrative squid fishery and damage piers and vessels, participants all indicated the system would ultimately endure the most severe event. We discovered that fishery management acknowledges the role of ENSO, fosters strong attitudes toward adaptive management, and has engaged in discussions regarding ENSO regulatory triggers particularly within the squid fishery management plan. However, no specific ENSO policy or regulation exists. The strategies identified in this study explain how the system is able to withstand such a stressor.

Adaptive capacity literature discusses fundamental system transformations. We postulate that this system underwent a fundamental transformation in the 1950s with the crash of the sardine fishery, which resulted in long-lasting ecological and economic damage. Moreover, the level of infrastructure and industry never recovered from this
crash (Radovich, 1982). It is not surprising the fishery participants and those involved in the industry “roll with the punches,” as fisheries globally are typically well accustomed to fluctuating conditions. Interviews confirmed that this feature indeed exists in this system, and ENSO is considered only one of many drivers that fisheries must cope with and respond to. However, this study goes beyond this common response of fisheries to fluctuations, and explores other social-ecological adaptive capacity strategies that exist within the system. While a reasonable argument may be that fisheries are simply ready to handle any stressor, adaptive capacity theory stems from studies of transformations. No system is guaranteed to remain in a continuous, stable state forever, and thus we explore the conditions for which this current system remains.

3.4.2 Strategies

The most influential categories of adaptive capacity were safety net, access to early warning systems, social capital, diversity, and learning. The greatest threat to adaptive capacity in natural resource management comes when the resource is managed for a stable state. While the management system examined in this case study aims to stabilize the fisheries to reach social and ecological goals (ensuring the fisheries do not crash ecologically or economically), strong attitudes exist in encouraging adaptive management. These attitudes also exist within the industry and greater community, and are best observed through the high value dedicated to learning within the system.

Participants from all roles within the fishing community aim to continuously learn how the system responds to ENSO events. Multiple agencies, organizations, and individuals monitor the ecosystem, and increase monitoring efforts with an ENSO forecast. Users are open to various flavors of ENSO, illustrated by the many
conversations within the community regarding the wide variety of potential impacts and adaptation options with different types of events. In the sardine harvest guideline equation, the SST parameter is one component of the equation that determines each season’s catch limit. This parameter is used as a proxy for environmental change and aims for the fishery to fluctuate with environmental stressors such as ENSO. Interviews indicated strong willingness to learn how other parameters or information may better inform ecosystem adaptive management strategies. Analysis of the learning strategies identified where learning is needed the most when ENSO factors into in the system: linking climatology to biology, and understanding local (Monterey Bay specific) ENSO impacts.

Building economic safety nets was the most commonly cited active decision in light of an approaching ENSO; no other real long-term decisions were considered. However, for many the most important strategy was consulting early warning systems. Early warning contributed the most to activation, with the first component (forecasts) specific to global ENSO indicators, and the second component (local observations), specific to the area. This distinction was reflected in the variety of decisions users made. The strong social learning found in this system reflects the strong social capital in the system. Community cohesion in the “hyper-connected” system (as one participant called it) ensured individuals that others would inform them of an ENSO event and expected impacts, allow them to make their own decisions, or assist them to financially withstand an event.

Interviews confirmed findings from the second chapter that flexibility in a diverse portfolio substantially contributes to the adaptive capacity of this system to ENSO. This
study furthers this previous finding to show that a diversity of options is a reflection of the strong social capital and linking strategies. Social capital in the form of captains assisting crew financially during ENSO years, other fisheries reporting to the wetfish industry observed oceanic changes (e.g., squid egg capsules in unusual areas), and trust that ENSO information will be reliable, non-biased, and shared with plenty of time for the industry to decide whether to assess options, contributes to portfolio diversity. Strategies that contribute to the diversity of options include linking different knowledge networks to understand how physical changes may soon result in biological shifts (thus preparing to switch target species) and connecting to the greater West Coast industry so that fishermen and processors are able to access different systems (e.g., different products such as within the agriculture industry or different areas such as San Francisco and Alaska).

3.4.2.1 Unexpected Strategies Findings

We expected the learning strategy ‘maintain a collective memory’ to strengthen the system’s adaptive capacity. However, we found that because of the nature of ENSO, this was not the case. The participants’ average experience was 20 years, but experience ranged from 2 to 57 years. Many participants cited that this (2015-16) was their first ENSO event. Often, participants who voiced this meant they were not in the industry in 1997-98, and despite having been in the area during weaker events, did not recall them. These participants sought knowledge and guidance on what to expect from those well seasoned in the fisheries/community. Individuals and organizations did record memory of previous ENSO events, but this was not necessarily helpful in contributing to the adaptive capacity of the current event because of the variety of types and strengths of ENSO and
the wide range of potential impacts. Reading the forecast gave many participants a general sense of what to expect, but often did not elicit a salient memory. The 1957-58, 1982-83, and 1997-98 events were most remembered, and some participants expected the same consequences during this event as from these very strong events. Additionally, many recollections of ENSO events were recollections of warmer or wetter years that were not necessarily during an El Niño event, complicating the collective memory and muddling the expected impacts of ENSO in the area.

Another learning strategy, ‘change policies and management strategies according to new knowledge,’ also contradicted our expectation that it would contribute to adaptive capacity. When new knowledge about ENSO is presented, fishery policies are not changed. While perhaps optimistic, we expected fisheries policies to dictate a shift in management practice with new information, such as ENSO information informing harvest guidelines or catch limits. We expected this especially considering the strong attitudes of valuing adaptive management; instead, we found a prevalent attitude against changing policies. Policies were slow to change because of uncertainty of the biological responses to ENSO, the requirement for well-developed science-based reasons for a change, the long-term process of policy deliberation, and for fear of opening policies for discussion as it might result in unintended changes such as an increase or decrease of catch limits. Additionally, ENSO was considered a short-term perturbation, with expectations that the system would bounce back. The attitudes and practices within fishery policy formation reflect the need for adaptive capacity. The governance system is cautious and values learning; but without perfect predictability and a thorough understanding of local ENSO impacts, even while policies may attempt to be adaptive,
match system dynamics, and incorporate environmental conditions into harvest
guidelines, ultimately the system must rely on real-time monitoring. Thus, the system is
largely dependent on its adaptive capacity.

While not necessarily contradictory, an unexpected finding is that the strategy
‘learn from mistakes in practice’ was not found in the wetfish fisheries, but rather we
found evidence of it contributing to the wetfish fisheries’ adaptive capacity from activity
within a different fishery. Many participants (including managers, fishers, processors, and
NGO representatives) looked to the southern California gillnet swordfish fishery to test
an ENSO-specific regulation in a fishery. To protect sea turtles, the National Marine
Fisheries Service (NMFS) is required by a 2003 law to close the swordfish fishery within
the Pacific Loggerhead Conservation Area (south of Point Conception to the Mexican
border) when an El Niño event is occurring or is forecasted, as sea turtles are expected to
migrate to this area in search of cooler water temperatures during an El Niño event. The
implemented regulation, Title 50, §660.713 of the Code of Federal Regulations mandates
that the assistant administrator for NOAA’s fisheries determine whether that trigger has
been met by examining NOAA SST anomaly data for southern California for the second
and third months prior to the month of closure, but otherwise sets no quantitative
requirements and gives that administrator wide discretion to determine whether an El
Niño event is in fact present or imminent. Though the regulation was implemented in
2004, NMFS did not close the drift gillnet fishery during documented El Niño events in
2004-2005, 2006-2007, and 2009-2010; it was not until the 2014 El Niño forecast that
NMFS did so, and then only after conservation groups filed a lawsuit in federal court to
compel that closure (Steiner, Kilduff, & Enticknap, 2014). While El Niño can
significantly affect many fisheries, particularly off the West Coast, this stipulation in the swordfish fishery is the only ENSO-specific policy instrument that currently exists. However, the early closure in 2014 in the swordfish fishery was not perceived to be effective, and many participants noted that it was improper to use an ENSO forecast as a trigger, rather SST should have been the primary metric for change. As such, this ‘mistake’ in the swordfish fishery guides decisions in the wetfish fisheries to remain focused on SST, rather than to trigger any regulatory change with an ENSO forecast or declaration. This example supports our argument that adaptive capacity studies should widen their scope to other ecosystems or institutional levels when studying a system.

The last unexpected strategy was ‘involve stakeholders through active participation in decision-making processes.’ We observed that management and the greater community perceive participation frameworks as helpful, as we expected. However, while stakeholder engagement programs, public deliberation, and industry consultation processes exist and contribute to the system’s adaptive capacity, we also found that many fishermen and buyers believe traditional knowledge is ignored by the governance system and that only scientific knowledge is valued. In terms of ENSO, strengthening this strategy would greatly enhance the adaptive capacity of the system since activation heavily relies upon local observation of ENSO impacts, which fishermen and processors may observe before scientists. We also found that participation largely depends on the strategy ‘empowerment’, where effective stakeholder involvement is a factor in supporting local people’s creativity and determination as well as in institutional frameworks for self-organization and autonomous response to change. While participation processes exist, they are effective because of the community leaders who
are determined to link knowledge networks (e.g., connect resource users to ENSO information providers and managers). Knowledge sharing is a product of the highly connected community. While involving stakeholders in management processes is helpful, doing so is more effective if the system empowers individuals, allowing them to create their own response mechanisms and create their own learning networks. This is observed within information providers, where specific individuals, and their ability to act upon their own creativity and determination, create decision support tools and develop community outreach initiatives. Allowing fishermen and processors to access ENSO information and respond to ENSO changes in their own fashion, without any top-down imposition, allows for creativity (e.g., fish processors turn to processing strawberries to make ends meet if fish landings are low) and industry success (e.g., fishermen continue fishing in warm water brought by ENSO until conditions dictate it is no longer economically viable, rather than being told to stop fishing with an ENSO forecast). We argue that building participation adaptive capacity strategies without also building empowerment strategies would be detrimental to a resource system’s adaptive capacity.

3.4.2.2 Proactive and Unintentional Strategies

A key question when reviewing adaptive capacity strategies is: which strategies were developed specifically for this stressor, which were proactively developed for any stressor, and which exist in the system through no apparent planning but still contribute to the system’s adaptive capacity? We found that no strategies were developed specifically for ENSO, as ENSO is one of a number of environmentally driven stressors expected. There are a number of strategies proactively developed for environmental stressors, including but not limited to: monitor ecosystems, flexible multi-level
governance aiming to learn and handle change, institutional flexibility in problem solving, provide access to early warning systems, promote learning through uncertainty and through crises, and advance technology and access. Strategies that exist in the system and contribute to ENSO-related adaptive capacity but were not specifically designed include: ecological memory, institutional diversity and redundancy, diversity of management options, recognize community heterogeneity, support local people’s creativity and determination, ecological flexibility, and strengthen personal leadership skills and promote vision. While these may not have been designed in this case, other systems can purposely build many of these strategies, and this system can deliberately attempt to strengthen some of these strategies.

3.4.3 Activation

A key characteristic of ENSO, which affects activation, is that ENSO is not officially declared until three months into an event, when biological changes are potentially already being experienced. Activation of ENSO adaptive capacity strategies in the Monterey Bay system was not found to be contingent on an official declaration. Rather, the two steps of activation, first with a forecast, and second with observations, were appropriate, triggering some strategies with a likely event but waiting to implement more severe strategies until they are needed. Figure 3.1 illustrates this two-step activation by using two examples, one strategy activated with the forecast (social learning) and one strategy that was not yet activated in 2014, but would potentially be if biological changes were observed (diversify livelihoods). This two-step activation showed beneficial for the fishing industry in 2014; if the forecast triggered fishermen and processors to target other
species or transition to the Alaskan fisheries, they would have missed out of one of the most abundant squid seasons in Monterey Bay.

Figure 3.1. Two step activation for adaptive capacity strategies in relation to ENSO.

In addition to the strategy of diversify livelihoods being held off, during the time of interviews, social safety nets were not yet needed, fishery management did not need to respond, and processing workers were not reduced. So while some strategies were identified as key characteristics to fall back on, these were not adopted until absolutely needed. This two-step activation appropriately reflects the behavior of ENSO, because even if an ENSO event is declared, such a classification is made in regard to conditions at the equatorial Pacific. The local system does not fully rely on adaptive capacity until ENSO is proven to have reached the California region. Interviews reflected high levels of uncertainty in terms of the timing of an ENSO event, the local impacts, and the variety of
types of events. While narrowing these knowledge gaps would better inform and guide users, we reason that the adaptive capacity of the system is high enough that it is not contingent on these unknowns.

3.4.4 Future Studies

As with any analysis of adaptive capacity, findings are spatially, temporally, and conditionally context-specific; any measure of adaptive capacity cannot be objective or independently-derived because its value depends on factors such as the scale of analysis, data availability, and context (Allison et al., 2009, Turner et al., 2003). While our findings are predominately specific to the Monterey Bay wetfish fishing community in 2014, our methodological approach and general findings can be useful as a framework for developing adaptive capacity analyses of any resource system. Future analysis could identify the coping range of this case (Smit & Wandel, 2006). By the defined categories in Fabricius et al. (2007), this case is considered an “adaptive manager” community because it has both adaptive capacity and the governance capacity to sustain and internalize this adaptation while investing in the long-term management of ecosystem services. Future studies can use this example by relating it to other adaptive manager communities, as well as the other types described by Fabricius et al. (2007). In terms of ENSO research and development, the Monterey Bay wetfish fisheries community is an excellent case for testing new efforts for improved ENSO information communication and dissemination strategies. Many participants in this case are well acquainted with current available information, and many voiced their desire for more localized information connecting ENSO shifts to biological changes, and to information about the different ‘flavors’ of ENSO, which current ENSO research is also focused on.
3.4.5 Climate Change Implications

Understanding smaller-scale adaptive capacity may be increasingly pertinent with anthropogenic climate change, as many systems are expected to rely most heavily on their local-level social networks when facing climate change consequences (Adger, 2003). Additionally, as a global climate variation predominately connected to temperature changes, how an ecosystem or community responds to a short-term ENSO climate event may reflect reactions to longer-term climate changes. We speculate the strategies activated during an ENSO event would contribute to adaptive capacity of the system in response to climate change stressors. A core goal of adaptive capacity, to keep options open and provide the system with an armory of choices when unexpected challenges emerge is shown to be essential in this system in relation to ENSO. Options include management strategies, conservation efforts, market opportunities, and future resource use, among others.

Sustainability aims to maintain the same functionality and elements while adaptive capacity encourages fundamental transformations (Walker et al., 2002). Thus it is wiser for us to manage for adaptive capacity rather than manage for sustainability of a stable state, since change is inherent. The questions then are: what will the system transform to when it ultimately does, who will benefit, and who will lose? Often, transformability is framed in opposition to adaptive capacity (Folke et al., 2010), i.e., as its counterpart: adaptive capacity maintains processes throughout any ecological, economic, or social perturbation, and transformability creates a fundamentally new system (Walker, Holling, Carpenter, & Kinzig, 2004). However, here we argue that adaptive capacity is not focused on maintaining a stable state, rather on allowing a system
to persist despite disturbances even if the system must shift in fundamental ways. The idea that the system is transformed once the current conditions become untenable, and thus a fundamentally new system begins out of necessity, is key to grasping such transformation (Nelson et al., 2007). Ignoring inherent change threatens adaptive capacity, and thus transformability is a central component to understanding and implementing adaptive capacity. The question for this case is not “how does adaptive capacity materialize into maintaining the same Monterey Bay wetfish industry system”, but how does the system persist through disturbances such as El Niño events and climate change. If the system does go through a transformation, a valuation of such movement can be structured as: does the social and ecological system benefit more, less, or the same as the previous system?

3.5 Conclusions

Our understanding of systems will always be incomplete, a fact that should be continuously acknowledged in natural resource studies. Adaptive capacity helps to ensure that resource system sustainability is not compromised through incomplete understanding. While managers and resource users may be the groups most interested in a particular resource system’s adaptive capacity, because they depend on the system the most, building and activating adaptive capacity extends to any actor at any level within the system or that can influence the system. As operationalizing adaptive capacity is not the responsibility of any one group or person, it is also not the responsibility of any level of a system (e.g., national, local). Instead, efforts to enhance adaptive capacity within a system’s social and ecological components can be strengthened by all levels. This case shows the many levels and many actors involved in various adaptive capacity strategies.
This study contributes an analytical framework to studying adaptive capacity, provides evidential support for adaptive capacity building strategies that have been identified by previous studies, and offers a case study where decision-making is shown to reflect adaptive capacity strategies and the strength of adaptive capacity of a resource system.
Chapter 4

Measuring Squid Fishery Governance Efficacy:
A Social-Ecological System Analysis
4.1 Motivation for the Study

In the face of rising demand for seafood and dwindling fish stocks, resource managers play a critical role in influencing sustainability. Fisheries involve numerous interacting biological, physical, and social factors, but traditional fisheries governance has tended to rely on simplistic models focused on inputs (such as growth rate) and outputs (such as catch rate and mortality). More recent approaches to fisheries management incorporate principles of systems analysis that are better suited to examining complex and dynamic systems such as fisheries that involve both biophysical and social elements. One of the best developed approaches that addresses the many elements of a particular system is Elinor Ostrom’s Social-Ecological Systems (SES) framework, which has been used and built upon by numerous researchers studying common pool resources (Ostrom, 2009). Applying this theoretical framework and using the Social-Ecological Systems Meta-Analysis Database (SESMAD), supplemented with semi-structured interviews, I qualitatively analyze and compare three case studies of squid fisheries to assess which SES variables contribute significantly to effective squid fishery governance. I measure governance effectiveness by assessing the extent to which goals stated by each management body have been met since active management began. In general, these goals are a combination of achieving ecological sustainability, economic profit, and social stability. I further the scope of governance effectiveness by considering commonly cited social and ecological outcomes of fishery management, if they are not specified in management goals.

The three squid governance regimes examined here are: 1) The California Department of Fish and Wildlife Market Squid Fishery Management Plan for the
California market squid (*Loligo opalescens*); (2) The Falkland Islands Government (FIG) Fisheries Department’s Falklands Interim Conservation and Management Zone (FICZ) for the Patagonian squid (*Loligo gahi*); (3) The New Zealand Quota Management System for the Arrow squid (*Nototodarus spp.*). These cases were selected because of their direct competition with each other in the global seafood market, their growing importance in this market, and the availability of social and ecological data (Sonu, 1993; Vojkovich, 1998). Details regarding fishery features such as social, biological, regulatory, and industry information are provided in Appendix C (Text A.3.1). While the Japanese flying squid (*Todarodes pacificus*) also competes directly with these species, it was excluded from this study due to limited governance information.

### 4.1.1 Background

Squid exist in almost all marine habitats—including the pelagic and shelf areas of all oceans—and contribute to commercial, recreational, and artisanal direct and bycatch fisheries around the world. Of the 290 known species of squid (Order Teuthida), 30 to 40 squid species support developed commercial fisheries (Arkhipkin et al., 2015). Over the last few decades, squid fisheries have become increasingly significant in the global seafood market (Arkhipkin et al., 2015; Rodhouse et al., 2014). In 1970, global cephalopod catches reached approximately 1 million tonnes, increasing to over 4.3 million tonnes in 2007 (Jereb & Roper, 2010). Some researchers have proposed that fishing effort is increasingly directed towards cephalopods as finfish stocks are overfished (Boyle & Pierce, 1994; Lymer, Funge-Smith, Clausen, & Miao, 2010; Rodhouse et al., 2014).
The fundamental challenge to squid fishery management relates to the squid’s life cycle. Much of fishery management for other species relies on Maximum Sustainable Yield (MSY), but this approach is not suitable for squid fisheries because of the “gonzo” life strategy of squid that includes fast growth rates, short life spans, poor stock-recruitment relationships, and death after spawning (Mattlin & Colman, 1988; O’Dor, 1998). This weak relationship in stock size from year-to-year demands a different approach for squid than for most other fisheries, which are composed of longer-lived species that survive spawning (McGregor & Large, 2016). Squid specific management approaches are particularly necessary considering the large effect climate variability has on squid dynamics (Hoving et al., 2013).

Globally, squid fisheries are managed in multiple ways. Many smaller squid fisheries remain unregulated (Arkhipkin et al., 2015), as do many squid bycatch fisheries such as Uroteuthis duvauceli in India and Loligo forbesi in Scotland (Rodhouse et al., 2014). Where squid fisheries are managed, the focus tends to be on harvesting input and output control tools, though marine protected areas (MPAs), integrated coastal zone management, and ecosystem-based approaches are increasingly utilized. There is support among managers for the argument that the best form of management for squid is limiting the effort according to environmental conditions and allowing a maximum proportion of

---

1 Current squid management strategies employ a wide assortment of control tools such as limited access (Dosidicus gigas in Peru), trip limits (Doryteuthis pealeii in the USA), minimum landing size (Loligo vulgaris in Portugal), limit on number of crew (Loligo reynaudi in South Africa), restricted fishing areas (Berryteuthis magister in Russia), seasonal closures (Loligo gahi in the Falkland Islands), limiting use for human consumption (Dosidicus gigas in Chile), spawning escapement retainment (Dosidicus gigas in Mexico), total allowable effort (TAE) (Nototodarus gouldi in Australia), total allowable catch (TAC) (Nototodarus sloanii in New Zealand), temporal restrictions other than seasons (Loligo opalescens in USA), and technological requirements such as light intensity restrictions (Todarodes pacificus in Japan) and minimum net mesh sizes (Loligo opalescens in the USA) (Arkhipkin et al., 2015; Rodhouse et al., 2014). Many of these strategies are used in conjunction with one another. Squid fisheries also differ widely in the attention and effort allocated to their management.
the catchable biomass to escape each year (through consistent monitoring for spawner escapement, which is often a theoretical construct) which does not require a formal stock assessment (Caddy, 1983; McKinnon, 2006). However, it is uncertain whether this approach, which requires significant financial and scientific inputs, is feasible for all squid fisheries.

Preliminary interviews for this study with industry representatives in Monterey, California in 2014 indicate that many within the squid fishing industry think that squid fishery management is often ineffective and unnecessary, on the basis that such fisheries “manage themselves naturally.” This may be a reflection of squid’s natural environmental variability and low stock-recruitment relationship. Across global squid fisheries, only two stocks have collapsed: the northwest Pacific Todarodes pacificus fishery in the 1970s, and the northwest Atlantic Illex illecebrosus fishery in the 1980s (Jereb & Roper, 2010). While fishing effort likely played a role in these two cases, the primary cause is considered to be unfavorable environmental conditions (Dawe & Warren, 1993). In such environmentally sensitive fisheries, highly adaptive governance structures are particularly valuable.

While management has been shown to play a significant role in squid fisheries in terms of outcomes such as portfolio flexibility (e.g., Aguilera et al., 2015) and bycatch reduction (Chilvers, 2008), further understanding is needed of how management can play a role in situations where squid availability naturally fluctuates. Fisheries are complex social-ecological systems and thus research studies, particularly those considering management objectives, should include both social and ecological perspectives for effective management. This study examines a variety of squid management outcomes
from both perspectives and attempts to identify effective practices that can inform future governance decisions.

