Assessing sustainability in lobster fisheries as social-ecological systems: A framework and research protocol

Stefan Partelow

Master Thesis Series in Environmental Studies and Sustainability Science,
No 2014:021

A thesis submitted in partial fulfillment of the requirements of Lund University International Master's Programme in Environmental Studies and Sustainability Science (30hp/credits)

LUCSUS
Lund University Centre for Sustainability Studies

LUND UNIVERSITY

Assessing sustainability in lobster fisheries as social-ecological systems: A framework and research protocol

Stefan Partelow

sbpartelow@gmail.com

A thesis submitted in partial fulfillment of the requirements of Lund University International Master's Program in Environmental Studies and Sustainability Science

Submitted May 15, 2014

Supervisor: Chad Boda, LUCSUS, Lund University

(This page is intentionally left blank)

Abstract

Global marine ecosystems are increasingly understood as complex social-ecological systems (SESs), and indicate that anthropogenic impacts are a main driver of global environmental change. Fisheries exemplify this, as well as demonstrate that the human use of marine resources increasingly stresses marine ecosystems and presents social-institutional challenges for managing fisheries sustainably. The purpose of this study is to contribute to the knowledge of lobster fisheries as complex social-ecological systems in aims towards better understanding sustainable governance policies and management mechanisms that associate with sustainable outcomes. However, contributions of this paper go beyond lobster fisheries, framing the discussion and approaches for how to use the Ostrom (2009) social-ecological system framework empirically while implementing research that analyzes complex social-ecological systems. In addition, this study enhances the capacity for solution-oriented research through facilitating a better understanding of institutional processes and how to operationalize research into management. An updated social-ecological system classification framework was developed for lobster fisheries through a systematic literature review, and implemented on the Southern California Spiny Lobster fishery to demonstrate its application. Interactions between the framework components facilitate the means for sustainable outcomes, and are often very complex and multivariate. Understanding these interactions is essential for management aimed at achieving sustainable outcomes. The Institutional Analysis and Development (IAD) framework is used to analyze the Lobster Advisory Committee (LAC), the stakeholder comprised management group of the Southern California Spiny Lobster fishery (SCSLF), as an action situation of interacting system components. Evaluative criteria associated with sustainable outcomes are discussed and used to identify five notable SES characteristics in the fishery indicative of sustainable outcomes. In a reflective response to existing literature, expert interviews and the methods undertaken in this study, a heuristic conceptual model is presented for how to implement the Ostrom (2009) SES framework aimed at operationalizing research into management. In further conclusion, four key recommendations for further SES research in lobster fisheries and related natural resource systems are presented.

Acknowledgements

I would first like to thank my wonderful and supportive family both here in Sweden and back in the US. I would not have made it to where I am today without them and their ability to encourage me to follow my passions and varying endeavors. A special thanks to Olga and Chris for the countless academic and home-economic discussions as well as the great times along the way. Thanks to my supervisor Chad Boda for the guidance and motivation, this thesis has improved substantially due to his inputs. Thank you to those who contributed significantly to this project through interviews, and the LAC representatives for participating in the survey. Additionally, thanks to the LUMES staff and all of my friends in the program for an awesome two years of fun, learning and inspiration!

(This page is intentionally left blank)

Table of Contents

Acronyms and Abbreviations

LAC	Lobster Advisory Committee
SES	Social-Ecological System
SCSLF	Southern California Spiny Lobster Fishery
IAD	Institutional Analysis and Development (framework)
MPA	Marine Protected Area
LEK	Local Ecological Knowledge
TEK	Traditional Ecological Knowledge
SMK	Western Science & Management Knowledge
CADFW	California Department of Fish & Wildlife
FMP	Fishery Management Plan
MSC	Marine Stewardship Council

Word Count: 12,379

(This page is intentionally left blank)

1 Introduction

1.1 Introduction

Global marine ecosystems increasingly demonstrate the impacts showing that human integration into natural environment systems is a core driver of global environmental change (Halpern et al., 2008; Worm et al., 2006). Fisheries exemplify how the use of marine resources can cause significant change to system drivers that threaten marine ecosystems globally (Berkes et al., 2006). Ongoing changes to marine ecosystems that effect the sustainability of fisheries impact the livelihoods (Checkley et al., 2013; Kittinger et al., 2013), cultural identities (Ernst et al., 2010; van Putten, Lalancette, et al., 2013), and the economic stability (Gourguet et al., 2013; Martinet, Thébaud, & Doyen, 2007) of those individuals and communities integrated into the resource system. In turn, all humanly used natural resource systems are embedded in complex social-ecological systems (Ostrom, 2007, 2009). An understanding of these complex system components and their interactions has vital implications for system management approaches that aim towards achieving sustainable outcomes (Agrawal, 2001, 2003; Lange, Driessen, Sauer, Bornemann, & Burger, 2013). Assessments of SES's conducted to support sustainable system management, such as a fishery, need to consider multiple dimensions (Basurto, Gelcich, & Ostrom, 2013; Ernst et al., 2013a). Although many studies research human-nature interactions, the complexity of coupled social-ecological systems is not well understood (Liu et al., 2007; Ostrom, 2007).

While research aimed at identifying SES components in fisheries has been undertaken (Basurto et al., 2013; Ernst et al., 2013a; Hearn, 2008), there has been far less attention aimed at understanding management configurations and social-institutional interactions that effect the sustainability of outcomes (Basurto & Coleman, 2010; Basurto et al., 2013; Kittinger et al., 2013). Policies and management of social-ecological systems has historically taken a simplistic, blue-print approach implementing universal solutions, panaceas, that have been largely unsuccessful in attaining sustainable outcomes (Ostrom, 2007). To create contextually based

solution options, solid foundations in sustainability science are required that aim at undertaking well documented and sound research on complex interlinked social-ecological systems (Clark & Dickson, 2003; Ostrom, 2007). This is particularly evident with marine resources as they are immensely complex and integrated with human activities (Berkes et al., 2006).

Worldwide, lobster fisheries present resource systems that are largely common-pool in nature (Ostrom, 2007), relatively well researched, and are globally distributed in locations with very different historical (Davis & Wagner, 2006; Ernst et al., 2013a) and social-institutional settings (Basurto & Coleman, 2010; Brewer, 2012a). Lobster fisheries are the focal point within this study for a few distinctive reasons, although the methodological contributions of this study, which were a main driver for conducting this research, are not limited to a particular social-ecological system. With these settings being different in how each fishery approaches utilizing and managing the resource, it makes the study of fisheries very unique when researching the complex and dynamic components that have interacted to create the current state of the fishery. Although lobster fisheries exhibit these characteristics, distinctive contextual settings support case-specific diagnostic research approaches relevant to all complex social-ecological systems.

Therefore, a core purpose of this study is to contribute to the knowledge of lobster fisheries as complex social-ecological systems in aims towards aiding sustainable governance policies and management mechanisms. However, while contributions to lobster fisheries through is study may be inherent, the methodological approach used with a theoretical backing in sustainability science, contributes and demonstrates how to approach research in social-ecological systems in aims to assess and ultimately understand the mechanisms and feedbacks leading to sustainable outcomes. Additionally, the methods for contextually gaining SES knowledge to provide solution oriented system interaction analyses for assessing outcomes, lay the foundations for a research protocol that can guide research aimed at utilizing SES framework for practical management. This study, demonstrating these methods, contributes the first summarized review of lobster fishery characteristics and the SES research on those fisheries as well as an updated SES framework for classifying a lobster fishery as a SES. Further more, a contextual SES component

interaction analysis and sustainability outcome assessment of the Southern California Spiny Lobster fishery (SCSLF) is conducted. Finally, the foundations for operationalizing these methods into practical management are presented in a heuristic conceptual model that can guide research within SESs.

1.2 Research foundations & conceptual framework

1.2.1 Foundations in sustainability science

Scholarship in sustainability science has been linked, referenced and or defined as research in social-ecological systems (Agrawal & Chhatre, 2011; Folke, Hahn, Olsson, & Norberg, 2005; Lange et al., 2013; Perrings, 2007). Sustainability science aims to influence a transition towards sustainability by understanding a system in its entirety through engaging in problem-driven, action oriented research that embraces a transdisciplinary methodological approach (Jerneck et al., 2010; Kerkhoff, 2013; Perrings, 2007). Conducting research in social-ecological systems is therefore vital for further principle development of inter-disciplinary approaches and collaborations aimed at achieving sustainable outcomes. Using a SES framework to achieve sustainable outcomes incorporates multiple epistemological and theoretical viewpoints, often transdisciplinary and focused on research collaborations with non-academic stakeholders (Lang et al., 2012), based in sustainability science. Unique within academia, sustainability science depends on conducting empirical research that combines theory and practice while also embracing sound epistemological foundations with a richer research agenda and quality criteria (Wiek, Ness, Schweizer-Ries, Brand, & Farioli, 2012). This is particularly relevant when integrated into SES research (Miller et al., 2008).

1.2.2 Inheriting a SES research agenda

In aims to develop sound research in complex SESs and move beyond governance panaceas, Ostrom & Cox (2010) and Ostrom (2007, 2009) proposed diagnostic approaches for assessing the inter-linkages and governance of social-ecological systems through the classificatory social-ecological system (SES) framework, in part derived from the Institutional Analysis and Development (IAD) framework. The SES framework encompasses multi-tiered sub-systems or

variables that allow for the theoretical identification of as many of the interacting aspects as possible within a SES, displayed in *Figure 1*. Identifying these sub-systems, or system components, is the first step towards understanding how they interact and what outcomes may occur. The initial and generalized first and second tier variables are shown in *Figure 2*. While the framework allows for the best possibility of identifying all of the context specific components in a given SES, all sub-systems or variables in the framework may not be relevant to context specific systems. Additional and or more specifically defined components will need to be included, and their interactions within the framework considered.