### 4.1.2 Social-Ecological Systems and SESMAD

Ostrom’s SES framework provides a theoretical structure for scholars to identify a multitude of variables that comprise any CPR system (Ostrom, 2007; Ostrom, 2009). The operationalization of this framework is exercised through the Social-Ecological System Meta-Analysis Database (SESMAD), a tool that offers an interdisciplinary approach to examine inherently complex resource systems (Cox, 2014; Rivero & Hakizimana, 2016; SESMAD, 2014).

SESMAD developers have identified over 200 nominal, ordinal, interval, and qualitative variables that pertain to the users, resource unit, resource system, and governance system, as well as to the interactions of these four subsystems (Cox, 2014). This collaborative tool for researchers to describe and compare various CPR systems is the first formal consistent operationalization of SES variables. While a relatively new tool, in its three years SESMAD has been applied to a variety of systems and research questions regarding resource management issues, ranging from fisheries to forests to the ozone layer (Epstein, Nenadovic, & Boustany, 2014; Evans, Ban, Schoon, & Nenadovic, 2014; Fleischman et al., 2014; Rivero & Hakizamana, 2016; Villamayor-Tomas, Avagyan, Firlus, Helbing, & Kabakova, 2016). SESMAD’s flexible design allows for a number of applications (Cox et al., 2016). This study uses it to identify and measure the most influential variables in order to answer four research questions: (1) How do management goals within each squid governance system compare? (2) Has each system met their respective goals? (3) Have these three squid fisheries experienced similar or
different social and ecological outcomes? (4) How has the governance system contributed to such outcomes? In answering these questions, this study tests one hypothesis: The presence of each of the institutional design principles formulated by CPR theory leads to more effective outcomes in squid fishery management.

Ostrom identified eight design principals as central to sustaining long-lasting small-scale resource systems (Ostrom, 1990). Cox, Arnold, and Villamayor-Tomás (2010) further built upon this work by dividing the first two principles each into two separate principles, totaling ten design principles. The ten design principles are listed and briefly described in Table 4.1.

Table 4.1. Design Principles for Long-Enduring Common Pool Resource Systems
As informed by Cox et al., 2010; Ostrom, 1990

<table>
<thead>
<tr>
<th>No.</th>
<th>Principle</th>
<th>Brief Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>Clearly defined community boundaries</td>
<td>Clear who is a resource user</td>
</tr>
<tr>
<td>1B</td>
<td>Clearly defined resource boundaries</td>
<td>Clear what the resource system’s physical boundaries are</td>
</tr>
<tr>
<td>2A</td>
<td>Appropriation and provision rules conform to local conditions</td>
<td>Appropriation (e.g., time, place, technology) and provision (e.g., labor, materials, finances) rules reflect the local context</td>
</tr>
<tr>
<td>2B</td>
<td>Congruence between appropriation and provision rules</td>
<td>Benefits of adhering to appropriate rules align with costs users incur (provision guidelines)</td>
</tr>
<tr>
<td>3</td>
<td>Collective-choice arrangements</td>
<td>Users are involved in the modification of operational rules if they are affected by them</td>
</tr>
<tr>
<td>4</td>
<td>Monitoring</td>
<td>Assessment of resource system conditions and resource users</td>
</tr>
<tr>
<td>5</td>
<td>Graduated sanctions</td>
<td>Sanctions applied if rules are violated, and reflect the gravity and frequency of violations</td>
</tr>
<tr>
<td>6</td>
<td>Conflict resolution mechanisms</td>
<td>Mechanisms for rules and violations to be discussed and clarified</td>
</tr>
<tr>
<td>7</td>
<td>Minimal recognition of rights to organize</td>
<td>External government authorities recognize and respect the rules users create</td>
</tr>
<tr>
<td>8</td>
<td>Nested enterprises</td>
<td>Multiple levels or scales that influence or manage the resource system are involved in system rules</td>
</tr>
</tbody>
</table>
These design principles are at the core of common-pool resource theory, which seeks to identify the institutional, social, and physical factors that contribute to effective resource management and, as explained by Cox et al. (2010), the design principles describe the conditions required to build and maintain trust and reciprocity in order to embrace collective action and overcome issues occasionally observed in CPR systems (e.g., those described by Gordon (1954) and Hardin (1968)). Ostrom’s research, including the development of the SES framework and these design principles, was a response to the notion that groups of people cannot self-regulate a CPR. Her work challenges the state-based solution, providing numerous examples of sustainable community-oriented natural resource management cases (Ostrom, 1990). While these principles have been verified in many small-scale case studies (e.g., Quinn, Huby, Kiwasi, & Lovett, 2007; Wittayakpak & Dearden, 1999), researchers are just beginning to test the validity of the principles as applied to large-scale social-ecological systems (Fleischman et al., 2014; Villamayor-Tomas et al., 2016). This study uses SESMAD to test the validity of this theoretical framework to medium-size CPRs (14,000km$^2$ (CA) – 5,900,000km$^2$ (NZ)) as one of a number of studies carried out to determine the conditions in which these principles still hold.

4.2 Methods

I applied methods similar to studies that used SESMAD to test the validity of Ostrom’s design principles in specific CPR cases (Ban et al., 2017; Villamayor-Tomas et al., 2016). I used a meta-analysis approach implemented through SESMAD to systematically determine the social and ecological attributes that may contribute to various outcomes in squid fishery governance (Cox, 2014).
4.2.1 SESMAD Coding Strategy

Variables\(^2\) were coded based on a literature review of sources including peer-reviewed studies, management plans, government publications, industry reports, and NGO publications\(^3\). In accordance with grounded theory methodology described by Glaser and Strauss (1999), sources were collected until no significant new information was found in the literature review.

For each case in this study I coded one governance system, one environmental commons, and two actor groups (fishers and fishery managers). Based on the literature review, I selected the components that are the most influential on the system. For each case I also coded one interaction in which the relationship among the four components was investigated. The database is designed to produce outcomes within these interactions. Coding was limited to include information during a time period in which the fishery was actively managed. Table 4.2 summarizes the components coded for each case. Figure 4.1 shows the coding structure of one case, the California market squid case, to depict the different coded sections.

\^2 SESMAD variables are scientifically important concepts that have been assigned a level of measurement and range of possible values, defining an attribute of objects such as actor groups, governance systems, or environmental commons (Cox et al., 2016). Details on those used in this study are in Appendix C (Tables A.1.1, A.1.2, A.1.3).

\(^3\) As the coder of these three cases, I participated in two workshops dedicated to inter-coder reliability, to ensure variables are interpreted correctly, to ensure consistency among the three cases of the study, and to establish consistency of this study with other SESMAD studies. In addition, SESMAD includes an online coding resource with definitions of variables and possible value options to standardize coding results among cases.
### Table 4.2. Coded Components Per Case

<table>
<thead>
<tr>
<th>Case</th>
<th>Time Period</th>
<th>Governance System</th>
<th>Environmental Commons</th>
<th>Actor 1 (Managers)</th>
<th>Actor 2 (Fishers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Falkland Islands</td>
<td>1986-2016</td>
<td>Falklands Interim Conservation and Management Zone (FICZ)</td>
<td>Patagonian squid (<em>Loligo gahi</em>)</td>
<td>Falkland Islands Government (FIG) Fisheries Department</td>
<td>Patagonian Squid Trawling Fishermen</td>
</tr>
<tr>
<td>New Zealand</td>
<td>1987-2016</td>
<td>New Zealand Quota Management System</td>
<td>Arrow Squid (<em>Nototodarus spp.</em>)</td>
<td>New Zealand Ministry of Primary Industries</td>
<td>New Zealand Deepwater Fishermen</td>
</tr>
<tr>
<td>California</td>
<td>2005-2016</td>
<td>California Department of Fish &amp; Wildlife Market Squid Fishery Management Plan</td>
<td>California market squid (<em>Loligo opalescens</em>)</td>
<td>California Department of Fish and Wildlife Coastal Pelagic Species Team</td>
<td>California Wetfish Roundhaul Fishermen</td>
</tr>
</tbody>
</table>

Figure 4.1. California market squid case coding diagram.
Each colored box indicates a separately coded component. In the governance interaction box, each colored box is coded again, but in relation to the other components. Red lines represent the linkages among the four coded components indicating that within the governance interaction, each component takes the others into consideration.
4.2.2 Informant Interviews

I also conducted semi-structured interviews with key informants for each case to fill in missing data gaps after initial coding. Informants were selected based on their involvement in the governance, industry, or scientific monitoring programs within each fishery. The research protocol was reviewed and approved by the University of Miami Institutional Review Board (protocol #20160912). Interviews were conducted over the phone, computer conferencing, or email. Fourteen interviews averaging an hour long occurred from November 2016 to January 2017 with three participants involved with the Falkland Islands fishery, eight persons related to the New Zealand fishery, and three participants from the California fishery.

4.2.3 Analytic Approach

Due to the low sample size of this study (n=3), and following the traditional case study method, I analyzed the data using mixed methods. Of the coded outcomes, I identified and measured those that would contribute to better understanding the efficacy of governance. I then identified and measured the coded variables that contribute to each of Ostrom’s design principles. To test this study’s hypothesis, I compared the design principle variables in relation to the identified outcomes. I applied a pattern-matching logic technique which compares empirically based patterns from the study’s findings with predicted patterns defined prior to data collection, in this case Ostrom’s SES design principle theory (Trochim, 1989; Yin, 2013). This methodology is well suited for case study analyses. I compared case study findings from the literature review and interviews with the SESMAD variables expected to indicate the presence or strength of the design principles in a resource system. In order to consider the potentially significant role of
variables in SESMAD other than the design principles, I coded all independent variables in SESMAD and selected those that were highly relevant to outcomes in one or more case.

4.3 Results

4.3.1 Outcomes

The primary variable this study tests is the governance system effect, indicating whether the goals of the squid governance system have been met, thus answering the first research question. To respond to the second research question, I identified four secondary outcomes from social and ecological perspectives: 1) Commons Condition Trend (Has the squid population improved or worsened?); 2) Basin Switch (Has the squid population experienced a switch in stable states? Is it currently in a desirable or undesirable state?); 3) User Group Well-being Change (Has fishermen well-being improved or worsened?); and 4) Compliance (Do users follow the rules of the fishery governance system?). Table 4.3 summarizes the coding results of each outcome in each case. Most SESMAD theories analyze the commons condition trend (Cox et al., 2016). This is likely because CPR management often focuses on maintaining or improving an environmental commons. Table A.3.1 in Appendix C summarizes how each secondary outcome is coded within SESMAD.
Table 4.3. Outcome Summary
Green indicates outcome increased/improved during analyzed time period, yellow indicates consistent/no-change outcome, and red (which is absent) would indicate outcome decreasing/weakening.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Falkland Islands</th>
<th>New Zealand</th>
<th>California</th>
</tr>
</thead>
<tbody>
<tr>
<td>Governance System Effect</td>
<td>Met goals</td>
<td>Met goals</td>
<td>Met goals</td>
</tr>
<tr>
<td>Commons Condition Trend</td>
<td>Remained the Same</td>
<td>Remained the Same</td>
<td>Remained the Same</td>
</tr>
<tr>
<td>Basin Switch</td>
<td>No desirable</td>
<td>No desirable</td>
<td>No desirable</td>
</tr>
<tr>
<td>Actor (Fisher) Well Being</td>
<td>Improved</td>
<td>Improved</td>
<td>Remained the Same</td>
</tr>
<tr>
<td>Compliance</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

4.3.2 Governance System Effect

The governance system effect variable is an ordinal variable with three options:
(1) Failed to meet goals, (2) Mixed effects on goals, (3) Met goals in response to the question: “To what extent has this governance system achieved its goals in relation to the environmental commons?” All three cases were coded as (3) Met goals. Below, I identify the squid management goals for each case and discuss the rationale behind why each case was considered to have met its goals.

4.3.2.1 Falkland Islands

The establishment of the Falklands Interim Conservation and Management Zone (FICZ) introduced three management objectives that apply to the squid fishery: 1) To conserve the resource, and thus ensure its continued productivity; 2) To maintain the economic viability of the fisheries as a whole; 3) To enable the Falklands to enjoy greater benefits from the resource (Anonymous, 1989). When the ITQ system was implemented in 2005, a range of additional goals were added to these greater goals, including greater diversification, higher economic performance, increased investment and cooperation with
industry for research and development, improved enforcement, increased international competitiveness, increased government income, and greater environmental stewardship (Harte & Barton, 2007). While this study considers these three original goals and the additional ITQ goals, it focuses on the primary goal of squid management, which is to stabilize the fishery.

Thus far, the Falkland Islands squid fishery management has met this goal of stability, as the squid population is still productive, the fishery has remained at an economically profitable level, and the greater community is profiting from the industry’s contribution to the GDP (Arkhipkin, Barton, Wallace, & Winter, 2013; Roper, Sweeney, & Nauen, 1984; Winter, 2016). While the second fishing season has been closed early a number of times, doing so has kept the squid population at a considered healthy status and has not created major economic consequences (Arkhipkin et al., 2013). The same fishing companies have remained in the fishery and many are beginning to invest in constructing new vessels, which indicates confidence in the stability of the fishery.

4.3.2.2 New Zealand

The *de jure* goals of New Zealand’s management of the squid fishery are two-fold. The first set of goals was determined through the Quota Management System (QMS) implementation, with a reevaluation of goals outlined in the Fisheries Act of 1996. As described by the Fisheries Act of 1983, the goals of the QMS are: “to conserve, enhance, protect, allocate, and manage the fishery resources within New Zealand fisheries waters having regard to the need for— (a) Planning, managing, controlling, and implementing such measures as may be necessary to achieve those purposes: (b) Promoting and developing commercial and recreational fishing: (c) Providing for
optimum yields from any fishery and maintaining the quality of the yield without detrimentally affecting the fishery habitat and environment.” The 1996 Fisheries Act restructured the goals to have a more sustainable ecosystem-based approach, designating that the goals for management are: “to provide for the utilisation of fisheries resources while ensuring sustainability. [Sustainability referring to]: (a) maintaining the potential of fisheries resources to meet the reasonably foreseeable needs of future generations; and (b) avoiding, remedying, or mitigating any adverse effects of fishing on the aquatic environment. [And utilisation meaning] conserving, using, enhancing, and developing fisheries resources to enable people to provide for their social, economic, and cultural well-being” (Section 8:a).

In the realization of these goals, squid management focuses on two aims: (1) to maintain a stable fishery through a Total Allowable Commercial Catch (TACC) in order to “maintain the stock at or above a level that can produce the maximum sustainable yield” (Fisheries Act, 1996, Section 13.2), and (2) to minimize bycatch mortality (primarily sea lion mortality) from fishery interactions. This second bycatch goal is outlined in Section 15.1 of the 1996 Fisheries Act, described in that the “Minister— (a) shall take all reasonable steps to ensure that the maximum allowable fishing-related mortality level set by the relevant population management plan is not exceeded: (b) may take such other measures as he or she considers necessary to further avoid, remedy, or mitigate any adverse effects of fishing on the relevant protected species.” While squid fishery management does monitor the TACC and has kept it at a stable level for multiple years, the primary goal and focus of management is to minimize mortality rates of the New Zealand sea lion (Phocarctos hookeri) from fishery interactions.
There has been a clear reduction in New Zealand sea lion bycatch mortality within the squid fishery (Hamilton & Baker, 2014; Thompson, Berkenbusch, & Abraham, 2016). Observed capture rate (sea lions per 100 trawls) and estimated sea lion captures have decreased during this study’s time period (Ministry of Primary Industries, 2016a; Ministry of Primary Industries, 2016b). The number of interactions has decreased, likely due to a combination of a declining sea lion population and efforts to minimize interactions (e.g., 12 nautical mile zone, spotter ships), and Sea Lion Exclusion Device (SLED) efficacy has increased, decreasing mortality rate (Ministry of Primary Industries, 2016a). In the mid 1990s, the squid fishery captured ~130 sea lions, substantially lower than the ~10 sea lions captured per season in the late 2000s (Ministry of Primary Industries, 2012b; Ministry of Primary Industries, 2016a). While consistent data on mortality rates pre-1980 are unavailable, fishery participates noted that that ~1 sea lion was killed per week in the early 1980s from the squid fishery, whereas reports indicate in the 2010s, ~1 sea lion was killed per year (Ministry of Primary Industries, 2016a).

4.3.2.3 California

The Market Squid Fishery Management Plan’s (MSFMP) goals are “to manage the market squid resource to ensure long term resource conservation and sustainability, reduce the potential for overfishing, and institute a framework for management that will be responsive to environmental and socioeconomic changes” (State of California Resources Agency, 2005). The MSFMP developed in accordance with broader federal and state fishery laws, the most influential being the California Marine Life Management Act (MLMA) that outlines the state’s goals to manage commercial fisheries by “sustainably prioritizing long-term health over short-term benefits, to restore and enhance
habitat, to rebuild depressed fisheries to highest sustainable yields consistent with environmental and habitat conditions, minimize bycatch, [ensure] fishery participant incorporation to reduce effort, [use] adaptive management based on best available science, incorporate stakeholder knowledge, observe long-term interest of people dependent on fishing, [ensure the] system is proactive and responds quickly to changing conditions, [and ensure that the] system is periodically reviewed for effectiveness” (MLMA 7056). The primary goal of market squid fishery management is to maintain a sustainable squid population (via seasonal catch limitation) for both social and ecological considerations.

In the time since the management plan was established, landings have continued with no fishery crashes to date. For all but two seasons (2010-11, 2011-12) when water temperatures were unusually warm, and thus squid were naturally more accessible, the fishery has remained under the seasonal catch limit of 118,000 short tons (California Department of Fish and Wildlife, 2016). While the catch limit represents historical high landings rather than a calculated ecological threshold, management has determined that squid population will remain healthy, as will the ecosystem dependent on it, if the catch remains under 118,000 short tons, and no evidence to contradict this assumption has been observed (Dorval, Crone, & McDaniel, 2013).

4.3.3 Design Principles

To assess the role of the design principles in each case, I coded between one and five variables within SESMAD for each principle. Coding results for each of the variables that contribute to each principle are shown in Table 4.4 Details on the coding structure of each of these variables are provided in Table A.3.2 of Appendix C. Based on
how a variable was coded and the level of uncertainty of the results, I determined that all
design principles are met, with three to six of the ten principles somewhat met in each
case.

Table 4.4. Coding Results of Variables Contributing to Presence of Design Principles
Colors indicate a variable’s association with CPR theory, green indicates the value is
more likely to contribute to resource sustainability, yellow to be somewhat met, and red
indicates it is least likely to contribute to resource sustainability, according to CPR
theory. Of the coded numbers, (3) indicates that component to its specific principle is
met, (2) indicates principle component somewhat met, and (1) indicates principle
component absent.

<table>
<thead>
<tr>
<th>Design Principle</th>
<th>Variable</th>
<th>Falkland Islands</th>
<th>New Zealand</th>
<th>California</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clearly defined</td>
<td>1.1a Actor group boundary clarity</td>
<td>Clear boundaries</td>
<td>Clear</td>
<td>Clear</td>
</tr>
<tr>
<td>community</td>
<td></td>
<td>(3)</td>
<td>boundaries</td>
<td>boundaries (3)</td>
</tr>
<tr>
<td>boundaries</td>
<td>1.1b Commons boundary negotiability</td>
<td>Rigid (3)</td>
<td>Rigid (3)</td>
<td>Moderate (2)</td>
</tr>
<tr>
<td></td>
<td>1.1c Actor group boundary fuzziness</td>
<td>Rigid (3)</td>
<td>Rigid (3)</td>
<td>Rigid (3)</td>
</tr>
<tr>
<td></td>
<td>1.1d Outsider exclusion</td>
<td>Some exclusion (2)</td>
<td>No exclusion (1)</td>
<td>No exclusion (1)</td>
</tr>
<tr>
<td>Clearly defined</td>
<td>1.2 Commons boundaries</td>
<td>Somewhat unclear</td>
<td>Somewhat</td>
<td>Somewhat</td>
</tr>
<tr>
<td>resource</td>
<td></td>
<td>boundaries (2)</td>
<td>unclear</td>
<td>unclear</td>
</tr>
<tr>
<td>boundaries</td>
<td>2.1 Social-ecological fit</td>
<td>High (3)</td>
<td>Medium (2)</td>
<td>Medium (2)</td>
</tr>
<tr>
<td>Appropriation</td>
<td>2.2 Proportionality of costs and benefits</td>
<td>Yes (3)</td>
<td>Yes (3)</td>
<td>Yes (3)</td>
</tr>
<tr>
<td>and provision</td>
<td>(fishers)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rules conform to</td>
<td>3a Participation in rule making</td>
<td>Medium (2)</td>
<td>Medium (2)</td>
<td>Medium (2)</td>
</tr>
<tr>
<td>local conditions</td>
<td>3b Commons political power (fishers)</td>
<td>Medium (2)</td>
<td>High (3)</td>
<td>Medium (2)</td>
</tr>
<tr>
<td></td>
<td>3c Collective action</td>
<td>Medium (2)</td>
<td>High (3)</td>
<td>High (3)</td>
</tr>
<tr>
<td>Collective-</td>
<td>4a Self monitoring</td>
<td>Yes (3)</td>
<td>Yes (3)</td>
<td>Yes (3)</td>
</tr>
<tr>
<td>choice</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>arrangements</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Graduated sanctions</td>
<td>4b Environmental monitoring (managers)</td>
<td>Moderate (2)</td>
<td>Moderate (2)</td>
<td>High (3)</td>
</tr>
<tr>
<td>---------------------</td>
<td>----------------------------------------</td>
<td>--------------</td>
<td>--------------</td>
<td>---------</td>
</tr>
<tr>
<td></td>
<td>4b Environmental monitoring (fishers)</td>
<td>High (3)</td>
<td>High (3)</td>
<td>Low (1)</td>
</tr>
<tr>
<td></td>
<td>4c Participation in environmental monitoring</td>
<td>Medium (2)</td>
<td>High (3)</td>
<td>Medium (2)</td>
</tr>
<tr>
<td></td>
<td>4d External monitoring</td>
<td>Yes (3)</td>
<td>Yes (3)</td>
<td>Yes (3)</td>
</tr>
<tr>
<td>Graduated sanctions</td>
<td>5a Self sanctions</td>
<td>No sanctions (1)</td>
<td>No sanctions (1)</td>
<td>No sanctions (1)</td>
</tr>
<tr>
<td></td>
<td>5b External sanctions</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>5c Participation in social monitoring</td>
<td>Medium (2)</td>
<td>High (3)</td>
<td>Medium (2)</td>
</tr>
<tr>
<td>Conflict resolution mechanism</td>
<td>6 Conflict resolution</td>
<td>Yes (3)</td>
<td>Yes (3)</td>
<td>Yes (3)</td>
</tr>
<tr>
<td>Minimal recognition of rights to organize</td>
<td>7 External recognition</td>
<td>Moderate - some recognition (2)</td>
<td>Moderate - some recognition (2)</td>
<td>High - complete recognition (3)</td>
</tr>
<tr>
<td>Nested enterprises</td>
<td>8 Multiple levels</td>
<td>Coordination among multiple levels (3)</td>
<td>Coordination among multiple levels (3)</td>
<td>Coordination among multiple levels (3)</td>
</tr>
</tbody>
</table>

### 4.3.4 Additional Variables

In addition to the design principles, I identified four noteworthy variables that contribute to a case’s social and ecological outcomes, particularly in terms of the governance system meeting its goal. These variables and their corresponding coding structures are listed in Table A.3.3 in Appendix C. Summarized coding results for each of these variables are displayed in Table 4.5.
Table 4.5. Coding Results Summary of Key Variables Contributing to Study Outcomes
Colors indicate a variable’s association with CPR theory, green indicates the value is more likely to contribute to resource sustainability, yellow to be somewhat met, and red (which is absent) would indicate it is least likely to contribute to resource sustainability, according to CPR theory. Of the coded numbers, (3) indicates the variable is present in the case, (2) indicates the variable is somewhat present, and (1) would indicate the variable is absent.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Falkland Islands</th>
<th>New Zealand</th>
<th>California</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic Dependence</td>
<td>Very dependent</td>
<td>Moderately dependent</td>
<td>Moderately dependent</td>
</tr>
<tr>
<td>Science-Based Policy</td>
<td>Yes (3)</td>
<td>Yes (3)</td>
<td>Yes (3)</td>
</tr>
<tr>
<td>Leakage of Benefits / Fringe Benefits</td>
<td>Yes Benefits (3)</td>
<td>Yes Benefits (3)</td>
<td>Yes Benefits (3)</td>
</tr>
<tr>
<td>Flexible Rights</td>
<td>Yes (3)</td>
<td>Yes (3)</td>
<td>Yes (3)</td>
</tr>
</tbody>
</table>

4.4 Discussion

The overarching goals of the three squid governance systems are similar in that they all aim for long-lasting fisheries that conserve natural resources while contributing to a robust economy. All three governance systems emphasize social and ecological goals. However, the primary goals of each system are very different, reflecting the particular context of each case. The Falkland Islands case aims for social stability, the New Zealand case aims for sea lion conservation, and the California case aims to maintain a sustainable squid population. While the New Zealand sea lion population is listed as ‘Endangered’ by the IUCN and is in decline, this study focuses on SLED efficacy and capture rate to determine if the Ministry of Primary Industries (MPI) management goal of reducing fishing related mortality has been met. This study does not attempt to determine if the sea lion population has recovered because of fishing management, only that is has not been further harmed. This study shows that each governance system has met its primary goals in the time since management first became effective until present (2016).
Of the other outcomes measured in this study, two are ecological (commons condition trend, basin switch) and two are social (actor well-being, compliance). Of these, all three cases have resulted in positive outcomes (positive referring to a trend towards healthy squid populations in a desirable state, fishers’ general well-being improved, and the observance of governance rules). The only exceptions to the positive (improved) results are the commons conditions in each case and well-being for California fishers. These four instances have stayed the same during the analyzed time period. However, this is not considered a negative outcome, since all were in a generally positive state before the coded management regime. Thus, I conclude that the governance systems of all three squid fisheries are effective (met goals) and are associated with positive social and ecological outcomes.

4.4.1 Design Principles

To assess how governance has contributed to these positive outcomes, this study analyzes the presence and role of each of Ostrom’s CPR theory-based design principles in each case. The following section reviews these principles for each case. All of the principles are met to a greater or lesser extent in each squid governance case, thus supporting the hypothesis that the presence of the ten institutional design principles leads to more effective outcomes in squid fishery management.

4.4.1.1 First Design Principle: 1A) Clearly defined community boundaries; 1B) Clearly defined resource boundaries

The first design principle can be considered two separate principles, one referring to a clear definition of resource user individuals and groups, and the other to a clear definition of the resource system’s physical boundaries (Cox et al., 2010; Ostrom, 1990).
This specification is a critical first step to applying outsider exclusion and other rules. Setting boundaries is also key to internalizing the positive and negative externalities of resource use, thus ensuring that users share the consequences (Cox et al., 2010). Well-defined boundaries provide the necessary scope for both applying rules and assessing outcomes.

In the cases examined in this study, the provided clarity of user boundaries contributes to management goals more than knowledge of the actual spatial distribution of the resource. The physical boundaries of squid populations are uncertain in most squid fisheries. Squid boundaries are often determined by depth and water mass, but vary according to environmental conditions. While these fisheries are among the most heavily studied, their exact distributions remain unknown. Of the three species, the distribution of arrow squid is the least certain. Effective management requires adequate range data within the Falkland Islands and California cases, as the Falkland Islands fishery is spatially directed and the California fishery is technologically constrained to the state coastline.

Despite this uncertainty, each management system is very clear on who can fish where (principle 1B). Quota systems are more rigid than permit systems, though both quotas and permits are allocated in each fishery according to management decisions. While the California system is most negotiable for new actors, new players are rare in all three systems. This is mostly a reflection of the high cost of entry in each fishery and the availability of quota and/or permits. The migration behavior of California market squid contributes to goals in that squid are often found nearshore, but migrate to areas that are not accessible by fishing vessels during periods of ecosystem stress, such as El Niño.
events. The clearly designated areas of the Loligo Box in the Falkland Islands and the 6T region of New Zealand simplify government enforcement and resources to focus on one area and minimize risk in the uncertainty of population distribution by consolidating effort in one area so that the population may thrive elsewhere. In terms of the Loligo Box, the area assists self-monitoring activity as vessels are aware that only licensed squid vessels may fish in the area.

4.4.1.2 Second Design Principle: 2A) Appropriation and provision rules conform to local conditions; 2B) Congruence between appropriation and provision rules

As in the first principle, the second original design principle has been divided into two separate principles. The first is that both appropriation and provision rules should align with the local conditions (Cox et al., 2010). Appropriation rules include guidelines that relate to time, place, technology, and quantity of resource units. Provision rules relate to labor, materials, and finances (Ostrom, 1990). Case-specific CPR system rules that reflect the local context must also appropriately fit within the set of rules that apply to the whole system if to best contribute to the long-term survival of the CPR system. The second principle in this section is that resource systems are more likely to lead to successful outcomes if the costs users incur (e.g., labor, material, money inputs as determined by the provision rules) align with benefits of adhering to the appropriation rules (Cox et al., 2010).

The variable social-ecological fit (SE fit) measures how governance reflects the local context, measuring the first design principle in this section. The Falkland Islands case has high SE fit, with squid most abundant in the Loligo box and key life stages safeguarded through protected areas. The Loligo box has successfully removed finfish
trawlers from the area and confined squid vessels to the area (Hatfield & DesClerks, 1998). The Falkland Islands Government has jurisdiction over this entire area, and containing fishing activity to an area comprising mainly one habitat has resulted in more effective and less costly enforcement. The New Zealand squid governance focuses management activity in the SQU6T region, since most of the landings and most of the sea lion interactions occur in that area. While the SQU6T fishery has a high SE fit, the other three squid arrow fisheries in New Zealand are considered low SE Fit. The SQU10T “fishery” has no fishing activity due to marine protected areas and low squid availability in the area. The SQU1T region incorporates multiple habitats and is a reflection of geopolitical boundaries (EEZ): since the range and preferred habitats of arrow squid are uncertain, the social (EEZ) and ecological (squid distribution) systems in this area are misaligned. The California case has a medium SE fit because, while the squid are predominately found in California waters, their distribution extends to two other states and two other nations (Mexico and Canada). Thus, not all users of the squid population fall under state jurisdiction. The primary mechanisms for satisfying SE fit in all cases are well-placed active fishing areas and scientifically-based protected areas. Management in all cases focuses on where squid population is most abundant. The relatively high social-ecological fit shows that each governance system has attempted to consider local contextual situations in fishery management.

For the second part of this section (principle 2B), all three fisheries exact high costs from fishers, particularly for the factory trawlers in the Falkland Islands and New Zealand. However, fishers also benefit in all three cases from participation in collective action. While each fishery produces high revenue, each governing entity continues to
allocate quota/catch limits, retain the same users from year to year, and maintain a squid population with no evidence of overfishing.

4.4.1.3 Third Design Principle: Collective-choice arrangements

The collective-choice arrangement design principle pertains to the involvement of users in the modification of operational rules if they are affected by such rules. This principle is similar to the previous in that it emphasizes localized application. Ostrom clarifies that such participant involvement does not necessarily lead to compliance, commitment, or effective rules. Rather, such a system decreases the likelihood that rules will need to be changed, which would result in avoidable costs and would interrupt any continuous long-term monitoring or assessment of system progress. These first three listed principles are considered to be the most necessary elements in creating the most appropriate and effective rules for CPR management (Ostrom, 1990).

Fishers in all three cases are consulted regarding management decisions, with the government management body as the ultimate decision-maker. Formal processes encourage fishers to engage, debate, and share knowledge with fishery managers. In every case, a fishing industry association represents fishing industry interests: Falkland Islands Fishing Companies Association in the Falkland Islands, Deepwater Group in New Zealand, and the California Wetfish Producers Association in California. Participants within each of the three squid fisheries generally know the other participants in their system well, and social pressure to adhere to the rules is evident in each case. Collective action in the New Zealand and California cases has largely been a response to the potential of government management bodies closing the fishery down. Through collective action, the industry presents a united front, and acknowledges the likelihood of
the governance system limiting future fishing effort due to one or a few deviants. In the Falkland Islands, collective action is a factor of the small community, and the fishing association was formed through law via the Fisheries (Conservation and Management) Ordinance 2005. A strong social stigma against violations and a strong sense of community encourage collective action mechanisms in all three cases. However, the strongest form is observed with the role of the New Zealand Deepwater Group (DWG), which represents squid quota holders and makes industry-level changes in practice standards and informal requirements. DWG decides on rules and enforces them, even if there is no legal aspect to these industry created rules. Participants acknowledge that the role of the DWG contribute the most to management goals. The DWG formed such rules without management recommendation in order to get ahead of any movement toward fishery closure, which would be a reaction to sea lion interactions. SLEDs are not mandatory by MPI, but DWG leaders ensure that every squid vessel uses one and that each vessel signs a Code of Conduct. These informal regulations are adhered to by the fishing industry primarily as a result of social pressure. Collective action benefits are also observed in vessel maneuvering, where vessels remain in the 1T region and send a scouter vessel to occasionally check if the squid population has returned to the 6T region. This arrangement minimizes the risk of sea lion-fishery interaction by minimizing the number of vessels in the 6T region until necessary. This allows more fishing time before the fishery is closed due to the fishing mortality rate limit that season, and contributes to management achieving its goal of minimizing sea lion mortality incidents. In California, a fisher-led proposal to close the fishery during the weekends to allow for community relief (fishers to spend time with families during the weekends without feeling the need to
compete on the water) was adopted by management, as uninterrupted spawning led to ecological benefits. Many fishermen in this system are relatives, which contributes some social pressure to adhere to the rules.

The role of local knowledge in natural resource management also contributes to this principle (Berkes, Colding, & Folke, 2000; Cox et al., 2010). However, historical knowledge of these fisheries only extends a few decades, since the fishery gained momentum (California) or since the fishery was recently discovered (New Zealand, Falkland Islands). However, all management systems are open to incorporating local knowledge when it presents itself.

**4.4.1.4 Fourth Design Principle: Monitoring**

The monitoring design principle applies to the assessment of the CPR conditions or CPR users. According to CPR theory, monitors should be held accountable to the resource users, or should be the resource users themselves for maximum effectiveness (Ostrom, 1990). Both the presence and accountability of monitors must be ongoing to achieve best CPR management results, though not every case presents both (Cox, 2014). Monitoring is often considered necessary for enforcement and is essential for implementing the next design principle: graduated sanctions.

All three fisheries monitor fishing activity and track the squid population, though the New Zealand fishery employs minimal monitoring of the squid population and relies on industry reports. All three fisheries have external monitoring by a government management body. In all three cases, fishers self-monitor the fishery in that vessels report violations they observe. Landings are carefully tracked in each fishery. While the fishing industry associations in all three cases participate in fishery monitoring to some extent,
the New Zealand Deepwater Group plays the largest role. The DWG established its own standardized monitoring program related to sea lion and sea bird interaction. SLED use is tracked by DWG rather than by MPI. The real-time monitoring in the Falkland Islands depends heavily on industry participation. Onboard observers play a crucial role in monitoring both in the Falkland Islands and in New Zealand, and in both cases observers report back to the government frequently. The Falkland Islands observers focus primarily on catch and characteristics of the catch (e.g., location, size of species) and the New Zealand observers focus primarily on SLED use and bycatch interaction. Government monitoring in both of these cases includes high technology such as aircraft and patrol boats. California experiences more monitoring from land than the other two fisheries, since fishing activity in California tends to be coastal and dockside monitoring has recently been implemented. Designated scientists within the management team are responsible for surveying and monitoring the squid population. While industry contributes some funding for monitoring in California, the state and federal governments fund squid monitoring. By comparison, industry primarily funds monitoring in New Zealand and the Falkland Islands.

4.4.1.5 Fifth Design Principle: Sanctioning

The first four design principles converge to make the fifth principle more achievable. The first three create rules and the fourth assesses system condition and compliance. When the operationalized rules are broken, the graduated sanctions principle suggests that penalties must exist to hold resource users accountable for violations. Such sanctions should appropriately reflect the gravity and frequency of the infraction. Sanctioning deters excessive violations, and helps maintain community cohesion (Cox et
al., 2010). Ostrom notes that the enforcers can be officials and/or other resource appropriators (Ostrom, 1990).

All three fisheries have external sanctions given by the fishery management body, and sanctions reflect the gravity and frequency of violations. Top forms of sanctions in all three cases include fines, loss of privileges, imprisonment and/or confiscation. Vessels in each case report misconduct, though in California and especially in New Zealand, consequences are often internalized with social repercussions. In all three cases, fishers do not impose sanctions. However, informal internal social pressure exists in all three. The Deepwater Group offers the most official form of informal sanctions, in that the industry group requires all squid vessels to sign a Code of Conduct before each season. Since most of the key rules in the New Zealand case, such as SLED use, are not required legally, social pressure plays a larger role than formal sanctions. Similarly, participants in the Falkland Islands note that sanctions are not imposed lightly, as they result in consequential social stigma. Such stigma is likely a product of a small, isolated population that heavily depends on the resource, and is thus wary of population collapse.

4.4.1.6 Sixth Design Principle: Conflict resolution

Rules in true CPR systems are never completely unambiguous or enforced by external, all-knowing officials (Ostrom, 1990). Rules cannot be, because they often do not fully describe every scenario, possible interpretation, or violation for every case. Often, these missing details can result in loopholes where rules can be broken purposefully or unintentionally. Therefore, systems need a forum for discussing rules and violations and for clarifying rule information. Such a mechanism is crucial for system longevity, even though Ostrom notes that it does not necessarily guarantee it. The
availability of a low-cost conflict management arrangement is more likely to be adopted by resource appropriators and managers.

Formal conflict resolution mechanisms are present in each of the three cases. In the Falkland Islands, companies can petition if they feel unjustly dealt with. However, these formal processes are rarely used. In the New Zealand case, fishers are able to take advantage of defended and non-defended hearing options (Ministry of Primary Industries, 2012a). Any disagreements can go to court, as has been particularly relevant in the early 2000s when the fishing industry took the Minister to high court which overturned a fishery closure (Ministry of Primary Industries, 2016b). The CWPA engages in conflicts to protect fishers and processors, and can bring issues to state court. Official stakeholder engagement processes such as public hearings allow conflicts to be discussed in a formal procedure. Having a pathway for conflicts to reach an official court when necessary, even while many cases can be resolved more informally through constant dialogue, contributes to continuous evaluation and discussion that adds to positive outcomes in all three cases.

4.4.1.7 Seventh Design Principle: External recognition

While formal governmental jurisdictions may have a critical role in creating and enforcing rules, this design principle stresses the importance of user-dictated rules. In this principle, it is equally vital to CPR longevity that external government authorities recognize and respect the rules that users may devise (Ostrom, 1990).

In the Falkland Islands and New Zealand, fisheries are managed at a large scale and rules are made at the national level. However, users do influence rules and users are recognized as critical to rule-making. The Falkland Islands are a relatively new official sovereign that is not recognized by Argentina or a number of other countries, but they are
recognized by many nations including the United States. As a dependency, the United Kingdom recognizes the Falkland Islands government and their right to manage their own fisheries. While management may be at the national level, the Falkland Islands population is small (2840 people in 2012) and most residents know each other, so this case can be considered community-based management where users have substantial influence in rule making (Falkland Islands Government, 2012). In New Zealand, most of the decision-making is at the national level, but management does take community requests into consideration and looks to DWG to implement their own standards. MPI recognizes DWG’s leadership in implementing their own rules, which are often stricter than the formal rules. The Minister makes ultimate decisions regarding the fishery, but the court can overturn any decision to recognize other interests. External recognition is high in the California case because, while federal policies take precedence and the Pacific Council includes market squid as a monitored species, CDFW is recognized as the primary management body. Within CDFW, the CPS team is the responsible decision-making party, and this team is located primarily in the two regions where squid fishing is most active.

4.4.1.8 Eighth Design Principle: Nested enterprises

The last design principle characterizes the complexity of CPRs. ‘Nested enterprises’ refers to the multiple levels, or multiple scales, that influence or manage the CPR. Such levels include appropriation, provision, monitoring, enforcement, and conflict resolution (Ostrom, 1990). For each of these activities, local, regional, national, and sometimes international levels all play significant roles, and often focus on very different
goals, problems, and constraints. This principle suggests that each level involved needs to have established rules regarding that CPR.

The global seafood market influences each fishery. Falkland Islands squid dominates the market, but during its less abundant years New Zealand and California are able to fill its void as demand for arrow and market squid increases. Management for each fishery is influenced by multiple levels, most of which coordinate amongst each other. The national level management of the New Zealand and Falkland Islands fisheries allows international and national issues to be directly dealt with. Falkland Island’s relationship with the United Kingdom allows for defense-support should their claim to highly lucrative fisheries such as squid be threatened. California can rely on federal policies or federal agencies should interstate or international issues arise. All fishery systems allow for the communication of concerns, and consider input from representatives from multiple levels, including fishing community concerns, national interests concerns, and international conservation concerns. In New Zealand, financial limitations from the government make it difficult to provide resources for every level (e.g., jigging monitoring, squid assessments). However, the system is open to outside players such as contractors and NGOs contributing to the system, especially in relation to international concerns regarding the New Zealand sea lion population.

4.4.2 Other Contributing Variables

While the design principles indicate evidence that supports how each governance system has led to positive social and ecological outcomes, this study is also open to the possible role of other social-ecological system variables from CPR theory that may contribute to meeting governance goals. Of the other contributing variables identified, the
most significant is economic dependence. CPR theory denotes that greater economic
dependence oftentimes motivates and encourages sustainable practices and collective
action (Agrawal, 2002; Ostrom, 2007). This is particularly true in the Falkland Islands.
The entire population of the Falkland Islands is aware of squid fishing activity because of
squid’s large contribution to the government’s GDP. Defense aside, the Falkland Islands
are able to be completely self sufficient from the United Kingdom because of the two
squid fisheries. It is in the interest of the nation to keep the squid fishery stable, which
greatly contributes to meeting management goals. In New Zealand and California, squid
play a central economic role. In both cases, squid contribute a significant amount of the
economic profit from the fishing industry, and provide financial support that enables the
fishery at large to target a wide portfolio. In this view, squid can be considered a keystone
species in the economic portfolio of the fisheries. As it partially depends on squid, New
Zealand fishery management is able to keep the squid fishery active as it proves to be
important, but can focus their efforts on satisfying their goals of sea lion conservation and
a healthy ecosystem. This tradeoff between maximizing economic potential and
satisfying management goals can be avoided because of the economic dependence of
these fisheries.

The variable ‘leakage of benefits’ of squid governance onto other systems also
plays a significant role and is present in all three cases. Management actions have
decreased bycatch rates (primarily of seabirds and sea lions) in the three squid fisheries,
thus benefitting greater ecosystem conservation. In the Falkland Islands, license fees
often pay for 50% national budget (providing for roads, schools, etc.), and fishing
company taxations contribute to further benefit national infrastructure (Harte & Barton,
2007). In the Falkland Islands and New Zealand, reflagging of vessels to Falkland Islands/New Zealand led to improvements in working conditions on squid vessels, often benefiting foreign crewmembers. While such benefits are not necessarily directly related to management goals, they encourage continued support of management efforts.

Science-based policy, the third identified variable, is strongly evident in each of the three cases, both in terms of policy formation and in consistent system reevaluation. In New Zealand, the robustness of science has become an issue concerning efficacy of SLEDs. However, this debate is handled through the court system. Each management system encourages the presentation of new material and practices to reflect the best available science. As these are relatively new (60 years old) and rapidly expanding fisheries, it is constructive for these squid fisheries to have policies to allow new information to be incorporated, such as the relationship with ENSO events, distribution information, and the influences of climate change. In the Falkland Islands, *I. argentines* has occasionally expanded into the *L. gahi* range due to changing water temperatures and predated upon *L. gahi*, decreasing its stock size. Science-based, adaptive policies allow management to account for new drivers of change, such as the influx of *I. argentines*, in order to ensure the population remains at a sustainable level. Scientific efforts have significantly contributed to designing more effective SLEDs and to understanding the multiple drivers behind sea lion population declines (Hamilton & Baker, 2014; Roe, 2009). Surveys of spawning areas allow critical habitats to be protected in California and the Falkland Islands (Arkhipkin & Middleton, 2002; Zeidberg et al., 2012). Egg escapement models have been successful in maintaining healthy market squid populations (Dorval et al., 2013. This study finds that the careful emphasis on science-
based policy has contributed to management goals, as expected by theory (Sullivan et al., 2006).

Science-based policies contribute to the last identified variable, flexible rights. Each governance system allows for changes in approaches and practices according to new knowledge. In-season daily monitoring allows the Falkland Islands Government to employ in-season changes according to conditions (e.g., spawning times) or sudden disturbances (e.g., unusual Illex predation). In New Zealand, industry reports are sent weekly to the Minister and other interested parties regarding sea lion interactions. Managers constantly converse with scientists and review observation data so that changes may be made according to new information. New information such as higher squid abundance can lead to an increase in the fishing mortality rate limit allocated for that year, allowing for more fishing days in the SQU6T region. New information on SLED efficacy can increase or decrease the allocated discount or can even close the fishery. In California, a daily tracking system helps inform managers on how close the fisheries are to catch limits, and a constant evaluation process indicates when the fishery should be closed in the case of low availability, thus allocating the remnants of the population to support squid predators. The acknowledgement of scientific and other stakeholder input can lead to increased or decreased fishing effort, as dictated by the pursuance of management meeting its goals.