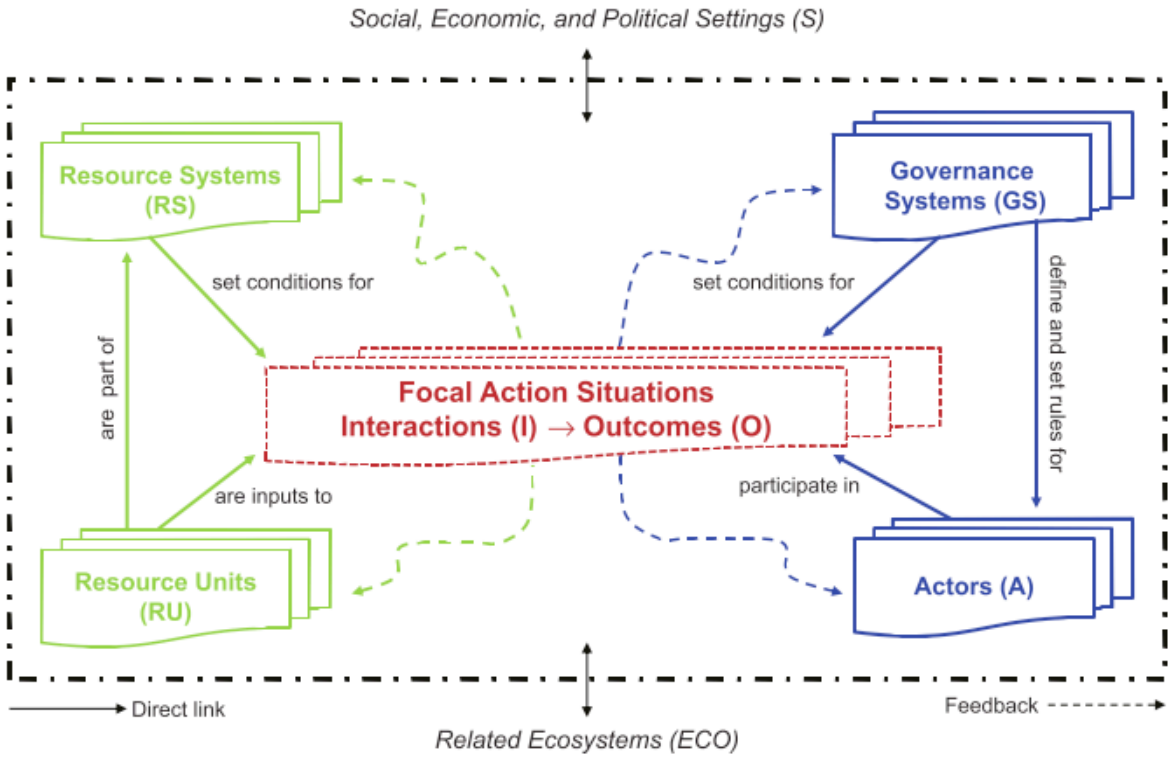


Figure 1. A Social-Ecological System (SES) framework with first-tier variables, including interactions and outcomes through 'action situations'. Second-tier variables, shown in *Figure 2*, fall under first-tier groups and can be expanded further to contextualize a specific SES. Adopted from (Ostrom, 2011).

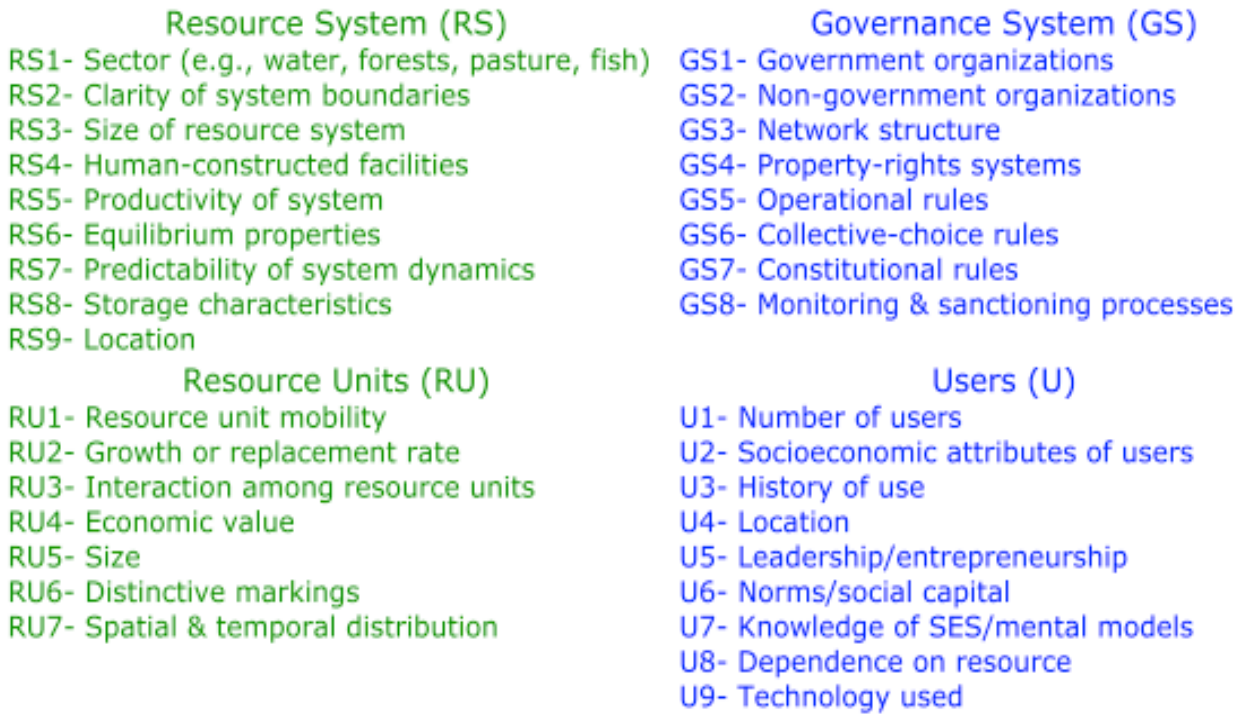


Figure 2. First and second-tier sub-system classification components of the Ostrom (2009) social-ecological system framework. These tiers are later expanded and contextualized for the classification of lobster fisheries as social-ecological systems in this study.