4.4.3 Study Limitations

While studies of governance, particularly fisheries governance, constitute an enormous body of literature, this study focuses on the governance of common pool resource systems as one of the subsystems within Ostrom’s social-ecological system
framework. This distinction is key to understanding the limitations of this study, as it is not specifically a governance analysis but rather an examination of the structure and influence of governance systems in relation to the greater context (the entire SES system). While coding identified many factors that influence outcomes in these fisheries, results are not considered deterministic (e.g., show no cause and effect, only relationships). Results are useful in comparing the key attributes of each system, and in highlighting factors that contribute to meeting management goals. This study contributes a new meta-case study analyzing design principles within specific common pool resource systems, and provides potential avenues for future research to use SESMAD for similar comparative analyses. While results show that each governance system has met its respective goals, this study acknowledges that there is no guarantee that such success will continue. Additionally, identifying goals as having been met is not an indication that such goals are completely satisfied to the full extent possible. For example, while sea lion mortalities have decreased in the New Zealand case, there is room for further progress in decreasing that rate even more. The ten design principles apply to long-term success of CPR systems, and this study is only a subset of time and is not to say that the systems have reached long-term success. Lastly, the other contributing variables should not be viewed as theory-tested evidence, but rather explanatory factors whose relevance to CPR systems are supported through the studies used to build SESMAD.

4.5 Conclusions

This study compares three commercial squid fisheries that compete in the global market, and finds that while the de jure goals are similar in each governance system and aim for both social and ecological benefits, the primary goals are very different. These
goals reflect the particular social-ecological context of each case. From the implementation of each governance system until present, results indicate that each governance system has met its specific goals. The positive social and ecological outcomes tested in this study other than management specified goals suggest that the fishery management primary goals likely appropriately reflect the broader goals of the governance system, in that no one outcome was obviously prioritized over another.

As squid fisheries become increasingly significant to the global seafood market, creative and effective management strategies specific to squid’s particular dynamics will also become increasingly necessary. While a variety of management options are discussed in the literature, here I present three cases each with a different approach but all with successful outcomes: the Falkland Islands case is an ITQ system based on Total Allowable Effort, the New Zealand case is an ITQ system based on Total Allowable Catch and Fishing Mortality Rate Limit, and the California case is a limited entry fishery based on a seasonal catch limitation. This study suggests that squid management is likely to be effective with any approach that takes into consideration the design principles and is open to other SES factors relevant to each case. Study results highlight the need for local context-based policies and practices in squid fishery systems. While the design principles are present in each governance system, each case’s particular situation is illuminated by one specific variable. The Falkland Islands case is shaped primarily by external recognition, as local ownership of this resource leads to high economic and cultural dependence, contributing to local users developing effective mechanisms such as careful monitoring and social pressure to maintain a socially and ecologically stable fishery.
The New Zealand case is largely shaped by collective action mechanisms, as the DWG imposes its own set of informal rules and enforcement strategies to ensure fishing related sea lion mortality rates decline. The California case is mostly shaped by nested enterprises, as local California managers work with local users to ensure practices and policies reflect the local context, but are guided by greater state and federal policies which provide resources and frameworks that contribute to a sustainable social and ecological squid population.

While these three fisheries do experience climate variability, climate change will undoubtedly present new stresses to each system. In particular, population migration in response to temperature changes will present spatial and technological challenges to the industry and management. In accordance with CPR theory, I speculate the strong presence of the design principles will position these systems to better adapt to and mitigate climate change consequences.

The novelty of SESMAD encourages creative applications for the tool, particularly in exploring new ways to conduct social-ecological case studies. This study gained from the diagnostic format of coding each SES variable, as it required multiple perspectives and multi-disciplinary data that may have been unintentionally excluded had the database not identified them. Environmental resource systems are inherently complex, and their issues are often considered “wicked” where there is no clear boundary to the problem or to the factors that influence it. A tool such as SESMAD allows for the comprehensive and interdisciplinary analysis required for such wicked issues. Interdisciplinary teams are often best suited for studying social-ecological systems, as many factors from many areas of study are relevant. However, SESMAD provides the
operational structure for a single researcher to conduct such studies, as I was able to tap into the knowledge of the many scholars from multiple fields who contributed variables, theories, and examples to SESMAD. As a database user, I was able to expand beyond my individual knowledge to better grasp potentially important factors when assessing these complex fisheries. While not utilized in this study, the ability to compare snapshots in time has the potential to contribute significantly to the study of system transformations, as all resource systems will experience substantial transformations (Nelson, Adger, & Brown, 2007). The database is particularly helpful in assessing data poor fisheries, such as many squid fisheries, as they benefit from full system studies that can integrate information from multiple perspectives and sources of knowledge and thus can contribute to a more complete knowledge of the dynamics in the fishery.

This study supports the hypothesis that design principles remain valid in larger common pool resource systems. The design principles are associated with squid governance meeting both social and ecological goals. Results converge with CPR theory and also demonstrate that CPR theory (design principles and other SES factors) is useful in comparing system outcomes in dynamic, globally influenced fisheries. These fisheries are complex with multiple levels, and their effective governance is largely a factor of user-involvement in system operations. This study also contributes three medium-sized common pool resource system cases to SESMAD to help build the database for future collaborative research projects.
Chapter 5

Conclusions
5.1 The Brickyard

In October 1963, *Science* published a letter by Bernard Forscher entitled “Chaos in the Brickyard.” Forscher tells the story of a fictitious world where brickmakers, obsessed with making bricks, flood the land until it is overrun with loose bricks with no space for edifices to be built. He paints a world easily mistaken for one of Theodor Seuss Geisel’s creations. Though rather than a storybook for children, the Brickyard is a warning for scientists. Contrived as a metaphorical fantasy, Forscher relates construction to science, where bricks are facts, brickmakers are junior researchers, builders are scientists, blueprints are hypotheses, edifices are explanations; so that where sound bricks build durable edifices, robust facts build concrete scientific explanations. As the story goes, more bricks were needed to build more edifices, and so brickmakers obsessed over making new bricks, until there were so many bricks that to compete successfully, only easy to make bricks were created. As resources poured into making new bricks, the number of brickmakers skyrocketed, some making so many bricks that they considered themselves builders, and true builders became rare. As competition and demand increased, creativity and quality of brick making diminished. There were too many bricks to find the right ones to build an edifice, and avalanches of falling loose bricks destroyed new buildings. The story concludes with “and, saddest of all, sometimes no effort was made even to maintain the distinction between a pile of bricks and a true edifice.”

As I reflect on Forscher’s narrative half a century later, I wonder: have the builders survived? Have the brickmakers heeded Forscher’s warning? In reflection of his warning, have I too contributed to the avalanche of loose bricks? Has this dissertation added another shovel of cheap, hastily made bricks onto a growing pile, or has it
contributed to a structurally sound edifice? In this concluding chapter, I will review the key findings from each of the research chapters, with attention to their contribution to various edifices.

5.2 Dissertation Synthesis

Globally, fisheries are influenced by dynamic climate, governance, and market drivers, which present social and ecological challenges and opportunities. As is true for all natural resource systems, the interaction of these multiple drivers complicates the sustainable use and effective management of those resources. The decline of the world’s fish stocks amid increasing demand for animal protein calls for well-designed and effective fishery management strategies if they are to remain viable. In this dissertation, I deploy an interdisciplinary systems-lens to examine social and ecological fisheries outcomes with direct application to formulating effective management strategies. I use the Monterey Bay wetfish fisheries as a case study to explore the relative influence of large-scale drivers on shifts in fishing effort and social-ecological outcomes. I measure the level of the system’s adaptive capacity to a known driver of such change (ENSO), and examine the role of adaptive capacity building strategies during an impending disturbance. I then compare the Monterey Bay market squid fishery to the Falkland Islands Patagonian squid fishery and the New Zealand arrow squid fishery to characterize the social-ecological system variables that contribute to governance effectiveness. This dissertation is largely shaped by scholarship on social-ecological systems, common-pool resources, and adaptive fisheries management.

The findings suggest that a variety of adaptive capacity strategies contribute to the Monterey Bay wetfish fisheries’ social and ecological resilience. It provides a number of
recommendations for fishery managers, such as in enabling shifts in effort among fisheries and retaining existing flexibility, creating contextually-based policies for specific fishery systems, and accounting for the many factors that may augment or threaten the system’s ability to rely on, or design and implement, effective adaptation strategies. The integrative, mixed methods approach applied in this research supports the value of studying a system’s many components, as social and ecological outcomes such as governance effectiveness and user well-being are determined by factors from multiple subsystems (e.g., market fluctuations, community network, government stability). The study of fisheries systems not only has the potential to contribute to more effective marine resource management, but it also elucidates many of the dynamics within the global food industry, characterizing the demanding challenges society must face with natural resources.

5.3 Managing for Flexibility

The second chapter integrates available physical, social, biological, and economic information about the Monterey Bay wetfish fisheries to better understand fishery dynamics and other key factors to consider within the case study. By analyzing a 38-year time series, it explores the relative influence of large-scale drivers on shifts in fishing effort and on social-ecological outcomes. The chapter sets up the remainder of this dissertation in that it identifies the three studied Monterey Bay wetfish fisheries as a tightly linked complex, where fishery participants move among various fisheries to provide a buffer against any one fishery becoming economically or ecologically unviable. This shifting focus among fisheries is a key element to the social-ecological system’s adaptive capacity and in reducing the system’s social and ecological vulnerability. The
findings from this chapter suggest that governance drivers play the most significant role in determining fishing trends through time, while climate and market drivers play the most significant roles in determining short term trends such as fishery dominance, or when fishermen participation switches from one fishery to another in any given year.

Chapter 2 focuses on flexibility as a strategy for building adaptive capacity, showing fishery participants’ dependence upon and utilization of flexibility to ensure continued social and ecological resilience during fluctuating conditions. It provides evidence to support fishery management efforts for enhancing industry flexibility, encouraging a diverse fishing portfolio, and accounting for the many factors that could reduce flexibility of an interconnected fisheries network such as these (e.g., expensive single-species permits, gear restrictions, climate-induced migrations).

While it is not surprising that these fisheries are subject to multiple drivers of change that stem from different subsystems (market, governance, climate), specifically identifying their relative roles can potentially enhance the study and management of this and similar systems. The fishery management body studied in this chapter is heavily dependent upon scientific information, as science-based policies are at the core of the most fundamental laws guiding management (e.g., Magnuson-Stevens Act) and shape management practice. While the role of system components may be well known or even obvious to actors, systems-based studies provide an effective methodological tool for scientifically examining system components and documenting their purpose for management to refer to in the rigorous policy process. This study delivers a systematic analysis of the many drivers of change in the fisheries for which management can take into consideration. It is also able to provide lessons learned to the greater understanding
of flexibility in fisheries because of the high availability of data in this case, which many fisheries do not have. The mixed methods applied in this study aim to elucidate avenues for data-poor fisheries in terms of types of data that could be collected for similar investigations. In particular, time series analysis of adaptive capacity is difficult because a system’s adaptive capacity is specific to each stressor (or each combination of stressors) (Gallopín, 2006). Chapter 2 is able to show that one strategy, flexibility, has contributed to the system’s adaptive capacity over time, providing further support that managers should encourage that particular strategy since it has contributed to the system withstanding multiple stressors. However, the study of adaptive capacity strategies over an extended time period depends on the availability of data and a thorough inclusion of most, if not all, drivers of change in the studied system.

5.4 Adaptive Capacity to El Niño Southern Oscillation

While Chapter 2 examines a variety of drivers related to one particular strategy of building adaptive capacity, Chapter 3 zooms in on one driver by examining a wide range of possible strategies in augmenting adaptive capacity. Chapter 2 identifies the historical role ENSO has in shifting biological and social fishery system components. In Chapter 3, I take advantage of the 2014 El Niño forecast (for the 2015-16 event) to detail elements other than flexibility that contribute to the system’s adaptive capacity to this reoccurring stressor. From the second chapters’ findings, Chapter 3 is able to further examine the case by acknowledging the multi-species complex as one system.

Many of the fishery managers interviewed for this chapter implied that the system is resistant to fishery regulation changing with short-term environmental conditions, but also indicated a strong desire to have enough information about the climate linkages with
biological changes in order to practice adaptive management. While filling this knowledge gap of biological linkages to climatology would contribute to more efficient fishery management and industry practices, the findings in this dissertation recommend fishery regulatory and scientific managers specifically account for ways to measure and build adaptive capacity. Particularly in California fishery governance, the tendency is for fishery management plans and practices to focus on very specific metrics (e.g., sea surface temperature to approximate future fishery trends). Because of the narrow focus on these metrics (which remain important to understanding and monitoring fishery trends), there are missed opportunities for purposeful augmentation of the system’s overall adaptive capacity. For example, management could become more involved in discussions regarding the physical infrastructure the fishery is dependent on, which is increasingly competing with space for tourism activities, and is needed in more northern areas as species distributions shift north with warming temperatures. Additionally, with climate change rapidly changing environments at unprecedented rates, while better understanding biological and climatological linkages may be useful, such relationships may not hold in future conditions. Therefore, focusing on the system’s adaptive capacity rather than focusing on calculating biological-climate relationships may be better suited for managing fisheries in a warming world. If management plans were to include language on the different adaptive capacity strategies discussed in this dissertation, or language reflecting the SES characteristics such as Ostrom’s design principles, I expect the social-ecological system would be better prepared to withstand disturbances. While some strategies may be outside the jurisdiction of fishery managers (e.g., stabilize national government), the acknowledgement of the each strategy’s potential role in
fishery sustainability would provide a more systems approach to management considerations. Such a change would be unlikely to be adopted in the near future, as it would require a major institutional shift in management practice.

While this chapter aims to contribute to the study and management of the Monterey Bay wetfish fisheries, it also builds upon broader adaptive capacity scholarship by proposing and testing a new approach to analyzing adaptive capacity that incorporates a three-step analysis pathway of assessment, strategies, and activation. This chapter concentrates on the strategies step, but urges future studies to place just as much focus on one or both of the other two steps. Many of the analyzed strategies relate to each other (e.g., flexible management relates to diversity of options, enhanced social capital through collaboration relates to the participatory approach of facilitating actors at multiple levels to interact with each other, and supporting local people’s creativity and determination relates to inspiring innovation). Since the analyzed strategies were selected because they were identified in previous studies and have nuanced differences among them, the methodology used in this chapter included examining many overlapping strategies; however, this is only a first step at streamlining the evaluation of all known adaptive capacity strategies.

Further work is needed in consolidating the strategies and simplifying analysis. The findings here provide evidence for the Monterey Bay fishing community to further encourage and promote observed strategies, but also for the community to recognize that the strategies found absent in relation to the El Niño forecast for the 2015-16 event may contribute to future ability to withstand ENSO events, or to withstand other stressors. The multitude of strategies shown to contribute to this case’s overall adaptive capacity
supports the argument that building adaptive capacity is more effective for encouraging sustainable systems than focusing on one specific risk (Smit & Pilifosova, 2003). This chapter also attempts to provide structure and terminology to the system components (e.g., social capital) which many actors already identify as key to the system’s success in withstanding ENSO events, allowing management and other users to point to the findings presented here to argue for maintaining system components and developing identified adaptive capacity strategies for future known or unknown stressors. While many strategies may not be under management jurisdiction from a legal perspective (e.g., strengthening leadership and reducing political corruption is not an aim of the Magnuson-Stevens Act), building stakeholder relationships and incorporating stakeholders into management discussions is a way for fishery management to help guide such strategies, even if in indirect ways. Findings from this dissertation will be shared with participants to facilitate these suggested discussions among users.

This chapter also identifies what users consider as a fundamental system transformation. Participants reported that they would consider the Monterey Bay wetfish fisheries system as transformed if 1) the governance system closed the wetfish fisheries for multiple years and/or 2) the traditional fishing community exits the fishery, sells vessels and processing plants, and “outsiders” take control of the industry. This unintended finding in identifying what would constitute a transformation in the eyes of the users has management implications and further supports the value of adaptive capacity studies, as an analysis of adaptive capacity can help to reevaluate management aims in order to manage toward or away from a transformation so as to maximize what is beneficial to the actors. This would be particularly relevant in cases such as co-managed
fisheries, which place high value on various actor’s goals for the system (Pomeroy, Katon, & Harkes, 2001). A complication in managing toward or away from a system transformation is that actors from different perspectives may consider a particular system change to be beneficial while others consider it to be harmful (e.g., a sea urchin dominated ecosystem may be viewed as beneficial to urchin fishers while an alternate ecosystem that is otter dominated may be viewed as beneficial to the tourism industry) (Loomis, 2006).

The social and economic disruptions associated with transformations or ecosystem ‘tipping points’ can be somewhat alleviated if management works to identify mechanisms to redistribute benefits among stakeholders, such as by engaging user groups to explore the distribution of costs and benefits (Selkoe et al., 2015). During any transformation, managers can identify the benefits, burdens, and preferences associated with an ecosystem shift and various users, and ensure that marginalized groups or industries are incorporated in discussions and decisions. This chapter presents a high adaptive capacity case to compare to medium or low adaptive capacity cases (fisheries or other resource systems). This study does not attempt to work with the communities in building adaptive capacity, it only identifies where adaptive capacity can be built.

Participatory research could expand to include such efforts, noting the pathways and barriers to proactively implementing strategies. For example, which strategies do users place more value on (e.g., perhaps users value social capital more than technology), and which strategies are encouraged or discouraged by local and national governments? Such initiatives would also be useful in modernizing strategies to reflect rapidly changing environmental conditions. For example, the strategy of “keep options open” may need to
be revised with climate change as old options diminish and new options present themselves.

5.5 Governance Effectiveness

The fourth chapter applies common pool resource (CPR) theory methodologies, including the operationalization of Ostrom’s SES framework and the assessment of Ostrom’s design principles, to the comparison of globally competitive squid fisheries (Ostrom, 1990). I compare three squid governance cases to find that while each targeted a similar species of squid that compete in the global seafood market, each governance system employs a fundamentally different approach to fishery management. Despite this, this chapter finds that each was successful in meeting their respective management goals from the time the current management plan was implemented to the present (2016). Findings suggest squid governance efficacy is not dependent on one management approach, but rather positive outcomes are associated with user involvement in system operations and contextually based policies. The presence of the eight design principles in these fisheries supports Ostrom’s theories, suggesting that these principles do in fact contribute to sustainable resource systems (a common goal of fisheries management). While squid fisheries are slowly gaining more attention in fisheries scholarship, the study of squid is relatively sparse compared to finfish, and there are many unknowns that limit such analysis, particularly in the biology of squid (Rodhouse et al., 2014).

Full system studies are particularly helpful in assessing squid fisheries, since they incorporate information from multiple perspectives and sources of knowledge and thus can contribute to a more complete knowledge of the dynamics in this fishery. Incorporating stakeholder knowledge can fill in biological knowledge gaps, and
understanding the market and users of the resource system can help explain observed landings trends. SESMAD proved to be a useful tool in this regard, as the diagnostic format of the questions for each SES variable guided the project to incorporate multiple perspectives and multi-disciplinary data, providing comprehensive insight into the governance system and the role of the design principles. This study is just an initial investigation into squid specific management strategies. I hope that future analyses take into consideration full SES system variables, as this study has shown they can be important for positive outcomes.

Chapter 2 warns against the consolidation of fisheries, which may lead to social and ecological threats (Kasperski & Holland, 2013; Le Gallic & Mongruel, 2006; Pinkerton & Edwards, 2009). Chapter 4 compares the Monterey Bay case to two consolidated (quota based) fisheries, which are shown to produce positive social and ecological outcomes. These two consolidated fisheries, the New Zealand arrow squid fishery (an ITQ system based on Total Allowable Catch) and the Falkland Islands Patagonian squid fishery (an ITQ system based on Total Allowable Effort), however, are still multi-species complexes. While this dissertation does not attempt to compare non-consolidated and consolidated single- and multi- species fisheries, its findings suggest consolidated fisheries that remain multi-species (targeting a diverse portfolio) can mitigate negative consolidation consequences. These fisheries were selected because of their relationship as direct competitors in the global market. This analysis could be enhanced in the future via a comparison among the SES characteristics within these three relatively well-managed and fully-exploited squid fisheries to the more typical squid fisheries of the world, which are less well developed and less actively managed. Such an
assessment has the potential to inform areas for growth and management focus in the sustainable development of squid fisheries. Additionally, since this chapter advocates for squid-specific management approaches, similar analyses with finfish or other non-squid fisheries would provide additional insight into squid fishery-specific attributes and management recommendations.

SESMAD is best applied through an interdisciplinary lens, since the theoretical framework underlying the database comes from multiple disciplines, which are then integrated to form the different SES variables; as such, multi-disciplinary data are integrated to support a variable’s evidentiary diagnosis (final coded value). The novelty of SESMAD encourages creative applications for the tool. The creators of the database provided a comprehensive and interdisciplinary structure for the examination and comparison of many different systems. I argue one approach that would substantially contribute to a better understanding of natural resource systems and the role of each SES variable within the system would be to bring the coding process to the systems’ users. While either an interview or survey format would suffice, allowing users to diagnose their own system not only elucidates prevalent perceptions and attitudes of users, but may also lead to a more accurate examination of the system. This has not yet been implemented, likely because the coding process is quite extensive (over 200 variables), and the terminology is precise, encouraging new coders to work with previous SESMAD coders or undergo some kind of training. However, the execution of participatory SESMAD analyses could answer many contemporary questions in natural resource system research. For example, such methodologies could assist in identifying perceptions and cognitive barriers to proposed resource solutions (e.g., water reuse, recycling,
resource extraction compliance). Other potential applications include identifying mechanisms for improved energy conservation and use efficiency, or developing a multi-faceted threat analysis of data poor resource systems.

5.6 Integrative, Interdisciplinary, and Comprehensive

Ecosystem-based management, adaptive policies for resilient systems, and integrated ecosystem assessments have been considered as essential for effective natural resource management (Crowder et al., 2008; Folke, Hahn, Olsson, & Norberg, 2005; Levin, Fogarty, Murawski, & Fluharty, 2009). Social-ecological systems, along with other systems frameworks, have increased in study as it has become clear that such structures are helpful for these approaches (Meadows, 2008; Ostrom, 2009). However, few studies are truly integrative. In describing the Monterey Bay wetfish fisheries, this dissertation is inclusive of other stakeholders beyond the fishermen themselves, including local national weather service officers and harbor employees. Without needing to redefine the concept of community, this dissertation has been open to various local stakeholders and information holders and has integrated those demonstrated to be essential to the case study. When this dissertation acknowledges multiple drivers, it does not simply list factors such as “market” or “climate” as external drivers of change, but rather considers these factors integral parts of the system. Thus, this dissertation exemplifies an approach that is truly integrative. It incorporates multiple spatial and temporal scales, and multiple scales of influence (e.g., multiple levels of governance). This type of analysis is valuable in the study of fisheries, as fishing communities are sometimes studied without the broader scope of their position within not only the global
seafood market or local economy, but also within the wider food and commodity industry.