Adopting the Ostrom (2009) social-ecological system framework carries along a certain epistemological approach as well as an inherent ontological application. The ontological backing of the SES framework, that the complexity of integrated human-nature systems can be better understood through diagnostic and classificatory methods, implies that a systematic understanding of a SES can provide a platform for further knowledge accumulation towards certain typologies, such as governance arrangements (Basurto et al., 2013). Approaching epistemology as, the type of knowledge developed and how it is generated (Wiek et al., 2012), it is difficult to embrace a single epistemological approach within transdisciplinary research on social-ecological systems. While framework classification may indicate a rather systematic approach towards seeing and understanding a system, SES's are increasingly perceived and identified as complex and adaptive (Folke et al., 2005; Levin et al., 2012; Österblom & Folke, 2013), with the knowledge development of them often contingent or even narrative (Miller et al., 2008). Epistemological pluralism is more suitable to SES research as it contributes to the

acknowledgement of multiple ways of knowing and the cooperation of these knowledge modes across disciplines, as well as integrating results to achieve a more in-depth understanding of a system (Miller et al., 2008).

1.2.3 Epistemological approaches in SES's: A fisheries example

Conducting multi-method and collaborative approaches within this research generates multi-disciplinary epistemological knowledge that can be expressed as epistemological pluralism, or multiple viewpoints traditionally associated with singular disciplines. The epistemological approach of this research is part 'mechanistic' and part 'adaptive-narrative' (Miller et al., 2008; Zellmer, Allen, & Kesseboehmer, 2006) and can even be interpreted through multiple and varying metaphors (Raymond et al., 2013). It is different when updating framework components and applying the framework empirically, than it is when understanding interactions and outcomes. This is best understood with an example. If a 'fishing season' exists as part of the fishery, simple identification of this component within the fishery SES can be identified with the framework through a hierarchical and rather mechanistic structure. All of the aggregated and ordered components of this mechanistically structured framework combine to classify the fishery as complex SES. The interactions of the 'fishing season' with other components in the SES are based on our adaptive perceptions that seek contextual causality of how the system functions and how we should interact with it accordingly. How a fisherman interacts with the 'fishing season' is inherent to his values, and interpreted through a narrative or metaphor. As demonstrated through this example, a singular epistemological viewpoint is not sufficient for holistically analyzing a complex SES in fisheries, as a system cannot be fully understood or contextualized through a singular perspective.

1.2.4 The Institutional Analysis & Development (IAD) framework

The IAD framework, shown in *Figure 3,* is best thought of as a meta-theoretical conceptual map that identifies an action situation, patterns of interactions, outcomes and an evaluation of these outcomes (Ostrom & Cox, 2010). Framing an action situation and patterns of interactions in a complex SES depends on defining such a situation contextually, and similar to a geographical

map, the framework can be defined at very fine or broad scales (Ostrom, 2005). The IAD framework has a theoretical foundation in game theory, where the idea of rules within an action situation or 'game' effect the possibility of certain outcomes, although action situations cannot be analyzed as simply as formal games (Ostrom, 2005, 2011). An action situation is defined by seven criteria aimed at assessing the interactions between variables associated with it (McGinnis, 2011; Ostrom & Cox, 2010). These criteria are: (1) the set of actors, (2) the sets of positions actors fill in the context of this situation, (3) the set of allowable actions for actors in each position, (4) the level of control that an individual or group has over an action, (5) the potential outcomes associated with each possible combination of actions, (6) the amount of information available to actors, and (7) the costs and benefits associated with each possible action and outcome. While the IAD framework was initially developed to diagnostically facilitate the institutional analysis of natural resource management, it has evolved into and is often coupled with the more integrated and complex SES framework (Ostrom & Cox, 2010). As an action situation is defined by these seven criteria, the interactions and eventual outcomes in the action situation can be assessed through additional evaluative criteria. The evaluative criteria used in this study directly relate to sustainability, including equity, participation and democratic governance, adaption and precaution, and social-ecological system knowledge.

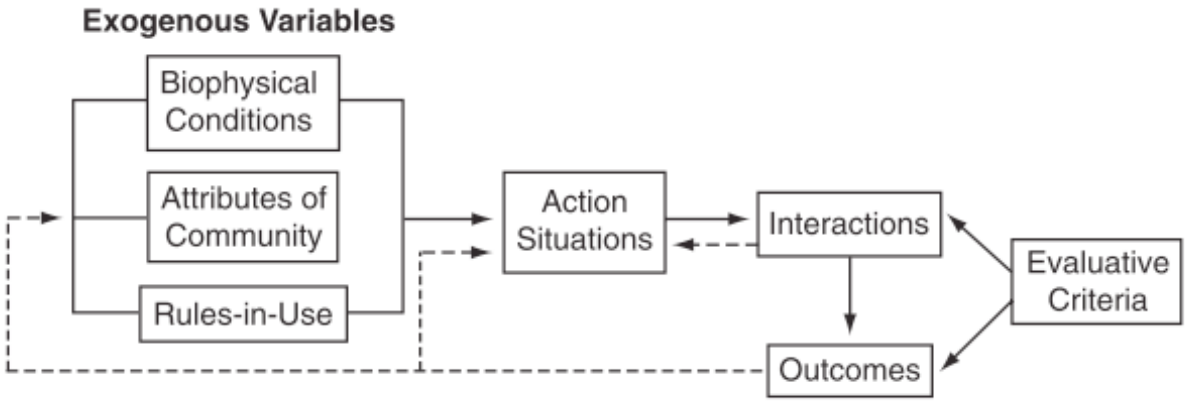


Figure 3. The Institutional Analysis & Development (IAD) framework, adopted from (Ostrom & Cox, 2010). Exogenous, or external, variables grouped on the left side while the interactions and outcomes derived from the action situation are assessed with evaluative criteria on the right side. An action situation is the focal point of the framework. Sustainability criteria are used for interaction and outcome analyses in this study.