This dissertation required true interdisciplinarity in research methodologies and approaches. Interdisciplinary methods are increasingly being cited as necessary for addressing environmental issues, which are often “wicked”, i.e., difficult to solve because they have no clear boundary, have a high degree of uncertainty, and comprise of multiple interacting systems each with their own dynamics (Balint, Stewart, Desai, & Walters, 2011; Rittel & Webber, 1973). Interdisciplinarity draws on disciplinary insights (and sometimes stakeholder views) and integrates them together, without relying on one method or theory from a specific discipline (Repko, 2012). It creates a new level of discourse and integration of knowledge (Choi & Pak, 2006). It is often confused with multidisciplinarity and transdisciplinarity. Multidisciplinarity draws from several disciplines and juxtaposes instead of integrating them (Repko, 2012). Transdisciplinarity goes beyond disciplines to unify all knowledge, providing a holistic examination of whole systems. While this dissertation is on the edge of transdisciplinarity, particularly in its systems lens and involvement of multiple stakeholders and experts, it is more so interdisciplinary as it builds upon common methodologies to link and synthesize disciplines (Choi & Pak, 2006). Some of the disciplines this dissertation draws from and contributes to include (but are not limited to): biology, earth sciences, economics, ecology, history, oceanography, environmental science, political science, decision science, anthropology, climate science, fisheries science, law, resource management, marine biology, systems analysis, atmospheric science, public administration, and psychology. Many of these cannot be singled out to show exactly how the discipline has
contributed to any one chapter. Accordingly, this dissertation is truly interdisciplinary as insights learned through the chapters are integrated in order to construct a more comprehensive understanding.

5.7 Multiple Scales

To embrace the comprehensive approach this dissertation pursues, each research chapter examines a different spatial scale and temporal scale: Chapter 2 focuses at the community level over 36 years, Chapter 3 concentrates at the community level but considers multiple levels (e.g., global ENSO dynamics, regional data collection, and national institutions) over five months, and Chapter 4 compares nation-wide case studies from across the globe in a time scale of 11 to 30 years. Future studies can expand the spatial scale to determine the degree to which findings scale up. This dissertation does not include scenario building, for which an adaptive capacity examination would be potentially fruitful for management planning. While some chapters include data over a time series, each analysis is a particular snapshot in time; while findings may hold true in the future, each chapter’s analyses are limited to the context of their investigation. New system components, new stressors, and system transformations will inevitably arise, and thus the “wicked” problems of managing and sustaining fisheries for continued social-ecological benefits will require continuous evaluation.

5.8 Valuing the Future of Fisheries

One participant who was interviewed for Chapter 3 claimed the Monterey Bay wetfish fisheries will “continue until the earth stops.” Since my interview questions did not address participants’ views on whether or not the fishery will exist in 10, 100, or 1,000 years, I cannot speak to how fishermen, processors, managers, or other community
members imagine the fishery will exist in the future, if they believe it will transform, and if so, how they would prefer it change. However, from my time spent in the community, I gathered the most likely deterioration of the current fishery would be from multigenerational loss—children of fishermen moving on to other industries, and from increasing corporatization of the fishery.

While I did not investigate this topic specifically, interviews indicated an awareness that younger generations might be better off pursuing other opportunities. Many permits and vessels are passed down from father to son/nephew (there are not many women in the fishing industry). While some participants are hopeful younger family members will stay in the fishery, many voiced their desire that their children will go to school for other careers and have a better life than they themselves experienced. Fishing is a physically and oftentimes economically challenging occupation. At the same time, other fishermen view the enterprise as affording them greater freedom than other jobs, are proud of their ability to be self-employed, and believe fishing is an important cultural practice that connects people with the natural environment. Many said they would experience a sense of identity loss if future generations do not participate in the fishery.

That is not to say that the fishery will necessarily decline if traditional families exit the industry. Fishing permits, particularly for California market squid, are highly desirable. At the time of interviews, users shared that market squid permits were selling for almost 3 million U.S. dollars, and could likely be worth more in the near future. Since most individuals in the region cannot afford to buy a permit, plus the costs of a new vessel, equipment, and crew, it is likely that large corporations will ultimately buy in.
Anecdotes pointed to East Coast “Wall-Streeters” as the probable buyers of permits, with Monterey participants noting that these potential owners would not hold the same values and have the same respect for the local resource and industry as current permit holders.

It will likely fall to U.S. fishery managers to decide what their vision is for the future of Monterey, California, and other American fisheries. In other fishery systems, such as those in Japan and the Philippines, governing bodies have taken regulatory measures to keep “outsiders” out of small-scale fisheries (Goodwin, 2001). Many of the managers responsible for the Monterey Bay wetfish fisheries are not from the local community; some do not even live in California. While some managers interviewed for this dissertation expressed their concern about the future of the fishery (e.g., loss of identity) and expressed personal preference for the conservation of the community tied to the industry, others were more accepting of changes in the structure of participants.

In terms of the greater community, the lucrative tourism industry is partly driven by the romantic notion of small-scale fisheries, particularly in supporting the value of eating locally and supporting local fishermen. Interestingly, Monterey’s “Fisherman’s Wharf” is only for tourists, and wharf number two is the working wharf. This physical placement of the working wharf to the side is a visible prediction that tourism will outlast fisheries. Many fishermen and fishing industry participants cited conflict with tourism representatives, who complain about the industry smells and industrial conditions that may offend vacationers (e.g., large trucks backing up, loud heavy machinery used to unload landings or equipment). The future of these fisheries likely largely depends on an assessment of the greater community’s and larger fishery management bodies’ values,
what resources are they willing to allocate, and what costs are they willing to bear to retain those values.

5.9 Final Thoughts

The seafood industry is likely to turn to innovative and creative solutions, as it always has, in order to meet rising demand for animal protein while fish populations decline from cumulative human impacts (Halpern et al., 2008). The research in this dissertation has taken a historical perspective to understanding fisheries. The findings here help us understand the dynamics and characteristics that have contributed to different social and ecological outcomes in these fisheries. To facilitate resilient and sustainable fisheries, future research should consider potential innovative and creative solutions that may play a significant role in the future. For example, some participants had ideas regarding managing the California sardine fishery by area. Others pointed to the potential linking of the agriculture industry and livestock industry with the wetfish industry, connecting facilities, encouraging reduction processing, and streamlining the fish to feed trade. Many cited the potential market expansion of wetfish in new forms of product for new dishes (e.g., squid steaks) and tapping into species that were not yet targeted. In fact, when interviews for Chapter 3 were being conducted, the Pacific Fishery Management Council was considering prohibiting the development of new, directed commercial fisheries for unmanaged forage fish without adequate assessments and analyses of potential impacts (Pacific Fishery Management Council, 2013a). Many of these species did not yet have a market for fishers to supply, but the cautionary step was considered by some in the industry to close off options that could help diversify the fishing portfolio and relieve pressure off some species by shifting market demand to
another species. While tapping into academic knowledge networks would help to develop innovative initiatives, I argue that the best starting place for doing so is through participatory research approaches. Many participants who contributed to the semi-structured interviews used in this study recognized the potential traps fisheries could fall into (e.g., losing markets, species migrations with climate shifts, over excessive regulations). In acknowledging these traps, they also shared ideas for solutions. Management that remains open to user’s creative ideas may be able to implement policies that benefit multiple management goals, such as policies that encourage ecosystem conservation while also meeting social goals. The Monterey Bay wetfish fisheries exemplified the success of this approach by incorporating a fishermen led proposal to close the squid fishery during weekends. The fishermen gained time off to spend with their families without the pressure to continue fishing in order to keep competitive in the market, and the ecosystem was given time to recover from fishing pressure (particularly allowing time for squid to spawn). Future research should recognize that system users are a source of inspiration for new ways to escape traps, and can provide a solid sounding board for potential answers to pressing challenges.

As Dr. Forscher has since passed, I can only speculate how he would elaborate upon his metaphorical world in today’s political climate in which the scientific process has become more visibly intertwined with. With an influx of false bricks, alternative bricks, and partisan bricks, whichever way the story continues to develop, leaders of the scientific world will likely affirm a number of warnings in an attempt to safeguard the scientific process and the construction of sound and useful edifices. For one, buildings often need different types of bricks. The funding of only specific types of bricks is a
dangerous practice, as builders need a variety of usable bricks for different purposes. The findings from this dissertation aim to be directly applicable to fisheries management and conservation efforts. However, it also aims to be exploratory without direct application, such as in exploring the potential role of adaptive capacity strategies from a theoretical standpoint, and in exploring the many variables provided by the SESMAD database. Basic science without discernible societal applications will always remain essential to progress, as proven with the National Academy of Sciences’ Golden Goose awards, referring to basic science projects that later proved to be quite useful. This dissertation does not aim to build one edifice. Instead, it creates new bricks and integrates new knowledge, making new linkages that could be useful for improving and streamlining the processes of adaptive management in fisheries. Its bricks are substantially stronger because of the many participants from the studied resource systems who contributed their expertise and knowledge to shape the findings presented in each chapter. This dissertation builds a strong foundation for a new structuring of use-oriented fisheries science and climate change science which would more effectively augment adaptive capacity in natural resource systems, in Monterey Bay and beyond.


Appendix A
Text A.1.1: Additional Information on Monterey Bay Wetfish Fisheries and the Management System

We use the term ‘fishermen’ instead of ‘fisher’ to refer to both men and women, as most fishery participants in the study area prefer the former. The Monterey Bay area, including Santa Cruz, Monterey, and Moss Landing ports, is one of three major centers of activity for the fisheries (the other two are Los Angeles/San Pedro and Ventura/Port Hueneme) (Pomeroy, Hunter, & Los Huertos, 2002). Whereas fishermen and buyers tend to operate primarily within one of those centers, most also operate within a second area (Pomeroy et al., 2002). Present day California wetfish fisheries have strong connections to the "traditional" or historic fishery of the early to mid 1900s (Pomeroy et al., 2002). Most fishermen and buyers have a long personal and family history in the fishery. Relationships among them are social as well as economic and have enabled many to withstand the challenges of variable and uncertain environmental, regulatory and economic conditions. Most of the catch from these fisheries is exported.

The Pacific Fishery Management Council (PFMC) actively manages the Pacific sardine (Sardinops sagax, Clupeidae) and Pacific chub mackerel (Scomber japonicas, Scombridae) fisheries, and monitors those for northern anchovy (Engraulis mordax, Engraulidae), market squid (Loligo opalescens, Loliginidae), and jack mackerel (Trachurus symmetricus, Carangidae). Pacific herring (Clupea pallasii, Clupeidae) and jacksmelt (Atherinopsis californiensis, Atherinopsidae) are important Ecosystem Component Species included in this fishery management plan and all species of West Coast krill or euphausiids (primarily Euphausia pacifica, Euphausiidae and Thysanoessa spinifera, Euphausiidae) are managed as prohibited harvest species (Pacific Fishery Management Council, 2011a).
The CPS limited entry plan for finfish was established in 2000. In 2003, the CPS FMP (Pacific Fishery Management Council, 2011a) then formulated a capacity goal that provided for limited entry permit transferability. In California, the management of market squid has been under the authority of the California Fish and Game Commission since SB 209 was enacted in 2001, pursuant to the goals and requirements of California’s Marine Life Management Act (MLMA) (State of California Resources Agency, 2005). The Market Squid Fishery Management Plan (MSFMP) implemented in 2005 includes a seasonal catch limit, monitoring programs, weekend closures, gear regulations, a restricted access program with provisions for initial entry, permit types, permit fees and transferability, as well as a seabird closure.

Text A.1.2: Examples of Drivers Influencing Fisheries as Categorized by Ostrom’s Social-Ecological Subsystems

**Governance Subsystem**

Regulatory measures can create situations in which fishermen choose to pursue one fishery over another (Degnbol & McCay, 2007). For example, in New Zealand, adoption of the Quota Management System in 1986 led to fishermen shifting effort completely over to fisheries not included in the quota system, such as tuna (Yandle & Dewees, 2008). In the case of Monterey Bay fisheries, state and federal policies play an important role in dictating how fisheries function and which fisheries appear to be more profitable. For instance, the groundfish fishery has seen a number of limitations, from gear restrictions and time and area closures to catch limits (Pomeroy & Dalton, 2003).

**Users Subsystem**

User agency can play a significant role in changing conditions of any common pool resource system (Bodin & Tengö, 2012). In Monterey Bay, fishing always has been
a part of the identity of the people living in the area (Palumbi & Sotka, 2010). Due in part to John Steinbeck’s *Cannery Row*, sardines and other wetfish are often associated with Monterey Bay as a place and tourism center. This link between the fisheries and the identity of Monterey Bay may contribute somewhat to the persistence of these fisheries.

**Resource System Subsystem**

The resource system is composed of the structure and processes of the fishery. Here we focus on the market and technological aspects of this subsystem. Changing and distorted markets also have been shown to affect fishery outcomes (Anderson, Flemming, Watson, & Lotze, 2011; Andrew et al., 2007; Berkes et al., 2006). For example, the strong preference for fresh seafood and decreasing local supplies in China led to a 552 percent increase in United States exports of crab to China from 2009 to 2010 (Bean & Han, 2011). In our study, opening of the Chinese market to California squid led to significant changes in squid fishery participation (Pomeroy & Dalton, 2003; Pomeroy et al., 2002). The role of technological change is evident in other fisheries such as the Atlantic bluefin tuna fishery, where storage innovations led to that fishery’s expansion (Sumaila & Huang, 2012) as well as in the case where deepwater trawl vessels are now able to aim for previously inaccessible Patagonian toothfish (Ainley, Brooks, Eastman, & Massaro, 2012). In Monterey Bay, improvements and adoptions of new technologies did occur during our time series, with notable advancements including the use of fish finders, GPS, satellite imagery, and communication tools, along with the power block, the wetfish pump, and, for squid, high intensity lights. These innovations increased access to resources and fishery efficiency, but were adopted gradually over time, precluding marked changes in trends or significant dominance mode shifts.
Resource Units Subsystem

The role of climate in these fisheries, especially large-scale phase variations such as the Pacific Decadal Oscillation (PDO) and El Niño Southern Oscillation (ENSO), is well documented as the strongest driver of production in these fisheries over the past 50 years (Chavez, Ryan, Lluch-Cota, & Ñiquen, 2003; Dalton, 2001; Jacobson & MacCall, 1995; Koslow & Allen, 2011). The three wetfish species respond differently to climatic events, such that fishermen shift effort among those fisheries as conditions warrant. Sardine tends to dominate during warm PDO periods, and anchovy tends to dominate during cool PDO periods. Market squid is known to be negatively affected by (warm-water) El Niño events, and anchovy tends to be more negatively affected by El Niño events than sardine. The sensitivity of squid to warmer water explains the considerable variation in landings from year to year. In addition, seasonal upwelling in Monterey Bay plays a significant role in ecosystem fluctuations (Breaker & Broenkow, 1994). Although our time series begins in 1976 in association with of a governance factor (passage of the Magnuson-Stevens Act), it coincides with one of the largest climate regime shifts (cold to warm) observed in this area (Overland et al., 2010).

Text A.1.3: Chapter 1 Data Limitations

While some social factors are not readily quantifiable (e.g., Plaganyi et al., 2013), this study was limited, as many are, in incorporating information from the users and community perspective over a 38-year time frame. The lack of time series data on the social aspects of Monterey Bay fisheries limits this type of analysis. We attempted to collect information on the number of fishermen, the portfolio of all local fishermen over time (fishery plurality), employment outside the fishing industry (occupational plurality),
and the location of catches, but data consistent with the temporal span and spatial scale of this study are not readily available. Time series data on squid and anchovy biomass and recruitment, the Gini index of income for the larger community over time, annual income per fisherman, annual fishermen demographics, and membership information for fishery organizations (to further understanding of community involvement) were unavailable for our entire time period at our three ports/two counties. Such data would enable assessment of the role of the community as a driver, would provide finer resolution of the fishery system, and would afford a more complete understanding of fishermen’s income diversity. Previous studies have generated data and insights to inform our approach and facilitate interpretation of our results (Pomeroy & Dalton, 2003; Pomeroy et al., 2002). Additionally, data for the smaller Monterey Bay ports could not be included as such information is not publically available due to small numbers and thus confidentiality rules. However, the three ports included in our study account for nearly all wetfish fishing activity in the area over the study period.
Appendix B
Table A.2.1: Adaptive Capacity Building Strategies within the Monterey Bay Wetfish Fisheries In Relation to ENSO Events

Strength denoted as: present, partial, absent. Present indicates strategy was observed strongly in the case. Absent indicates strategy was not observed in case (in relation to ENSO). Partial indicates strategy was somewhat observed, thus reflecting that the strategy may be present but weak, or may be present in one instance but absent in another instance where could be strengthened.

<table>
<thead>
<tr>
<th>Category</th>
<th>Strategy</th>
<th>Study Described</th>
<th>Strength</th>
<th>Role in Case</th>
<th>Illustrative Example(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diversity</td>
<td>Increase institutional diversity and redundancy</td>
<td>Armitage, 2005</td>
<td>Present</td>
<td>ENSO information originates from the same source (NOAA) and is dissipated</td>
<td>“Some years we've had years where we've tried to buy frozen stuff, and tried to re-market it, reprocess it... we'll bring squid in from the Falkland Islands, and then we'll clean it. We'll try to process it and clean it. Sell it as a clean product, or just resell it as whole. Thawed out and repackage it, in small packages.” – Processor</td>
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<td>throughout the community through multiple outlets. There are many ways same</td>
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<td>information is available to users. Local processors can rely on larger, even</td>
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<td>global, industry during ENSO events (e.g. buy frozen seafood from elsewhere,</td>
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<td>process and repackage squid caught in the Falkland Islands, send crew to</td>
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<td></td>
<td>Alaskan fisheries, reallocate plant laborers to local agricultural industry).</td>
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<td>From a monitoring perspective, multiple agencies, NGOs, &amp; individuals monitor</td>
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<td>the same ecosystem and record information.</td>
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<tr>
<td>Provide diversity of management options</td>
<td>Folke et al., 2002</td>
<td>Present</td>
<td>Wetfish fisheries are subject to a variety of management strategies including but not limited to: spatial limits, effort limits, quota limits, temporal limits.</td>
<td>“The fishery control rules provides a protocol for determining sustainable levels of market squid fishing that is enforced through the adoption of specific management tools such as seasonal catch limits, daily trip limits, area closures, time closures, and sustainable levels of egg escapement.” – California Department Fish and Wildlife Squid Fishery Management Plan, p. 176, 2005</td>
<td></td>
</tr>
<tr>
<td>Ecological memory: Diversity of species within and between functional group</td>
<td>Folke et al., 2002</td>
<td>Present</td>
<td>ENSO is associated with a new portfolio of species, primarily migration of warm water species from Southern California to Monterey. Coastal pelagic species, which are not as abundant during normal years (e.g. mackerel), replace the niche left by squid that disappear during El Niño events. A kind of emergent ecosystem appears in waters, presenting new dynamics.</td>
<td>“Usually in the past, let's say the squid was bad. Then maybe the sardines would come in and take up the slack. Or maybe the anchovies would pick up the slack. I mean like last year, squid wasn't as good as this year, but we did quite a bit of sardines last year. And we did the anchovies now too.” – Processor</td>
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<tr>
<td>Empowerment</td>
<td>Recognize community heterogeneity, consider</td>
<td>Armitage, 2005</td>
<td>Present</td>
<td>Strong recognition from all participants that the industry is family and culture-oriented. A common attitude is to</td>
<td>“There is, I think, a cultural knowledge in the fishing industry, about how to adapt to these things, and what the risks are and the threats</td>
</tr>
<tr>
<td>respective norms, values, and world views</td>
<td>conserve the traditional fishing community.</td>
<td>are, and how things change. And if we all give them credit for that and if we all understand it, as managers and researchers, those that live in the conservation community.</td>
<td>– Buyer</td>
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<tr>
<td>Foster policies aimed at empowering communities</td>
<td>Fabricius et al., 2007</td>
<td>Partial</td>
<td>While fisheries policy does not indicate this strategy, local ENSO sources foster policies to provide information to empower the community.</td>
<td>“The meteorologists here locally want to do the right thing, don't want to alarm people, that kind of stuff. They just want to give them the information, let them use it the way they want, yeah.”</td>
<td>– Information Provider</td>
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<tr>
<td>Create policies for institutional frameworks to self-organize and autonomously respond to change</td>
<td>Fabricius et al., 2007</td>
<td>Partial</td>
<td>The community fosters a climate that prioritizes decision-support tools to support individual’s own informed choices. Management does not impose any ENSO-specific rules, and understands that industry will respond how they choose. There are policies for fishers to engage in multiple fisheries and move up and down the coast, allowing options.</td>
<td>“We know if there’s, especially a strong El Niño, the [squid] landings are going to decrease significantly--close to nothing, for potentially a couple of months. But they'll rebound when La Niña comes back. So there's nothing we can do in terms of management to prepare for that, because it's going to happen. We have the landings set, so the result is there isn't that much squid around that season. That's results. And how industry prepares for that or responds to that [is their decision]”</td>
<td>– Manager (regulatory)</td>
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<tr>
<td>Mobilize marginalized</td>
<td>Robinson &amp; Berkes, 2011</td>
<td>Absent</td>
<td>No evidence to support this strategy in terms of adaptive</td>
<td>NA</td>
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<tr>
<td>groups</td>
<td>capacity to ENSO</td>
<td>NA</td>
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<td>Promote access of grassroots voices to higher level participation opportunities</td>
<td>Formal participation processes for stakeholders to engage with management. There is no evidence to support this strategy specifically in terms of adaptive capacity to ENSO</td>
<td>NA</td>
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<tr>
<td>Robinson &amp; Berkes, 2011</td>
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<tr>
<td>Support local people’s creativity and determination</td>
<td>Support exists for information sources to find creative ways to reach to the fishing community and general public. Processing plants support creative ideas to use staffing and facilities (e.g. agriculture products, tapping into the specialized local community based seafood market).</td>
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<tr>
<td>Eriksen et al., 2005</td>
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</table>

“Some years ago, we formed a kind of, Marine Users Group. That, and that is just people, you know, in the waters that we have responsibility for, so local to our office. These are groups that like, someone who you know is in charge of some organization of coastal fishermen…And you know, to the degree we could we try to reach out to all these people and sort of invite them to, kind of, meet with us once and a while, and we talk with them, what are your concerns, what are your interests, I think that program for, and other offices have done things along those lines, but that's the kind of thing that's, kind of, left up to a particular office to decide what works best for them and not the sort of things that national headquarters
Inspire motivation in all actors | Fabricius et al., 2007 | Absent | No evidence to support this strategy in terms of adaptive capacity to ENSO | NA

Flexibility | Flexible collaboration | Folke et al., 2002 | Partial | No contracts exist between vessels and processors or between light boats and vessels; it is all verbal agreements. However, this strategy is not observed between local suppliers and overseas buyers. The global market is not as flexible, if ENSO results in loss of product, it may take a much longer time to revive that buyer-supplier relationship. | “We lose buyers. See buyers, overseas buyers, they want to be sure they're going to buy fish every year. If they knew they couldn't buy from me next year, and then--I don't have 'em, them I have them--they'd rather go buy over here that guarantees them every year. So once we don't have them for a couple years, they start to buy here, it's hard to get them to come back to you for the volume we need to sell. So it's good to have them, and we do lose them--the sardines, we lost them. When they came back, it wasn't really that good, because we didn't have no orders for smaller fish, for this and that. And we had a hard time. Now it's gotten back up and everything, but now they're cutting our quotas to nothing, and we're losing out on that again. And
| Flexible management | Folke et al., 2002 | Partial | Institutional attitudes supporting flexible and adaptive management are strong. There is no fisheries management flexibility specifically for ENSO, but the SST parameter in the sardine harvest guideline allows for flexibility in relation to temperature changes from ENSO events. Management recognizes fishermen’s portfolio as key to industry during ENSO events, though concern exists among some industry participants that management may cut such opportunities. | it's... it's a game. Before it used to be a local thing, fishing. Now it's world wide market. You can get fresh fish anywhere the next day anywhere in the world. It's just like that”
– Fisherman

1) “Now [for finfish] there is flexibility if we feel like the temperature is not accounting for something we are seeing on the water or a predicted change like El Niño, if we're seeing typically, or happening to see sort of major effect by say an El Niño or any sort of other oceanographic event that we didn't feel like the temperature component in the control is accounting for, we could reduce harvest because of that, we don't really have a mechanism to increase harvest beyond what the temperature part is telling us. If that makes sense.”
– Manager (regulatory)

2) “[For squid,] there's nothing specific in terms of protocol and how we make long-term decisions considering El Niño.”
– Manager (regulatory)

Flexible | Folke et al., 2002 | Present | Multiple agencies monitor | “Regarding squid, we know that
| multi-level governance aiming to learn and handle change | 2002 | and document changes in the local system (e.g. National Marine Sanctuaries, National Weather Service, local universities) and greater system (e.g. Climate Prediction Center). Fishery managers at the state and federal level collect that information and incorporate knowledge into plans. | there's going to be decreased landings because of El Niño, and a strong comeback as soon as squid are present again, during the La Niña period. How that impacts long-term decisions, like specific management decisions, there's really nothing that we have in place yet. There are no regulations that say 'well when El Niño happens, fishing must go down to this level.' There's nothing like that in place. So it's just kind of something that happens, and we adjust as it comes.” – Manager (regulatory) |
| Institutional flexibility in problem solving | Folke et al., 2002 | The fishing culture is open to trying new products when problems arise. Agencies are ready to act if ENSO causes problems, e.g. with vessel groundings (Sanctuaries, Coast Guard, Department of Justice). The fishery management in this case study has a history of solving problems through learning, participatory processes, and legal approaches. Other fisheries in similar 1) Industry. “[Fisheries in] Monterey are very family oriented, very kind of set in their ways, have become a little more non-Mediterranean and a little more, open to new things. And I think that, I mean the value of squid it's, every year now, it's often the most valuable fishery in California and the big market is in China. And it seems that will probably continue. And they have the incentive to search for new ground.” – NGO 2) Management. “I mentioned that Humboldt squid were very abundant |
| Governance systems have shown flexibility, providing a precedence for wetfish fisheries. | that fall in the Strait of Juan de Fuca and on the Washington coast, and salmon fishermen were catching more squid than salmon, those trawlers. They lobbied Department of Fish and Wildlife to open up a commercial fishery for squid, which was not on the books. And they quickly turned that around and said "OK you guys can go out and catch squid." There wasn't an existing market for them, so they had to develop a market. Or maybe they used that for crab bait that fall and winter, but that was sort of a rapid response to some change in the marine food web that provides more sort of real time reaction to the conditions on the ground.” – Manager (science) |
| Keep options open | Nelson et al., 2007 | Present | Processors are open to new products (e.g. new seafood, agricultural products), and are geographically open to new areas. | “We always keep some capital set aside for improvements, so if an opportunity arises- I just start spending a lot more time [on new projects]” – Processor |
| Ecological flexibility | Turner et al., 2003 | Present | As ENSO has been a reoccurring cycle for thousands of years, we expect | “They spawn all the way to the coast. They’ve been known to spawn as far north as Sitka Alaska. So and the |
| Infrastructure | Build social and physical infrastructure | McClanahan et al., 2008 | Partial | Physical infrastructure is historically tied to wetfish, and is being maintained, rather than necessarily building new infrastructure. There are limited options because landings must occur close to processing facilities. Harbors are physically ready for ENSO impacts (primarily storms). The recent growth of seasonality was, my sense again, is just that the conditions have to be right in that area at that time, and in southern California in particular--But because we have this amazing productivity, really strong el Niño conditions could supply a number of years--when conditions are right all over the place, they'll spawn all over. They were spawning down in Baja. They're spawning all at the same time, that was the thing that was just phenomenal the last couple years. We've never seen it before that they spawn at the same time for the duration, in both Monterey and southern California. It's really curious.” – NGO

“...Infrastructure Build social and physical infrastructure McClanahan et al., 2008 Partial | Physical infrastructure is historically tied to wetfish, and is being maintained, rather than necessarily building new infrastructure. There are limited options because landings must occur close to processing facilities. Harbors are physically ready for ENSO impacts (primarily storms). The recent growth of seasonality was, my sense again, is just that the conditions have to be right in that area at that time, and in southern California in particular--But because we have this amazing productivity, really strong el Niño conditions could supply a number of years--when conditions are right all over the place, they'll spawn all over. They were spawning down in Baja. They're spawning all at the same time, that was the thing that was just phenomenal the last couple years. We've never seen it before that they spawn at the same time for the duration, in both Monterey and southern California. It's really curious.” – NGO

“I mean Monterey as just a story you know, is 100 years of fishery centered around wetfish... And you know, we got a whole, the whole development of enormous infrastructure around that fishery.” – Harbor

“We kind of are coastal fishermen, and our fish is, how am I gonna say. It's far away, it goes bad. So we can't go a long ways to--we have to have
larger vessels is thought to bring the price down, threatening the fishery. Social infrastructure is strong, the considered “hyper-connected” and there are various forums for “ocean related” groups to network.

| Information | Provide access to early warning systems (EWSs) | Cinner et al., 2012 | Present | EWSs are produced at a global/national level (primarily Climate Prediction Center), and then distributed through the community by multiple sources (e.g. National Weather Service, Coast Watch website, community leaders) through face-to-face communication, phone, email, social media, mainstream media, or public posting. All participants were confident they would hear/see early warning for an ENSO event in plenty of time to prepare. Fishermen and processors recognize observations in sea surface temperature and biological places to unload them close by. So it's not like I can go out for three days, put fish on the boat for three days of fish, I have to catch them and get them back in with refrigeration and everything, the whole... so we're actually really limited to coastal areas, where we unload it.”
– Fisherman

1) “El Niño is tragic for a squid. Evidently I read in the paper just the other day that the prediction of El Niño is waning and there is only 65% prediction now compared to 85% and that actually they claim it may be a mild one. A mild one is not as devastating, a severe one is total disaster. I read where it was 4 degrees warmer earlier in the year and now I think it's set at one point, it's a half degree colder than normal.”
– Fisherman

2) “I think probably the challenge is though there's a lot of information, it's often not clear--at least speaking for myself--how to use that information, and what information is meaningful to the coastal pelagic species. Because what I might need
shifts as local early warnings; they subscribe to services to track changing oceanic conditions and buoy data. Forecasts were used by participants ranging for purposes from general awareness to planning monitoring activities to conserving funds. Challenges include lack of warning specifically for the Monterey region, abundance of potentially helpful information, and lack of confidence for direct use of EWSs in management activities.

<table>
<thead>
<tr>
<th>Innovation</th>
<th>Inspire innovation</th>
<th>Armitage, 2005</th>
<th>Partial</th>
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</table>

Innovation is stifled because the fishery management system requires science-based and well-documented information to change activities. Costs of canning/reduction in California has become too expensive, and so is no longer an option. The only evidence of this strategy is that the

“We were in the canning business for, let me see since 19... we started canning fish in 1970 to about 2005. Then we got out in '05, because of the high cost. You know in California, the costs were expensive. Of sewer, the cost of energy, all this stuff. So canning fish was labor intensive, so now we're doing all this packing by hand.” – Processor
The cyclical activity of ENSO inspires local information sources to develop decision support tools.

<table>
<thead>
<tr>
<th>Leadership</th>
<th>Minimize corruption</th>
<th>Cinner et al., 2012</th>
<th>Absent</th>
<th>No evidence to support this strategy in terms of adaptive capacity to ENSO</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase political transparency</td>
<td>Cinner et al., 2012</td>
<td>Absent</td>
<td></td>
<td>No evidence to support this strategy in terms of adaptive capacity to ENSO</td>
<td>NA</td>
</tr>
<tr>
<td>Strengthen personal leadership skills and promote vision</td>
<td>Fabricius et al., 2007</td>
<td>Present</td>
<td></td>
<td>While leaders did not identify a desire to strengthen their skills, others in the community recognized their strong leadership skills and visionary abilities. Most participants recognize a leader who they are confident will provide them information about ENSO when necessary.</td>
<td>One individual referred to as “The Voice of El Niño”</td>
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| Learning                                      | Promote learning through uncertainty and through crises | Armitage, 2005 | Present | Many participants voiced high uncertainty related to ENSO (particularly in terms of local impacts, and temporal span of impacts). ENSO as a crisis promotes cautionary awareness, and so an ENSO forecast encourages additional monitoring of ecosystems, | 1) “We haven't really been confronted with actually being in business during an El Niño event. So everything that I'm doing right now is sort of learning about how, if an El Niño event comes about, how I adapt to it. And what that means for fishermen, and what that means for business or supply to our customers,” |


attention to climate information, and increased communication within the community. Some managers and NGO representatives recognized different flavors of ENSO events, encouraging learning new impacts and trends with each new event. ENSO is often used to explain data and trends after the fact, both in science and industry.

<table>
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<tr>
<th>Learn from mistakes in practice</th>
<th>Armitage, 2005</th>
<th>Present</th>
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<tr>
<td>This strategy is observed in two primary ways. First, participants are aware of the “cry wolf” phenomena with ENSO, and so many wait to observe changes before making changes. Second, participants learn from the management policy within the swordfish fishery. The California gillnet swordfish fishery is the only fishery with ENSO-specific regulation, but this policy is</td>
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<td>“So we said to the best of our knowledge, it's warm now, and if this El Niño develops, it's probably going to stay warm or get warmer. And therefore by law, they need to close the drift gillnet fishery. And so that was the advice we gave to the region. You know how it works. There's the Science Center regional office, which would make the policy. So we gave that advice to the region, but we were also like &quot;You know, this is really kind of a stupid rule, because first of all, you can have warm temperatures&quot;</td>
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ineffective. Wetfish participants took to this mistake as an example to inform policy discussion in wetfish fisheries (e.g. uncertainty of ENSO, local impacts, identifying actual causes of change rather than rely on proxies) when there's not an El Niño. So why does it have to be an El Niño?" And I think actually by definition, it actually has to be defined an El Niño for them to do this. Well you could have anomalously warm water for many other reasons, which would--if temperature's what's impacting the loggerhead distribution, then it doesn't really matter what it is. So we told them all this, and they agreed that yeah there are issues. It's way over simplified and all that, but you know, in my mind it's also I like the idea that they're trying to use environmental data to manage a fishery. In this case, I think they're using the wrong metric, and I think they're doing it on timescales that are ineffective."

– Information Provider

| Encourage social learning / participatory learning | Berkes & Ross, 2013; Robinson & Berkes, 2011 | Present | Participants from all roles identified a key person or group of people that they communicate about ENSO to, many of which depend on that person for all or most information about ENSO (including but not limited to 1) “I just kind of go by what I see. Like I'll see something on the news, says "oh the El Niño", then I look it up, call up the guys say "hey what are you seeing up in there?" You know call a guy in Monterey, call a guy in San Diego, wherever, whoever’s out, and just try to see what the conditions..."
local impacts, forecast likelihood, oceanic condition changes). Those on the water share observational information. Scientists engage in formal conference calls regarding ENSO, but managers and scientists also engage in informal conversations regarding ENSO with local community members and the global research community. Since ENSO potentially can lead to multiple impacts (weather, storm damage, marine biological, terrestrial biological changes), there are multiple point people to gain information from (e.g. fishermen from multiple fisheries, emergency services, military, bird biologists, oceanographers). ENSO is commonly discussed within the community, particularly after a forecast, and so there is high confidence they will learn from the community are. That's my best way to do it.” -- Fisherman

2) “I just rely on NOAA's information, we'll get email announcements, so here's what's currently going on so the private thing is going out to the public but then we'll also contact scientists and researchers locally, the folks I just mentioned, and sort of, get them on the phone and have conference calls and say okay what are you seeing, what are your thoughts on this. And depending on the issue, we'll be at a group of folks going on so we can sort of get a wide pulse of both like you know, what sort of animals people are seeing, in terms of, it's not an El Niño direct sort of thing but you know it's trying to get a better grasp of what's going on in the environment, so not really focus on the definition itself of El Niño yes or no, and what does that mean, but just trying to get a handle on okay what are the conditions we are seeing now, both biologically and physically, to just help understand where we might be going and what we might see over
about an approaching ENSO or impacts. Processors and buyers share information with their vessels and their customer base. Fishing associations dissipate information to the industry. Newer people in the community and industry look to seasoned individuals to gauge what to expect in an El Niño. Fishery managers meet with fishermen to learn from their experience.

- Manager (regulatory)

| Stimulate institutional learning | Folke et al., 2002 | Present | Fishery management incorporates numerous advisory bodies to provide the best available science. Visitor centers in the area aim to educate the general public about science and the local ecosystem. There were substantial changes in the past 40 years in identifying ENSO and learning more about it. Managers have opportunities to take classes to gain knowledge and skills. Local government agencies avenue the next couple of months. And then if it's an issue, like we really feel we're going to see a sustained long term sort of El Niño event, then we'll talk to those folks specifically.” – Manager (regulatory) |

| “There's a Pacific Fisheries Management Council, and the SSC [Scientific and Statistical Committee] is one of their advisory bodies. Whenever documents come to the council, analyses come to the council, information on data collections that are of a technical nature, they get reviewed by the SSC. And the SSC tells the council whether they represent the best available science, on which the Council can base its decisions. So again, in that arena they don't make any decisions. They are strictly a review body.” |
| Test various management policies | Folke et al., 2002 | Partial | Attitudes exist for trying new management approaches. Discussions and research focuses on possibilities, however, management will not implement any test policies until they are proven they will likely to contribute to goals. | “Lot of discussions. I know there's a lot of work being done to develop ecosystem models that would help inform, but generally those models still are not maybe ready yet to be applied to CPS fisheries. They're still in developmental stages that--they're not, I think that's probably the best way to characterize it. They're still under development and could potentially inform management. They're just not at that point yet.” – Manager (science) |
| Monitor ecosystems | Folke et al., 2002; Brooks & Adger, 2005 | Present | In terms of ENSO, monitoring ecosystem includes monitoring the tropical Pacific oceanic-atmospheric changes, local sea surface temperatures, local oceanic productivity rates, and marine species behavior (primarily migration changes). | 1) “We do recreational angler surveys, and commercial fishing surveys, both. And you never know how it will affect--and you know, because these wetfish are such key species, it can affect a number of other species, the abundance of other species. So if you want to look at something like wildlife watching, pay |
Monitoring is conducted by international and American state and federal government agencies, nonprofits in industry and conservation, and individuals (fishermen, processors). Challenges include decommissioned buoys, uncertainty of what indicators relate to ENSO, and lack of funding to monitor full ecosystem. Most participants cited an increase of self and institutional-wide monitoring when seeing ENSO forecast. Managers noted an increase of monitoring of other fisheries that may experience increased fishing pressure (e.g. sardine is targeted when squid disappear).

attention to that too, because in El Niño years for instance, bird mortality increases, you may see it affects the distribution of species, or where you're going to view wildlife. Like I say you can't control nature, and you often can't say "I'm going to sample, and it's going to be a normal year," because of all the advanced preparation that you need to do. So it affects us in that way. It also, when we're looking retrospectively at historical data, we consider factors like El Niños. Like when you look at California fishery data, clearly you can see the pronounced affects of El Niño, not just in the sardine fishery, but in the salmon fishery you can see dramatic affects. So if you want to interpret the data, you need to consider all the factors that affect the charts. So it's certainly on our radar.” – Manager (science)

2) “There's lots of stuff we look at. I mean we look at upwelling. We look at chlorophyll. I mean sea surface temperature. I think that's not nearly as valuable as knowing temperature at depth, which we don't have a lot of
| **Accumulate new knowledge** | Folke et al., 2002 | Present | All participants are open to new knowledge. Knowledge includes types or ‘flavors’ of ENSO and learning dynamics of different types of ENSO in relation to the local area. Many participants are open to new knowledge on how species may adapt to changing conditions. Many participants perceive ENSO as an excellent time to accumulate new information about system changes (related to ENSO but also in higher temperature instances). |

“There isn't a single, simple phenomenon, at least type of El Niño. And now, the sort of cutting edge of ENSO research is talking about the flavors of ENSO. The different types, and it's probably a continuum. It's not like there's a Central Pacific El Niño or an Eastern Pacific El Niño, but there's some continuum with lots of different types. And those types change based on things like the depth of the thermocline, or how sharp the thermocline is. Meaning what's the temperature difference between the surface waters and the deep waters in the Tropical Pacific? And those things change at different time scales,

...where the thermocline's at... There's biological indicators of what's going on. You know there's a trapline of information with other people involved in other fisheries. They have crab fishermen. There's traps on the bottom, and he's got egg casings on them. Says "hey we're seeing some sign." Or the guy drag fishing, trawling, saying squid are almost stopping the boat.”

– Processor
from one year to the next, one decade to the next, maybe even one century to the next, and we expect that it's going to continue to change, because of anthropogenic global warming. So we have climate models that are trying to incorporate all this information and these changes, and then simulate the outcomes as a kind of emergent properties of the climate system. But there are enough unknowns, or poorly known things, that subtle differences in different climate models lead to pretty dramatic differences in how they predict El Niño will change in the future. And I think that just points out the fact that there's this capacity for a whole variety of things to happen, and we're not likely to sort that out any time soon.” – Manager (science)

| Match rules (and change to match) to system dynamics | Folke et al., 2002 | Present | Fishery management seeks to ensure rules align with social interests and ecological conditions. In the sardine management, the SST parameter aims to match the harvest guideline to system changes through temperature changes. “And the other things, I think with respect to sardine and anchovy, just recognizing to the extent that these regional shifts are predictable. Just recognizing how those might affect fishers behavior. But the way those fisheries are managed, or at least the way the sardine fishery is managed, |
as a proxy. Rules for ENSO match system dynamics; ENSO impacts are not the same with each event, and so management stays aware and increases monitoring without engaging in any specific regulatory trigger. Researchers consider a continuum of ENSO events, and this trickles down through the system so that management is cautionary and not focused on the forecast. While El Niño events have an immediate impact on squid, sardine and anchovy often experience lags in impacts. As such, management aims for long-term stability (thus matching rules to system dynamics e.g. lags).

is based on stock assessment models that--they already account for this. One bad recruitment year is not going to destroy the stock unless the stock is at a very low level. If the stocks at a very low level, the harvest rate should already be low, or nothing, or basically to trivial or nuisance levels. So in theory, if we had a better sense of how the population really responded to both high frequency and low frequency climate, we could improve management. And we do have some sense of that, and that's actually in the management plan. It's the temperature control that drives the harvest rate. So climate's kind of recognized in there, but we don't have perfect understanding just of how climate is driving productivity. So going beyond what's currently in place is probably needs more science to understand what we can do better. But I think there's in general pretty reasonable agreement that we're doing a pretty good job now, based on what we know.”

-- Manager (science)

| Change | Folke et al., Partial | The management system is “I don't think there's an explicit |
Policies and management strategies according to new knowledge

Managers quote a pervasive attitude of leeriness to wards any substantial changes. However, there is evidence of this strategy was seen in that the source of temperature information changed from Scripps Pier to the CalCOFI transect, as it was discovered that CalCOFI was more accurate for the entire region.

For the entire region, the CalCOFI was more accurate, as it was discovered that CalCOFI was more accurate for the entire region. We always try to incorporate the best scientific information we can use to manage the act to incorporate into our management decisions. Managers quote a pervasive attitude of leeriness towards new knowledge. New knowledge is not always incorporated into management decisions.

We always try to incorporate the best scientific information we can use to manage the act to incorporate into our management decisions. Managers quote a pervasive attitude of leeriness towards new knowledge. New knowledge is not always incorporated into management decisions.
<table>
<thead>
<tr>
<th>Foster institutions that aim to learn and store knowledge and experience</th>
<th>Folke et al., 2002</th>
<th>Present</th>
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| Fishermen often take notes on oceanic and biological observations. Fishery management and greater governance (other agencies) heavily allocate time and resources into scientific observing and data collection enterprises. Local information sources aim to store information about local experiences, as this is not often detailed at agencies with national agendas. Most participants cited value and a pressing need for storing knowledge and experience in terms of ENSO events to implement any of that stuff, I'm not aware yet of other fisheries across the country if anybody else has started to do any work like that yet so. So if we were to understand you know some driver, then I think we would incorporate it if we thought it would better the management.” | 1) “I am slowly but surely looking at how different variables have impacted the landing rates of market squid. I'm looking at different SST sources. El Niño, because of temperature anomalies, different ocean indices, so like the Southern Oscillation and that, or the ocean Niño index, or the PDO upwelling indices, north wind information, and coastal sea level information. And so I'm trying to find relationships between all of those and landings and biological information that we have from our samples. That's kind of the clearest example of how we use climate information, the easiest example. Most the time we look at
learn how to better predict how future events will impact the local community and industry.

biological information from what was collected in our samples, and when possible relate back to climate trends, but like I said it's not a frequent occurrence.” – Manager (regulatory)

2) “That’s the whole reason to have an ocean observing system, is you don't know when something is going to happen like an El Niño or a Deepwater Horizon oil blowout, or a mass die-out of starfish or something else. So the point is that you've got a set of measurements of core measurements that’s already there, and in this case much of it is in real time. So I don't think that’s really been in place for previous el Niños.” – Information Provider

| Continuous evaluation and review of the system and management interactions | Brooks & Adger, 2005 | Present | Stakeholders continuously hold the management body accountable, and discuss system and management interactions. ENSO is well-monitored, and managers, scientists, and users continuously learn how the system responds to ENSO, where management can assist the industry (e.g. portfolio management) |
| “It goes back to your sort of trusting information. So there is a, say the stock assessment there's you know, maybe ten pieces of data, this is not accurate, but say there's ten pieces of data that we build in for the stock assessment, often we'll get one piece of that data say midthrough, midpart through the year and we may, some people may want to react to that, say hey look this is showing that the
flexibility), and where it could potentially harm the industry (e.g. if ENSO triggered regulatory quota cuts). The California swordfish gillnet fishery provides an example to evaluate how the management system interacts with ENSO in a formal regulation aspect.