1.2.5 Related theoretical and conceptual approaches

Social-ecological systems can be additionally understood and assessed using resilience theory and the ecosystem services concept. In this study, sustainability principles such as equity, democratic participation, adaption and system knowledge, and the Institutional Analysis and Development (IAD) framework are applied to assess interactions and outcomes associated with sustainability. However there are numerous ways of approaching this in research. One theoretical approach, resilience theory, and one conceptual approach and framework, ecosystem services, are particularly relevant and often integrated and mentioned in research on social-ecological systems. Resilience theory builds on the ideal of the ability of systems to absorb and adapt to reoccurring natural and human disturbances and continue to regenerate and not transform into an undesirable state (Folke et al., 2005). The ecosystem services concept frames natural resource systems into ecological structures, their functions, and eventual provided services resulting in contextually attained human benefits (Abson & Termansen, 2011). The ecosystem service concept aims to identify these benefits to better understand how to value and therefore manage ecological aspects in a resource system (Haines-Young & Potschin, 2010). These approaches are useful in providing diverse perspectives to assess interactions and outcomes in social-ecological systems. Addressing these approaches provides perspective to this study's methodological approach and recognizes the validity of multiple and diverse arrays of studying social-ecological systems. Exploring the presence of these approaches was conducted in the literature review on lobster fishery SES research and is further discussed. These approaches were not used as primary analysis and assessment approaches in this study, although they associate and often directly relate to research in SES's, due to preferences for the clarity of the SES classificatory framework to tangibly relate to social-institutional system components and to maintain action-oriented research foundations.

1.3 The Southern California Spiny Lobster Fishery

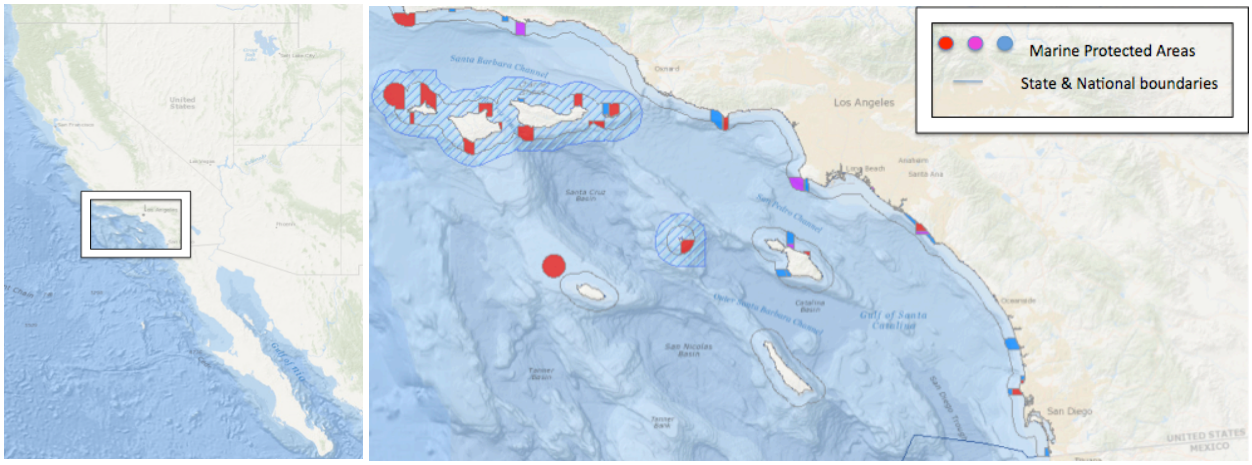


Figure 4. The image to the left displays the west coast of the United States and Mexico, highlighting the expanded SCSLF area in the right image. To the right, the boundaries of the SCSLF are in full view, with indicated Marine Protected Areas with the California state water boundaries. These boundaries include national marine park areas around the various Channel Islands (CADFW, 2014).

The Southern California Spiny Lobster is fished between Point Conception, California (northern boundary) and the US-Mexican border (southern boundary), see *Figure 4*. While the natural habitat of the Spiny Lobster (*Panulirus interruptus*) does not exist north of Point Conception, their habitat extends far beyond the US-Mexican border to Bahia Magdalena, Baja California, Mexico. Spiny lobster, pictured in *Figure 5*, are commonly found in rocky inter-tidal areas down to depths exceeding 73 meters. Spiny lobster reach sexual maturity between 3 and 9 years old, and spawning occurs yearly thereafter, usually spawning 2 to 3 times before they reach legal harvest size (Neilson & Barsky, 2011). Spiny lobster do not have claws, but rather a spiny body and large tail for protection and mobility respectively. Situated within the fishery boundaries is Los Angeles County, the county with the largest total number coastal population growth between 1970 and 2010 in the United States (NOAA, 2013). In addition, the population in coastal areas contributes to 81% of California's jobs and 86% of its economic output (Raheem et al., 2012). Considering the interactive complexity of SESs, these socio-economic factors support the need to assess the drivers of change within the SCSLF.

Figure 5. (1) Coastal view of Southern California from the water, to the left of the point is open to fishing and to the right is a newly established Marine Protected Area in southern coastal Los Angeles. (2) View of Pacific Ocean and fishery habitat from Palos Verdes, CA. (3) A SCUBA diver entering the water to conduct habitat restoration in the MPA near photo 1, from the Los Angeles Waterkeeper NGO boat. (4) A Spiny lobster in its natural habitat in the waters shown in photo 2. – All photos provided by the author--.

The Southern California Spiny Lobster fishery provides a complex social-institutional dynamic and a unique stakeholder management approach to collectively manage the fishery with the Lobster Advisory Committee (LAC). The Marine Life Management Act was passed in 1999, mandating that all marine fisheries in California prioritize the conservation, restoration and sustainable use of marine resources through the adoption of sustainable Fishery Management Plans (FMPs) for each fishery (California Department of Fish & Wildlife, 2001). All of the FMPs must include all of the relevant stakeholders to the fishery and be founded on good science. The

California Spiny Lobster was listed fifth in priority of 109 fisheries in California to develop a sustainable FMP for the fishery (ibid). This was largely due to the fact that lobsters are assumed to be long-lived and one of the most exploited fisheries in California (California Department of Fish & Wildlife, 2001; Neilson & Barsky, 2011). Simultaneously, landmark legislation was passed in California to create a statewide network of Marine Protected Areas (MPAs) to protect marine ecosystems and marine life populations. Each section of the state was responsible for designing and implementing them through a stakeholder engagement process. While the implementation of the MPA network was eventually effective in the Southern California section, the organizational process of incorporating diverse and conflicting stakeholder interests, science advisors, and government oversight was seen as 'poorly balanced' and collaborative efforts were experienced as 'very low' in a post-process survey (Fox et al., 2013). Largely in response to the reflections on the MPA process, the Lobster Advisory Committee (LAC) was formed (*Figure 7)*, by the California Department of Fish and Wildlife (CADFW) in 2012, to form a fishery management plan to manage the SCSLF. The LAC would consist of primarily the same stakeholders engaged in the MPA process, and aimed to provide a more fairly balanced, facilitated and collaborative stakeholder management process.

Figure 6. (1) A LAC stakeholder meeting, brainstorming ideas to create a sustainable fishery management plan led by the lead facilitator. (2) Recreational lobster divers displaying their catch. Spiny lobsters are nocturnal, coming out of their rock crevices and scavenging for food at night. This makes night diving popular among recreational divers, as they are easier to catch by hand then (the only legal recreational diving harvest method). (3) SCUBA diving gear on a commercially operated recreational diving boat. –All photos provided by the author--.

To further support contextual relevance and give perspective to the fishery studied in this research, I lived within the boundaries and had coastal access to the Southern California Spiny Lobster fishery for over twelve years. I have actively recreationally fished, non-consumptively enjoyed the ecosystem, conducted coastal intertidal habitat research and restoration, and been SCUBA diving over 120 times within the fishery's boundaries. This has provided me with irreplaceable contextual knowledge and familiarity with the resource system, including who the stakeholders are and how they interact with the system. In addition, I was an alternate representative for the non-consumptive recreational stakeholders on the advisory committee selected to develop a sustainable management plan for the fishery, pictured in *Figure 6* at an

LAC meeting. This position required gaining the knowledge of all stakeholder view points, a concrete ecological understanding of the fishery's ecosystem, and a working understanding of the governance mechanisms for implementing such policy. Along with extensive personal engagement, these experiences provided a comprehensive foundation to the research as well as a strong personal integration and motivation for supporting sound science-based contributions with this study.

2 Methods

2.1 Methods Overview

The multiple methods used in this study were chosen for their ability to provide the context specific quantitative and qualitative data necessary to ensure viable analytical use of the SES and IAD frameworks. The methodological approaches used are summarized in the following six steps, and elaborated on in further detail below:

1) A systematic literature review was conducted of an initial 140 peer-reviewed publications researching and/ or discussing various aspects of social-ecological systems in lobster fisheries. This was refined to 19 focal publications through systematic review and exclusion. This data supported the foundation of the updated lobster fishery SES framework.

2) Expert and consultative semi-structured interviews were conducted regarding various attributes to the Ostrom (2009) social-ecological system framework, as well as achieving sustainable outcomes in fisheries. These insights supported the studies methodological and theoretical foundations, as well as helping to frame the discussion.

3) An updated version of the Ostrom (2009) and Basurto et al., (2013) social-ecological system framework was developed for the specific classification of lobster fisheries, and sourced through the empirical and systematic review of case studies and expert opinion. This developed framework will provide a contextually designed classificatory outline for managing and researching lobster and related fisheries as social-ecological systems.

4) In parallel to the three previous steps, a case study was analyzed through a survey given to the stakeholder representatives on the Lobster Advisory Committee (LAC) of the SCSLF, which is responsible for developing a sustainable fishery management plan for the fishery. Survey questions pertained to management dynamics, functionality and effectiveness of the social-institutional arrangement. This data was used for context specific interaction analysis of the classified SES data with the IAD framework.