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<tr>
<th>Maintain a collective memory of experiences</th>
<th>Armitage, 2005</th>
<th>Present</th>
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| A number of participants from all roles noted that this was their first ENSO experience in the fishery and that they sought knowledge from those well seasoned in the fishery/community for guidance on what to expect. This strategy is observed in that individuals and organizations will record memory of previous ENSO events, but this is not necessarily helpful in contributing to adaptive capacity to ENSO. Reading the forecast gives many participants a general sense of what to expect, but not a stock is probably going to be really good next year. But until we actually sit down and incorporate all the data and do sort of a very rigorous scientific process to analyze that data, then we're usually fairly leary of just reacting quickly to one piece of information.” – Manager (science)

“There's been some dramatic cases in the past, 1982 the winter of 1982-83 and the winter of 1997-98 were both years that there was that very strong El Niños occurred. Actually the two strongest ones since 1950 and both were years that our area, Central California, had much above average precipitation and really stormy weather. And they're sort of significant historical events, if we start talking about an El Niño, people will, especially people who have been a while and will think back on those 82-83 and 97-98 winters and like oh does this mean that we're going to have another winter like that. So a lot of what we're doing is kind of clarification you know not all El
Additionally, many recollections of ENSO events were recollections of warmer or wetter years, not necessarily an El Niño event, thus complicating the collective memory and muddling the approximate impacts of ENSO in the area.

Niños result in the same impact. And those were really strong El Niños and although we are looking at a likelihood of an El Niño developing now, there is no indication at present that it will become a strong El Niño and if it's not a strong El Niño, doesn't it really have a lot of impact in any particular direction on how our winter plays out. So in a way people think that when they hear El Niño they know something, oh wow it's going to be a wet stormy winter, they're talking about an El Niño, and we're in a way trying to disabuse them of that perception.”
– Information Provider

| Linking                                                                 | Link different knowledge networks (to support learning and adaptation) | Armitage, 2005; Fabricius et al., 2007 | Present | Various knowledge networks include local fishermen and processors, local researchers (management and academic), local military (Coast Guard and Navy), government agencies focused on climate, weather, ecosystem health, and fisheries (e.g. National Weather Service, National Marine Fisheries Service, National Marine Sanctuaries), “It's challenging because our understanding for different links in this whole chain of climate to the ocean--ocean conditions and marine food webs to fish and then to fisheries--it's imperfect every step of the way. It's something that I have argued for and others have also argued for.”
– Manager (science) |
These networks are linked formally (e.g. advisory panels) and informally (e.g. interpersonal relationships). Each has its own agenda, but they share information and build on one another (e.g. local NWS builds upon Climate Prediction Center information). This links physical knowledge to biological knowledge to social system knowledge.

| Nest institutional arrangements across scales | Fabricius et al., 2007; Robinson & Berkes, 2011 | Present | The local industry is a subset of the larger West Coast industry, and even larger global industry. Fishermen and processors have networks of others in other regions/fisheries. ENSO information (e.g. impacts, observations) is presented as global, regional, national, and local. During El Niño events, players that are normally not as integrated with daily fishing activity play larger role (e.g. Coast Guard for 1) “I don't think you can disentangle the effect of squid availability from the effect of the larger-scale changes in ocean conditions that are associated with El Niño events. It's a combination of everything.” – Manager (science) 2) “I think the networking is a benefit for them too, because they get to meet all these different folks that are all ocean related in some way or form, and all the state and Coast Guard and Fish and Wildlife. All the agencies are represented” – Harbor |
| Link management with culture | Fabricius et al., 2007 | Present | A three-year average in the sardine equation was integrated with the intention to achieve a “socio-economic balance” to stabilize the fishery. Fishermen proposed weekend closures, which were accepted by the management body. This lifted social pressure from fishing all the time, and alleviated fishing pressure from the system, benefitting the ecosystem. Management frequently consults with local fishermen. | “The best thing we ever did was... myself and a couple of other guys decided we wanted to fish 5 days a week instead of 7. Oh, we thought that was the end of the world, that's the best thing we ever did. Because what happened was they gave us a day off, gave the freezer people time to get, take a break, the workers set the plans, time to do something. Not like the 7 days a week and it stretched out, it gave all the fish in the ocean the squid, 2 days and I use this word unmolested, okay. Two days a week, everywhere. Not just the reserve here, or reserve there but everywhere they went on, best way...And it immediately raised the value of the squid.” – Fisherman |

<p>| Livelihoods | Invest in economic alternatives to resource dependent livelihoods | McClanahan et al., 2008 | Present | Fishermen have access to other income sources including contracting, real estate, taxi services. Plant workers have access to agriculture work in the area. Processors can switch to non-marine products (e.g. | “A lot of them went into, fired by the El Niño, a lot of them went into contracting, remodeling jobs and stuff” – Fisherman |</p>
<table>
<thead>
<tr>
<th>Participation</th>
<th>Facilitate actors at multiple levels to interact with each other</th>
<th>Folke et al., 2002</th>
<th>Present</th>
<th>Actors interact at an individual personal level (small community, family oriented industry), community level (fishery fairs, religious gatherings), state management levels (e.g. CDFW public forms), and at federal</th>
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<tbody>
<tr>
<td>Diversify livelihoods</td>
<td>Eriksen et al., 2005</td>
<td>Present</td>
<td>A diverse portfolio is recognized as a key strategy to industry survival during El Niño events. Sardines and anchovies were primarily targeted during ENSO events, followed by mackerel, tuna, and other warm water species. Otherwise, fishermen travel to San Francisco or Alaska and work on fishing vessels there (though not as captains and not on their own vessels). Processors and buyers can rely on other species (e.g. opal, mackerel) or buy squid from other locations (e.g. Falkland Islands) to satisfy customer base.</td>
<td>“So if you're a commercial fishermen now, you've got to sort of diversify a little bit, to where you're gonna fish squid, sardines, mackerel, maybe have a chance to go to Alaska. So if you're going to depend on that to make a living, you're going to want to be able to jump around, have the opportunity. And for a while there, the opportunities weren't there. If you were a person, you really couldn't depend on fishing as a living. So a lot of guys got into construction, because most guys that were fishing were pretty outdoors type of people right. So they went into construction. There's carpentry or plumbing or general construction, and a lot of guys did that. Some guys got out.” – Fisherman</td>
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- strawberries).
management levels (e.g. Council advisory panels). ENSO encourages more multi-level interaction (e.g. processors communicating with buyers, local information sources answering inquiries from users, managers reaching out to global climate researchers, fishermen contacting network to move activity Northward).

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<tr>
<th>Improve stakeholder relationships</th>
<th>Leslie et al., 2015</th>
<th>Present</th>
<th>While some tension among stakeholder exists (primarily between fishing industry and conservation NGOs), a common view among participants is that stakeholder relationships are important. Information sources aim to contribute decision support tools to help connect their work with industry needs.</th>
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what they're seeing. So in the meeting and someone says "hey there's no fish," I go "wait a second we see fish here." So try to give an up to date, hands on, what's actually in the ocean, because there's all these different assessments, and sometimes they miss the fish. And just putting input doesn't do anything, they have hard facts, but at least kind of let everyone know what's out there. Then I just try to talk to the different council members, try to explain things to them. You know just explain to different people that don't really know what's going on out on the ocean, what's happening.” – Fisherman

“My job… to make sure the infrastructure doesn’t go away and defend the fishermen and we had done a really pretty good job of that. And frankly a lot of this is sort of emotional support to the remaining fishermen. To dock them up and have them get a sense of community and we did a year long community sustainability plan… I was pretty open with many of the guys about
Formal stakeholder engagement programs exist within management and other local institutions and agencies. Some within the industry voiced frustrations that the stakeholder engagement options are not as helpful, or that their input is not highly valued. However, all stakeholders voiced a desire to improve relationships.

| Involve stakeholders through consultation | McClanahan et al., 2008 | Present | Stakeholders (industry, NGOs, and information sources) are involved in management through formal consultation arrangements (primarily advisory panels). Those in the industry informally provide useful insight into local conditions, though such involvement could be enhanced to more directly integrate into management activities. | “I think it's clear in this fishery--we are completely wasting information that fishermen are able to get. None of that is going into the stock assessment. That seems ludicrous to me. You get these people that are out there all the time, on the water, with the best sonars, able to count and do their own biomass estimates of where they are, all the time. None of that information is collected by the government.” – NGO |

<p>| Involve stakeholders through active | Robinson &amp; Berkes 2011; McClanahan | Present | Most decisions are discussed actively with stakeholders and at public meetings, both at the | “Our regional office, Solution and Policy Office, Pacific Council, are the arenas where there's a lot more |</p>
<table>
<thead>
<tr>
<th>Participation in decision-making processes</th>
<th>et al., 2008</th>
<th>Federal and state level. However, decisions are ultimately backed by scientific knowledge and made by managers.</th>
<th>Public interaction. So people will come to the council— I don't know if you've ever been to a council meeting, but they have—it's a very public process. There's periods for public comment. There are committees that include members of the public, or particular constituent groups. That's often the arena where these things get hashed out, not at the science center level.” — Manager (science)</th>
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<tbody>
<tr>
<td>Involve stakeholders through compensation</td>
<td>McClanahan et al., 2008</td>
<td>Absent</td>
<td>No evidence to support this strategy in terms of adaptive capacity to ENSO</td>
</tr>
<tr>
<td>Encourage deliberation, and create new processes for multilevel nested deliberation processes</td>
<td>Robinson &amp; Berkes, 2011</td>
<td>Present</td>
<td>NGO representatives cite formal and informal deliberation with other NGOs and managers. While stakeholders may have conflicting interests, many recall engaging in respectful conversations and relying on science as a primary tool for deliberation. Formal stakeholder engagement and public review processes encourage deliberation. The “[With the other NGOs,] I think that we have heart to heart conversations quite a bit. We agree on a lot of things, but there's some significant things we disagree on. In particular this most recent issue around temperature dependent fishing rates. We did not agree on, and we had some hard discussions, but I think there's a healthy respect between us. And they've got science that supports their stuff, and we've got science that supports our stuff” — NGO</td>
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<tr>
<td>Legitimize collective decision-making</td>
<td>Adger, 2003</td>
<td>Absent</td>
<td>While stakeholders are consulted for decisions, decision-making in terms of the fishery falls to state and federal regulatory managers. In terms of ENSO, no apparent collective decisions are made.</td>
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<p>| | |
| | |
| | “You know and they were going over how they do stuff, like they'll give their research methods and all that. It was just so funny--and I can't say, I was one of the only fishermen there--I just thought it was so funny, because there wasn't anybody there trying to help out and lets get a better study, lets really learn from the ocean, because we see all these fish and we're telling everybody &quot;hey there’s all these fish here,&quot; but the government just doesn't have money, can't fund it, can't do this project, can't do that. Trying to get them to do put tags and we don't have the money for the tags now. It's just sad, because you'd think if you're an environmental group, you'd want to chip in money. Let's get these tags, we'll chip in--the fishermen, we'll...&quot; |</p>
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<tr>
<th>Step</th>
<th>Description</th>
<th>Reference</th>
<th>Status</th>
<th>Details</th>
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<tbody>
<tr>
<td>1</td>
<td>Involve stakeholders at all stages of operationalization</td>
<td>Brooks &amp; Adger, 2005</td>
<td>Partial</td>
<td>Stakeholders are primarily involved in consultation during public review. However, stakeholders can propose changes (first stage of operationalization, e.g. in the case of weekend closures) and bring decisions to a legal discussion (a later stage). Additionally, stakeholders are involved at all stages of ENSO in terms of monitoring ecosystem and industry trends (pre-event, event, and post-event).</td>
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<td>“Well management sets a framework, and the fishery operates on a working framework. So I think what management does and should do, is monitor. In fact we participate in helping, counts, catches, and we also participate in doing the research to show the relationship of biomass to environmental factors, so that’s a program funded entirely--for the most part funded--by the industry. And it takes that responsibility, because we want to continue to fish sustainably, and anything else than that is meddling, for no good reason. I don't see that there's any use to be gained by trying to structure a fishery all the way.” – NGO</td>
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<tr>
<td>2</td>
<td>Policy Formation</td>
<td>Create policies which enable options</td>
<td>Fabricius et al., 2007</td>
<td>Partial</td>
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<td>“So if we set a quota say for CPS species at X right now and we set it for the next three years, often, although we can always do emergency regulations of things but say if at that time we knew we had</td>
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species). During ENSO, no specific fishery policy is put in place. This allows users to decide how to respond on their own, rather than through top-down imposition. It is possible to write in emergency regulations in case of any crisis such as ENSO. The only option in sardine fishery is the harvest guideline, where the temperature parameter allows managers to be more or less conservative depending on oceanic conditions.

forecast information that said, some link that something is going to happen that is going to make it really good for species X in a couple years, then we could say, we could write our regulations to say although we're setting the quota at this now, because we're aware of this forecast, we'd write in sort of a revisiting clause that if we start to see something change over a certain threshold or something then we would reevaluate the quota and potentially increase it, but often if we, that's hard to do if we don't set it up ahead of time. And to use it is sort of the only way we can sort of set things up ahead of time is if we have that sort of forecast information. We're typically really leary of mid season, something happening, and us just making a change. But if we feel comfortable about some sort of correlation and forecast information, then we're able to write that in so we can make those sorts of changes more on the fly then we would be able to had we not had that information ahead of time.”

– Manager (regulatory)
<table>
<thead>
<tr>
<th>Strategy</th>
<th>Author(s)</th>
<th>Evidence</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Write policies with clear directions for purposefully building adaptive capacity</td>
<td>Folke et al., 2002</td>
<td>Absent</td>
<td>No evidence to support this strategy in terms of adaptive capacity to ENSO</td>
</tr>
<tr>
<td>Include active platforms for adaptive management processes in policies</td>
<td>Folke et al., 2002</td>
<td>Present</td>
<td>The most active adaptive management process is within the integration of the sea surface temperature parameter in the sardine harvest guideline. This has both a quantitative output, and a qualitative output in that it informs whether management should be more or less conservative.</td>
</tr>
<tr>
<td>Close loopholes which promote illegal</td>
<td>Leslie et al., 2015</td>
<td>Absent</td>
<td>No evidence to support this strategy in terms of adaptive capacity to ENSO</td>
</tr>
<tr>
<td>时序会话特征分析，2002</td>
<td>Present</td>
<td></td>
<td>“[We’d like to] incorporate inherent uncertainties in quotas using at least something scientific to base stuff on if that makes sense, so we know there's some uncertainty with what's going on with the stock, and we try to incorporate that the best we can. And knowing that, although not directly probably, temperature in some way effects sardine productivity, having that temperature parameter in there and sort of allowing harvest to go up when we think the stock is productive and then decreasing quotas when we think we're in or leading into a period of low production. I think is really useful.” – Manager (regulatory)</td>
</tr>
</tbody>
</table>

While no evidence supported the presence of this strategy, management bodies continually try to close such illegal loopholes. However, this is not a factor in terms
<table>
<thead>
<tr>
<th>Participation</th>
<th>Authors and Year</th>
<th>Status</th>
<th>Description</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stimulate social safety nets to prevent poverty traps</td>
<td>Cinner et al., 2012;</td>
<td>Present</td>
<td>Captains plan to help out crewmembers during El Niño events. There are agreements with buyers so that they are not in jeopardy during ENSO events. Processors build partnerships with captains to ensure vessels do not owe them anything during difficult times, but accept whatever catches they get. There is a small local market that the industry can somewhat rely on (rather than the normal large global market) and receive a higher price.</td>
<td>“You know, I mean when there is El Niño, there is nothing. Those other bills keep coming, then you got crew members, they have nothing. They spend every dime they make all the time. So if you want to keep a crew you got to advance some and then they call you, and oh, I don’t have money for rent. You got to pay the rent for them, no. And then you know, stuff like that.” – Fisherman</td>
</tr>
<tr>
<td>Increase stability of national government</td>
<td>Cinner et al., 2012</td>
<td>Absent</td>
<td>No evidence to support this strategy in terms of adaptive capacity to ENSO</td>
<td>Stability of government plays a role in that unemployment benefits, and disaster relief, provide options for participants, no active efforts were aimed at increasing government stability, probably because the government is considered stable</td>
</tr>
<tr>
<td>Build safety nets to endure political shifts</td>
<td>Eriksen et al., 2005</td>
<td>Absent</td>
<td>No evidence to support this strategy in terms of adaptive capacity to ENSO</td>
<td>NA</td>
</tr>
<tr>
<td>Build economic</td>
<td>Eriksen et al., 2005</td>
<td>Present</td>
<td>Actors are financially conservative for times such as “I'm saving my money, I'm not buying any real expensive new stuff.”</td>
<td></td>
</tr>
<tr>
<td>Social Capital</td>
<td>Enhance collaboration</td>
<td>Armitage, 2005</td>
<td>Present</td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>----------------------</td>
<td>----------------</td>
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<td></td>
</tr>
</tbody>
</table>

Vessels work to make room for each other on the water, and share light boats. Information sources expect to work with public and users more when an ENSO event is approaching, providing information and knowledge on how to interpret ENSO information. Management collaborates with fishing associations and the National  

1) “Everywhere other than part of Monterey Bay is unwritten law, unwritten that you have to stay up, 8 to the mile from each one. So that way there you get room, you get a little bit of room, so you can work, so somebody doesn’t come and jump you out of your spot like a clam jumper right.” – Fisherman  

2) “We collaborate a lot with the California Wetfish Producers Association. So we can get requests

safety nets

these, and especially conserve funds if they see ENSO forecast. Options for fishermen include tying up vessels and going on a new insurance plan (Port Risk), relying on unemployment, and collecting disaster loans from the government (only if ENSO proven disastrous). Options for processors include saving product for key buyers when expecting next year to be lean, processor/vessel companies increasing use of spotter planes (save time and money).

I'm not going into debt, just taking it easy, because if it does hit, I'll be able to get through the times. So my decision would be not to upgrade my business, not to spend a bunch of money right now into a fishing business that I can't recoup. So right now I'm in save mode and planning for when it hits, or if it hits, to have everything as low an expense as possible, where I can just get by for a couple years until it's over with.” – Fisherman
Marine Fishery Service to share biological and fishing industry information. Other fishermen (e.g. crab fishermen) collaborate in reporting egg casings in new areas (form of monitoring ecosystem).

from them, or even from specific fishermen. It all depends on what's happening. And then we collaborate with the National Marine Fishery Service and NOAA, so there might be data requests from them. We get data requests--I have received data requests in the past for biological information, and their aim was to relate it to different environmental changes like El Niño.”

– Manager (science)

<table>
<thead>
<tr>
<th>Stimulate power sharing</th>
<th>Armitage, 2005</th>
<th>Absent</th>
<th>No evidence to support this strategy in terms of adaptive capacity to ENSO</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Build social trust</td>
<td>Armitage, 2005; Eriksen et al., 2005</td>
<td>Present</td>
<td>Strong trust in community and industry leaders to share key climate (ENSO) information with individuals when pertinent. Many processor-buyer-vessel-light boat relationships are verbal agreements. Trust in fishermen/processors because many are family, or families have been close for multiple generations. ENSO information sources are seen as trustworthy because there</td>
<td>1) “I've just got such good friends [in the fishing industry] that would do anything for me. I would do anything for them too.” – Fisherman 2) “And you know, I have got a really good relationship what the fishermen here and I really think that it's not adversarial, lot of harbors it is an adversarial relationship between their and as fishermen or otherwise. And it's not like that [here]. It's really pretty old area. But one concern of diligence you know, fishermen is that, they know that I have worked</td>
</tr>
<tr>
<td>Problem</td>
<td>Enhance reciprocity among actors</td>
<td>Armitage, 2005; Eriksen et al., 2005</td>
<td>Present</td>
<td>Processors try to keep customers viable. They do not always try to go for ‘big dollar’ but do try to help out the middle/lower profit customers during stressed events such as ENSO years. Fishermen share information to keep each other safe (e.g., increased storms).</td>
</tr>
</tbody>
</table>
Encourage cohesion among networks | Armitage, 2005 | Present | The industry network is connected through families, and has been dominated by the same players for multiple decades. Fishermen and processors have a greater coastal (up to Alaska) industry to connect with during ENSO years. The management network includes 1) “Yeah it's that its super connected, hyper connected and anyone who has any sort of tie to it” – Buyer 2) “So [fishermen] could make a decision let's go to Alaska and fish pink salmon or herring. And they may decide to do that. So there's decisions that are made sometimes, in a severe--even by the fishermen. A few people go. Not everybody has
| Consider various norms and perspectives in policy development | Armitage, 2005 | Partial | Policies have been developed to consider sustainability from a social and an ecological perspective. The sardine harvest guideline is designed to ensure a smooth and economically viable fishery for a long time period, and to ensure enough of the sardine population remains to be used by natural predators. Science-based information is used |
| --- | --- | --- | |
|  |  |  | permits to go there. Some guys, even though they don't have permits, they'll go up there as deckhands and go fish with people that do. And because they're good experienced fishermen, sometimes they don't have a problem getting a job. You know they'll call their buddy, because it's all a network of people. Fishermen, they know everybody. You fish in California, you know guys that fish in Alaska. And they'll call someone, say you know what we're not doing anything down here, and they have a job up there on a boat, and they go as a deckhand. So people do that.” – Processor |
|  |  |  | “The three year average also was intended to sort of reduce volatility in the fishery. So if you had one warm year followed by a cold year, that you would moderate the impact to the fishery. So it was more of a socio-economic balance.” – Manager (regulatory) |
over traditional knowledge, though stakeholder engagement opportunities allow for multiple perspectives to be heard and considered. Weekend closures are an example of a norm considered for policy.

<table>
<thead>
<tr>
<th>Strengthen community relationships</th>
<th>Berkes &amp; Ross, 2013</th>
<th>Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>Community relationships are strengthened through sharing knowledge. Key people are particularly relied upon during ENSO events, since they pose uncertainty. Close family relationships within the industry strengthen the community. The fishing association helps bring industry interests to community and management discussions. Many outside the community perceive the Monterey fishing industry as intimidating and difficult to enter, thus the community that exists can be considered exclusive. There is tension between the public and the fishing industry, particularly</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1) “We have fishermen in the classroom, where we pay fishermen small stipends to go into school classrooms and kind of share their knowledge and wisdom and stories and techniques, and it's a very popular program.” – Harbor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2) “There is a strong relationship between the fishery and the community… Especially in Monterey. That's the part that I'm hoping is captured and maintained, because there is real strong community support for the history and culture.” – NGO</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
in that tourism is the largest industry in the area and is tied to the historical fishing industry, but the fishing industry is perceived to hurt tourism (e.g., with smells). Programs that bring seafood into schools and fishermen into classrooms try to strengthen community relationships. Annual fishing festivals strengthen the community’s tie to fishing.