5) The updated social-ecological system framework for lobster fisheries was applied to the SCSLF to exemplify its use empirically through document analysis, first-hand knowledge, and the LAC stakeholder representative survey results. This exemplifies the empirical classification process using the updated framework and provided data for assessing the SES interactions and sustainability assessment discussion.

6) The LAC, a part of the 'delegative co-management' component of the SCSLF SES, was classified as an 'action situation' through seven criteria with the Institutional Analysis and Development (IAD) framework. The seven criteria are used to identify interactions that lead to outcomes associated with sustainability within a defined action situation. The criteria for the LAC are defined through survey responses, the SCSLF SES classification, and document analysis. These interactions and their implications for achieving sustainable outcomes in the SCSLF SES are discussed through evaluative criteria. This step provides a means for analytically framing how SES components interact and how they can be evaluated in association with sustainability.

2.2 Literature review

The foundation of this study is based on acquiring a concrete empirical and theoretical understanding of lobster fisheries as social-ecological systems, and the existing research conducted on them. To best achieve this, a systematic literature review of scientifically published peer-reviewed articles was conducted and described in *Table 1* below. Literature reviews enable a thorough system overview (Bryman, 2008) of social-ecological system characteristics while also providing methodological and analytical insights from existing research.

Table 1. Literature review procedure. The seven steps used for gathering and extracting data.

Steps	**Procedure**	**Results**
1) Data Conception	Conceptualize the depth and scale of the study focus. Scope and gain an understanding of the search criteria and limitations.	Specifically developed search criteria relevant towards achieving the study focus. See *Appendix 2*[1] for search string.
2) Data Searching	Peer-reviewed article database search on Scopus, using a refined search string relevant to the study focus.	Title, abstract, and keyword information for 140 articles relevant to the search string.
3) Data Screening	Screening the titles, abstracts, and keywords for all 140 potentially relevant articles to eliminate those not relevant to the study focus. Guided by "Does the article focus on aspects of social-ecological systems or social-institutional dynamics in a lobster fishery?"	48 articles that fit the study focus criteria after this screening procedure.
4) Data Gathering	Downloading or gaining full text access to all of these 48 potentially relevant articles.	45 downloaded or full text accessible articles. (3 articles with no access)
5) Data Scoping	Reading the full text of the 45 articles to eliminate articles that were not relevant to the study focus.	19 articles that were relevant to the study focus. See *Appendix 5* for bibliography of the 19 articles used.

[1] The appendices are ordered at the end of the main text in terms of relevance and importance to the study contributions. The appendix numbering in the text is therefore not sequential.

6) Data Classification	Systematic classification of the 19 relevant articles using 32 defined categories relevant to gaining insights towards the study focus and background information regarding the fishery.	Dataset of 32 defined category variables for each relevant article.
7) Data Analysis	Compile, summarize, and analyze data categories by fishery.	12 lobster fisheries with specific data regarding fishery characteristics, social-institutional attributes, and current research. *For results, see Table 5.*

2.2.1 Classification of Articles

The definitions and reasoning for the 32 categories used for article classification are explained and defined in this section. The categories for data extraction served the purpose of either identifying social-ecological system research characteristics and trends in *Table 2,* or fishery characteristics shown in *Table 3*. For the elaborated combined table see *Appendix 10*. The categories were chosen and defined by the author to extract data relevant to the study focus. Data categories were stored and analyzed in Microsoft Excel. All of the relevant data used was summarized and grouped by fishery name into *Table 5*.

2.2.2 Research Characteristics

Table 2. Research characteristics literature review categories. The reference categories used to extract data from articles, and the methods used to do so.

Research Characteristics	***Identification Method, Definitions*** *(if available in article)*
Research funding source and reference point for the research	If present in article acknowledgment section
Use of specific terms (social-ecological system, sustainability, ecosystem service, resilience)	If mentioned in the article in relation to the fishery = Yes
Specific mention or use of the (Ostrom, 2009) SES framework	If mentioned or theoretical use = Yes If empirical use = Yes
Type of data used	Quantitative, Qualitative, or both
Concluding recommendations	Present in article, Yes or No. If yes then noted what they were.
Primary perspective of the article (only one chosen for each article). Articles with multiple perspectives were classified by the most dominant or relevant perspective.	**Ecology**: Primarily focusing on ecological aspects of the fishery. **Economics:** Primarily assessing economic dynamics. **Governance:** Focused primarily on institutional arrangements, policy, or management tools in relation to the fishery SES. **Methods:** Developing and/or implementing original methodological approaches. **Social:** Primarily focused on social aspects surrounding the fishery. **Other:** Any other perspective taken

2.2.3 Fishery Characteristics

Table 3. Fishery characteristics review categories and definitions.