<table>
<thead>
<tr>
<th>Action / Partnership Description</th>
<th>Authors</th>
<th>Timeframe</th>
<th>Details</th>
<th>Quote</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhance cooperation among groups through social learning</td>
<td>Robinson &amp; Berkes, 2011</td>
<td>Present</td>
<td>The whole fishing community shares information. Management aims to collect information from multiple sources to inform better policy. Managers are known to board vessels to learn from captains. Processors will share information (including ENSO information) to help vessels make more informed decisions on if to fish (or to conserve finances) and where to fish.</td>
<td>“A lot of times there are boats--now I mean everyone's got an iPad, a lot of this stuff is readily accessible, where in the past maybe I would make printouts, and I'd hand them out to guys unloading. Or have our unloader guy, hey pass this along, because some guys are like wake followers. They'll go where the whole fleets going.” – Processor</td>
<td>Robinson &amp; Berkes, 2011</td>
</tr>
<tr>
<td>Develop partnerships</td>
<td>Robinson &amp; Berkes, 2011</td>
<td>Present</td>
<td>The fishing association develops partnerships with the</td>
<td>“One of the jobs of the warning coordination meteorologists is to go...”</td>
<td>Robinson &amp; Berkes, 2011</td>
</tr>
</tbody>
</table>
through social learning

management body and scientific agencies and institutions, to monitor the ecosystem and to share data. Fishermen know which individuals pay attention and which don’t, so they know who to go to for information and who to share information with. Information sources seek to share information with vulnerable actors, and to provide a network in which users can rely on them during crises such as El Niño events.

out of the office and meet with these groups of people at other locations and say hey, let me tell you about the latest stuff we have. So the guy in that position, most of my stuff is kind of focused inside the office, a lot of what he does means traveling outside the office to meet with key groups of customers.” – Information Provider

<table>
<thead>
<tr>
<th>Balance power among interest groups</th>
<th>Folke et al., 2002</th>
<th>Absent</th>
<th>No evidence to support this strategy in terms of adaptive capacity to ENSO</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Willingness and availability of resources to be allocated for adaptation</td>
<td>Brooks &amp; Adger, 2005</td>
<td>Present</td>
<td>Information sources are especially willing to contribute to adaptation, and spend time dedicated to creating decision tools, easier access of information, and more localized data. Spotter planes are a resource used to better inform vessels. While management may be slow to change policies, substantial</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>“And that last phrase I think is sort of key, the protection of life and property in the enhancement of the national economy. And then the second set reads &quot;data and products form a national information data base and infrastructure which can be used by other governmental agencies, the private sector, the public, and the global community.&quot; So everything we do in my office is sort of, you know,</td>
<td></td>
</tr>
<tr>
<td>Technology and access</td>
<td>Folke et al., 2002</td>
<td>Partial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------</td>
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</tbody>
</table>

Scientific funding is allocated to better understanding dynamics and to supporting adaptive management (if only in the future). Lack of funding for buoys (both locally and in the tropical Pacific) indicates this strategy is not always well developed at national/international levels, but the high technology dedicated to the TOGA-TOA array, IOOS programs particularly for subsurface measurements, and NMFS biological-climate studies indicate a strong aspiration for this strategy.

Encapsulated by that overall mission statement, and that's true for the rest of the service's offices as well.”

— Information Provider

1) “We've seen everything from federal, state, and local agencies, to university researchers, to Indian tribes involved in management, to fishermen. And not only fishermen, but we happen to know that there are two or three services that provide data to fishermen and get their seminal data from us, and then they package it. Which is fine, and that's legal by the way. And we not only
information related to ENSO to the local community. Fishermen and processors have access to observational data on phones and computers. Advances in larger vessels are perceived to be threatening the fishery by lowering the product price. Less funding for buoy and NOAA observational ships in the equator perceived to be threatening access to information about ENSO.

know it, we know very well, because-so fishermen come in, that's one of the main responsibilities for Coast Watch. There's a wide range of users.” – Information Provider

2) “Like NOAA has a website. I also have like a Terrapin thing, that's just a local thing that I look up. It's like a local thing that we subscribe to. We also on one of the boats we use ocean imaging, called Ocean I, ocean imaging. That's expensive, it costs fifteen or eighteen hundred a year. We have a subscription to the ocean imaging also, and then... trying to think. That's about it. Those are the ones that I usually use.” – Fisherman
Appendix C
Text A.3.1: Case Details

Falkland Islands

The Falkland Islands fishery system is unique in that 60-80% of the annual catch is made up of two squid fisheries, *Illex argentinus* and *Loligo gahi* (Arkhipkin, Barton, Wallace, & Winter, 2013). This study focuses on *L. gahi* (also named *Doryteuthis gahi*), commonly known as Patagonian squid, since it is more similar biologically to California market squid. As a British Overseas Territory, the Falkland Islands are a British dependency with its own currency and government. The Falkland Island Fisheries Department manages the fisheries within the waters of the Falkland Islands Conservation Zones, and management strategies include limited entry through a license system, limited effort through a quota system, temporal restrictions (2 seasons), spatial restrictions (fishing limited to a certain area, and nursery habitat areas protected), and technological requirements (e.g., anti-seabird interaction devices required on all vessels).

The Falkland Islands Conservation Zone (FICZ) was established on October 26, 1986, with the first official fishing season and the issuance of licenses beginning February 1, 1987 (Argentina and the United Kingdom, 1990; Barton, 2002). Before the FICZ, the fishery was unregulated and targeted by primarily Spanish, Polish, and Soviet trawlers, which began fishing the area in 1982 (Csirke, 1987). An Individual Transferable Quota (ITQ) system was created in 2005 through the Fisheries (Conservation and Management) Ordinance. The ITQ system is structured as TAE (total allowable effort), where annual allocation is based on the effort cap set for the season, the number of shares held, and a vessel’s catchability coefficient. The fishery closes when the season ends (the first season runs from February to May, and the second from August to October) or when
in-season modeling (assessed by the DeLury depletion method) indicates nearing a minimum 10,000 tonnes spawning stock.

*L. gahi* is found off the coasts of Chile and Argentina, though is most abundant around the Falklands (Arkhipkin et al., 2013). A small squid with a maximum mantle length between 13 and 17 centimeters, *L. gahi* is a neritic squid with a one-year life cycle found most frequently between the surface and 350 meters depth (Arkhipkin et al., 2013; Roper, Sweeney, & Nauen, 1984).

*L. gahi* is caught by trawlers within a specific 9,700 square nautical mile zone, termed the “Loligo Box” (Hatfield & DesClers, 1998). Roughly 16 factory trawlers are licensed to fish *L. gahi*, ranging in size from 950 to 2849 gross registered tonnage. *L. gahi* quota is distributed among seven Falkland Island companies, which have formed Joint Venture arrangements with trawling vessels, most of which are run by Spanish masters and crew from various nations including Peru, Chile, and Indonesia. Most trawlers targeting *L. gahi* also participate in other fisheries including rock cod, hoki, hake, and red cod. All companies collaborate within the Falkland Islands Fishing Companies Association (FIFCA), which represents fishery industry interests (Arkhipkin et al., 2013). While catches fluctuate, the fishery lands an average of 51,000 tonnes (Arkhipkin et al., 2013). *L. gahi* is a major contributor to the government’s GDP (fishing on a whole contributes about a third). Fishing rights were a major factor to national claim in the early 1980s and remain central to the identity and life of the islands. The *L. gahi* market consists predominantly of European (primarily Spanish), South African, and Indian markets (Observatory of Economic Complexity, 2015a).
**New Zealand**

While a variety of squid are found in New Zealand waters, the most significant squid fishery is the arrow squid fishery. The New Zealand arrow squid fishery is made up of two similar species that are managed as one: *Nototodarus gouldi* (Gould’s Flying Squid) and *Nototodarus sloanii* (Wellington Flying Squid). The New Zealand Ministry of Primary Industries (MPI), specifically the MPI Deepwater Fisheries management team, manages the fishery. Arrow squid management includes a total allowable commercial catch (TACC) limit, quota allocated according to the TACC, commercial licenses, spatial restrictions (based on fishery management areas and protected areas), a fisheries-related mortality limit (in relation to sea lions), and technology requirements for large trawlers (e.g. seabird scaring devices).

The fishery began in the 1960s with Japanese jigging vessels (McKinnon, 2006). Substantial regulations emerged with the implementation of the Quota Management System (QMS) in 1986; squid were included in the system in 1987. The QMS awards allocations as a percentage of that year’s TACC, proportional to amount of quota owned. The squid fishery is divided into four separately managed fisheries, distinguished by fishing management areas (FMA): SQU1J and SQU1T are the jig (J) and trawl (T) fisheries found within most of the mainland exclusive economic zone (EEZ), SQU6T is the subantarctic trawl fishery near the Auckland islands, and SQU10T is the Kermadec Islands trawl fishery, although this area has been inactive since its inception. A separate TACC is allocated to each FMA. The Southern Islands area, SQU6T, is the focus of management and monitoring. The total squid TACC has not changed since the 1996-1997 season and is currently set at 127,322 tonnes (Ministry of Primary Industries, 2016a).
Arrow squid is one component of the Deepwater Fleet’s portfolio and is grouped with a number of other species (e.g., hoki, hake, warehou, jack mackerel, orange roughy) for both broader management and industry purposes.

The largest squid included in this study, both species have a maximum mantle length of 42 centimeters (Smith, Mattlin, Roeleveld, & Okutanp, 1987). Both Notototodarus species in New Zealand have a one-year life span and are thought to migrate to shallower water to spawn, though spawning areas are still unknown, a major gap impeding management choices. Both species are found over the continental shelf up to 500 meters depth, and are most frequently found in waters shallower than 300 meters. While the two species distributions overlap, *N. gouldi* is found primarily in Northern New Zealand waters, and *N. sloanii* is mostly found most often in Southern waters, particularly off the Snares and Auckland Islands (Smith et al., 1987).

The fishery is dominated by 12-15 trawling vessels, with a mean length of 43.6 meters and a mean tonnage of 793 tonnes, though a number (roughly 60-70) of smaller vessels do participate as well (Clement, Wells, & Gallagher, 2008). There is a very small recreational fishery, a small commercial jigging fishery, and no indigenous fishery, though New Zealand tribes are heavily involved with the New Zealand companies that involve squid. All vessels are flagged as New Zealand, and all quota is owned by New Zealanders, but some vessels are Joint Ventures which charter vessels from other countries, most notably from South Korea and Ukraine. New Zealand arrow squid is primarily exported, with major markets including China, Greece, Korea, United States, Taiwan, Spain, Italy, and Croatia (Observatory of Economic Complexity, 2015b).
Before the current management system landings peaked at 214,072 tonnes in 1983-84, and in the time since the system was implemented, landings have varied with an average of 53,000 tonnes, well below the TACC (McKinnon, 2006; Ministry of Primary Industries 2016a). According to study participants, the TACC has not been reached because of the sea lion fisheries-related mortality limit. The Deepwater Group (DWG), an industry non-profit, ensures squid vessels adhere to a number of non-legally binding mandates, many of which are stricter than MPI requirements.

The most important aspect of the New Zealand arrow squid fishery is its relation to the endangered and endemic New Zealand sea lion (rāpoka) *Phocarctos hookeri*, the rarest sea lion in the world. While MPI does not require Sea Lion Excluder Devices (SLEDs), DWG ensures all trawlers use SLEDs and organizes the monitoring and tracking of such devices and their effectiveness. MPI distributes discounts on the predetermined sea lion strike rate to SLED users. Many New Zealand conservation organizations aim to protect the New Zealand sea lion, of which the squid fishery is responsible for the most sea lion-fishery related deaths.

**California**

The California market squid (*Loligo opalescens*) fishery began in the 1860s in Monterey Bay as a primarily Chinese dry-squid fishery. Today market squid is one of the highest valued fisheries in California. California market squid was an open-access fishery before 1998, when Senate Bill (SB) 364 became effective, establishing a moratorium on new squid vessels.
The California Department of Fish and Wildlife (CDFW) Market Squid Fishery Management Plan (MSFMP) is the primary mechanism for squid management. Development of the plan took into consideration the Pacific Fishery Management Council’s Coastal Pelagic Species Fisheries Management Plan, which includes market squid as a monitored species. The Council considers market squid an actively managed species only in the circumstance where the egg escapement is measured to be below a 30 percent threshold for two consecutive years (Pacific Fishery Management Council, 2016). The state is the primary management body, since market squid is found predominately in state waters, but the Council also monitors squid because the natural population extends beyond state boundaries and is targeted both south and north of California’s waters. California market squid is managed according to a seasonal catch limitation (118,000 short tons (107,048 tonnes)), temporal restrictions (weekend closures), technological requirements (light wattage), effort limitation (capacity goal and permits), and spatial restrictions (area closures, Gulf of Farallones Sanctuary, state marine protected areas).

*L. opalescens* (more recently referred to as *Doryteuthis opalescens*) is a single population found from Baja California, Mexico (23° N latitude) to southeastern Alaska (55° N latitude). A small squid with an average mantle length of 152 millimeters, *L. opalescens* continually spawns throughout the year, with a new cohort added almost monthly. Market squid live about 6-9 months, dying after they spawn nearshore. While a small recreational bait fishery and a small commercial brail fishery exist, the overall fishery is dominated by American roundhaul vessels that work alongside smaller light boats. Roundhaul vessels are an average of 18.9 meters long with an average capacity of 81 gross tonnage, and use nets averaging 381 meters long and 48 meters deep (State of
California Resources Agency, 2005). Lightboats are an average of 11.8 meters long with a gross tonnage of 19 tons and their lights average 22,500 watts (below the 30,000 watts legal maximum) (Pomeroy & FitzSimmons, 2001). Recently, CDFW issued 75 vessel permits, 34 light boat permits, and 44 brail (netted scoop) permits, though the fishery is dominated by mostly 43 round haul vessels (Pacific Fishery Management Council, 2014).

Most vessels also target other coastal pelagic species including sardine, anchovy, and pacific mackerel. The squid fishing season runs from April 1st to March 31st, though is most active between May and September. *L. opalescens* is exported worldwide (it has been sent to 106 countries since the 1970s) but is primarily exported to China and, to a lesser extent, sent to Japan, Spain, the Philippines, and Vietnam (National Marine Fisheries Service, 2016). Since the management system was initiated, commercial landings have averaged 90,000 short tons (81,600 tonnes), and have exceeded the catch limit twice (2010 and 2011 seasons). Since then, a new daily tracking program has decreased the risk of exceeding the catch limit in future seasons. The California Wetfish Producers Association communicates industry interests to management and the public.

The California market squid fishery is sensitive to environmental conditions, particularly El Niño Southern Oscillation (ENSO) events; it becomes virtually inaccessible during El Niño events, while La Niña events often relate to population surges.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Variable Type</th>
<th>SESMAD Question</th>
<th>Coding Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commons Condition Trend</td>
<td>Ordinal</td>
<td>Based on your answers to the Beginning Condition and End Condition variables, would you say that the condition of this commons has improved, remained the same, or worsened during this time period?</td>
<td>1 Worsened, 2 Remained the same, 3 Improved</td>
</tr>
<tr>
<td>Basin Switch</td>
<td>Categorical</td>
<td>Does this natural resource show evidence of switching stable states during this time period? If not, is the current stable state considered to be in a desirable / undesirable state? If yes, is the new stable state considered to be desirable / undesirable?</td>
<td>Yes desirable, Yes undesirable, No desirable, No undesirable, Unclear - system may be transitioning</td>
</tr>
<tr>
<td>User Group Well-Being Change</td>
<td>Ordinal</td>
<td>How has the well-being of this commons user group changed during the time period identified in this interaction?</td>
<td>1 Worsened, 2 Remained the same, 3 Improved</td>
</tr>
<tr>
<td>Compliance</td>
<td>Ordinal</td>
<td>Do members of this actor group follow the rules of this governance system with respect to the emission or appropriation of this commons?</td>
<td>1 No, 2 Somewhat, 3 Yes</td>
</tr>
</tbody>
</table>
Table A.3.2: Characteristics of SESMAD Variables Contributing to Design Principles
Information from SESMAD, 2014

<table>
<thead>
<tr>
<th>Design Principle</th>
<th>SESMAD Variable</th>
<th>Variable Type</th>
<th>SESMAD Question</th>
<th>Coding Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clearly defined community boundaries</td>
<td>1.1a Actor group boundary clarity</td>
<td>Categorical</td>
<td>Are there clear rules that are followed about who and who isn't a member of this group?</td>
<td>No boundaries, Unclear boundaries, Clear boundaries</td>
</tr>
<tr>
<td></td>
<td>1.1b Commons boundary negotiability</td>
<td>Ordinal</td>
<td>How negotiable is access by non-members of this actor group to this environmental commons?</td>
<td>1 Rigid, 2 Moderate, 3 Negotiable</td>
</tr>
<tr>
<td></td>
<td>1.1c Actor group boundary fuzziness</td>
<td>Categorical</td>
<td>Is membership in this actor group subject to ongoing negotiations (fuzzy boundaries)? Or are the boundaries the group more rigid?</td>
<td>Fuzzy, Rigid</td>
</tr>
<tr>
<td></td>
<td>1.1d Outsider exclusion</td>
<td>Ordinal</td>
<td>To what extent are members of this commons user group able to exclude non-members (outsiders) from using this commons?</td>
<td>1 No exclusion, 2 Some exclusion, 3 Total exclusion</td>
</tr>
<tr>
<td>Clearly defined resource boundaries</td>
<td>1.2 Commons boundaries</td>
<td>Ordinal</td>
<td>Are the boundaries that define the spatial extent of this commons clearly defined and highly visible?</td>
<td>1 Very unclear boundaries, 2 Somewhat unclear boundaries, 3 Clear boundaries</td>
</tr>
</tbody>
</table>
### Appropriation and provision rules conform to local conditions

| 2.1 Social-ecological fit | Ordinal | To what extent (low, medium, or high) do the institutional arrangements of this governance system fit well with the ecological or physical features of the commons on which they are implemented? | 1 Low, 2 Medium, 3 High |

### Congruence between appropriation and provision rules

| 2.2 Proportionality of costs and benefits (fishers) | Binary | Is there general proportionality between the amount of costs group members incur and the amount of benefits received? | Yes, No |

### Collective-choice arrangements

| 3a Participation in rule making | Ordinal | How high is the level of participation of this actor group in the process that determines how this environmental commons is governed? | 1 Low, 2 Medium, 3 High |

| 3b Commons political power (fishers) | Ordinal | How much power does this actor group have in the process that determines the governance of this commons? | 1 Low, 2 Medium, 3 High |

<p>| 3c Collective action | Ordinal | What is the current level of collective action within the members of this actor group with respect to the use or management of this commons? | 1 Low, 2 Medium, 3 High |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Monitoring</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4a Self monitoring</td>
<td>Binary</td>
<td>Does this actor group monitor its own activities with respect to the use of this commons?</td>
<td>Yes, No</td>
</tr>
<tr>
<td>4b Environmental monitoring</td>
<td>Ordinal</td>
<td>How much environmental monitoring of this commons does this actor group engage in?</td>
<td>1 Low, 2 Moderate, 3 High</td>
</tr>
<tr>
<td>4c Participation in environmental monitoring</td>
<td>Ordinal</td>
<td>How high is the level of participation of this actor group or their representatives in environmental monitoring?</td>
<td>1 Low, 2 Medium, 3 High</td>
</tr>
<tr>
<td>4d External monitoring</td>
<td>Binary</td>
<td>Do external actors/organizations monitor the activities of this commons using actor group with respect to the use of this commons?</td>
<td>Yes, No</td>
</tr>
<tr>
<td><strong>Graduated sanctions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5a Self sanctions</td>
<td>Categorical</td>
<td>Are sanctions applied by and to the members of this group for violations of rules regarding extraction or emission? And if so, are these sanctions graduated (increasing with severity and repetition of offenses)?</td>
<td>Graduated sanctions, Non-graduated sanctions, No sanctions</td>
</tr>
<tr>
<td></td>
<td>Type</td>
<td>Description</td>
<td>Yes, No</td>
</tr>
<tr>
<td>------------------</td>
<td>------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>5b External sanctions</td>
<td>Binary</td>
<td>Are sanctions applied by other actor groups to the members of this group for violations of rules regarding extraction or emission? And if so, are these sanctions graduated (increasing with severity and repetition of offenses)?</td>
<td>Yes, No</td>
</tr>
<tr>
<td>5c Participation in social monitoring</td>
<td>Ordinal</td>
<td>How high is the level of participation of this commons user group or their representatives in social monitoring (enforcement)?</td>
<td>1 Low, 2 Medium, 3 High</td>
</tr>
<tr>
<td>Conflict resolution mechanism</td>
<td>6 Conflict resolution</td>
<td>Are mechanisms in place to address conflicts that arise over the use of this commons by this actor group?</td>
<td>Yes, No</td>
</tr>
<tr>
<td>Minimal recognition of rights to organize</td>
<td>7 External recognition</td>
<td>Within this governance system, do larger governmental jurisdictions (i.e. international agreements, nation states) recognize the autonomy of lower-level jurisdictions (states, regions, communities), and their right to make decisions regarding this commons?</td>
<td>1 Low - no recognition, 2 Moderate - some recognition, 3 High - complete recognition</td>
</tr>
<tr>
<td>Nested enterprises</td>
<td>8 Multiple levels</td>
<td>Categorical</td>
<td>Does this governance system contain multiple levels, with each level having a set of actors who conduct tasks with respect to the management of this commons? If so, is there active coordination across these levels, or not?</td>
</tr>
</tbody>
</table>


### Table A.3.3: Characteristics of Key SESMAD Variables Contributing to Study Outcomes

Information from SESMAD, 2014

<table>
<thead>
<tr>
<th>SESMAD Variable</th>
<th>Variable Type</th>
<th>SESMAD Question</th>
<th>Coding Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic Dependence</td>
<td>Ordinal</td>
<td>How dependent are the members of the group on this commons for their economic well-being?</td>
<td>1 Not dependent or Slightly dependent, 2 Moderately dependent, 3 Very dependent</td>
</tr>
<tr>
<td>Science-Based Policy</td>
<td>Ordinal</td>
<td>Is/are the policy/ies regarding this commons use and/or management set in accordance with the current scientific consensus?</td>
<td>1 No, 2 Somewhat, 3 Yes</td>
</tr>
<tr>
<td>Leakage (of Benefits/Costs; e.g., Fringe Benefits)</td>
<td>Categorical</td>
<td>Has the governance of this commons led to the leakage of costs or benefits onto other systems? For costs, has the governance of this commons increased extraction/pollution pressures?</td>
<td>Yes, leakage of benefits, Yes, leakage of costs, No leakage</td>
</tr>
<tr>
<td>Flexible Rights</td>
<td>Binary</td>
<td>Does the relevant governance system allow for changing rights and restrictions applied to this actor group in accordance with environmental shifts and new scientific knowledge?</td>
<td>Yes, No</td>
</tr>
</tbody>
</table>
Appendices Works Cited


Bean, R., & Han, A. (2011). Live crab and lobster exports boom *USDA Foreign Agricultural Service Global Agricultural Information Network (GAIN) Report* (pp. 5). Beijing, China: USDA.