Fishery Characteristics	***Identification Method, Definitions*** *(if available in article)*
Ocean and region of fishery	Recorded if mentioned in text
Fishery and species name; other specifically mentioned associated fisheries	Name of species fished or fisheries associated in management
State or health of the fishery	Recorded if mentioned in text
Number of Users	Recorded if mentioned in text
Physical size or area of the fishery	Recorded if mentioned in text
Threats to the fishery	Mentioned threats effecting SES components of the fishery
Value of the fishery	Recorded if mentioned in text
Primary consumer/ buyer of commercially caught lobster	Recorded if mentioned in text
Sustainability challenges	Mention challenges
Trade-offs addressed in management	Yes or No. If Yes then recorded between what
Type of management system	How the fishery is governed, organized and who is involved. Officially and/or unofficially
Rules and regulations used in the fishery	Official and/or unofficial rules to be followed when harvesting lobster
Who primarily governs the fishery	Who makes decisions on rules and management in the fishery
National policy based governance	Yes or No. Recorded if mentioned in text
Stakeholders involved in management	Which interest groups (stakeholder) are involved in governing or managing the fishery
Stakeholders involved in research	Which interest groups (stakeholder) are involved in research on the fishery
Other: relevant fishery details	Any other relevant details

2.3 Expert and consultative interviews

Expert consultation and insights were highly valued and appreciated as an integral interdisciplinary aspect of strengthening this study's use of the Ostrom (2009) SES framework empirically, its theoretical approach, as well as the development of the updated lobster fishery framework. The role of the interviews was to provide peer and expert insights towards

theoretical understanding, methodological approaches, and specific system knowledge. Those who were contacted had extensive empirical and/ or theoretical knowledge regarding lobster fisheries management, social-ecological system frameworks, and/or sustainable fisheries management. All interviewees contributed knowledge from a different fishery or geographic context and either authored key literature to the study focus or is a management practitioner. Five semi-structured interviews were conducted between February 17th – March 7th via Skype. Specific and differing questions were asked to each individual in order best utilize and tailor the discussion around each individual's knowledge related to the study focus. Each individual was asked at the beginning of the discussion if recording was permitted. A list of the individuals contacted is listed in *Appendix 8*.

2.4 Developing a social-ecological system classification framework for lobster fisheries

Development of the lobster fishery classification framework started by adopting all of the available variables, first and second-tier, from the Ostrom (2009) social-ecological system framework and analyzing them for relevance to lobster fisheries. Second-tier variables were excluded or added to the framework as well as the addition of subsequent third, fourth, fifth and sixth-tier variables. The updated lobster fishery framework is shown in *Table 4.* Additional tiers and relevant variables were included based on the literature review of lobster fisheries research (results shown in *Table 5)*, expert interviews and discussions, and guidance and insights from the Basurto et al., (2013) SES classification framework for benthic small-scale fisheries. For each variable in the framework, a definition and case study containing the variable within a lobster fishery is provided when available, and these contributions are shown in full extent in *Appendix 1*. The Basurto et al., (2013) framework provided a valuable broader scale perspective to fishery social-ecological system classifications and was used for variable definitions and references when lobster fishery specifics were not available or necessary. This was also an aim towards achieving coherency and common metrics within the social-ecological resource system sector of fisheries, as well as more generally when using the Ostrom (2009) social-ecological system classification framework.

Table 4. Updated social-ecological system classificatory framework for lobster fisheries.

Governance System	**Resource System**
GS1 Governance Policies	RS1 Sector
GS1.1 Marine Protection Area (MPA) policies	RS1.1 Lobster (Species)
GS1.2 National sanctions	RS2 Clarity of system boundaries
GS1.2.1 Endangered species policies	RS2.1 Recruitment Sourcing
GS1.3 Spatial Zoning	RS2.1.1 Within governance system boundaries
GS2 Organizations/Institutions	RS2.1.2 Outside of governance system boundaries
GS2.1 Government organizations	RS2.2 Zoning Districts/ Marine Protected Areas
GS2.1.1 National Level	RS2.3 International Waters
GS2.1.2 Regional level	RS3 Size of resource system
GS2.1.3 Local Level	RS3.1 Carrying capacity
GS2.1.4 Support Enforcement	RS4 Human-constructions
GS2.1.5 Support Funding	RS4.1 Human access structures
GS2.1.6 Restoration efforts	RS4.2 Artificial Habitat
GS2.2 Nongovernment organizations	RS5 Productivity of system
GS2.2.1 Environmental Organizations	RS5.1 Stock Status
GS2.2.2 Research Organizations	RS5.2 Biophysical Properties
GS2.2.3Social/ Welfare Organizations	RS6 Equilibrium properties
GS2.2.4 Restoration efforts	RS7 Predictability of system dynamics
GS3 Decision making structures	RS8 Storage characteristics
GS3.1 Network structure	RS9 Location
GS3.1.1 Vertical	**Resource Units**
GS3.1.2 Horizontal	RU1 Resource unit mobility
GS3.1.3 Transparency	RU1.1 Recruitment
GS3.2 Management Strategy	RU 1.2 Nocturnal movement
GS3.2.1 Co-management	RU2 Growth or replacement rate
GS3.2.1.1 Consultive	RU3 Interaction among resource units
GS3.2.1.2 Collaborative	RU3.1 Reproduction
GS3.2.1.3 Delegative	RU4 Economic dynamics
GS3.2.2 Adaptive management	RU4.1 Economic Value
GS3.2.3 Self-governance/ Community-based	RU4.1.1 Live
GS3.2.4 Stakeholder Involvement	RU4.1.2 Frozen
GS3.2.4.1 Committee/ Council	RU4.2 Market Predictability
GS3.2.4.2 Open forum/ comment	RU4.3 Market Diversity
GS3.2.4.4 Research Involvement	RU4.4 Recreational Value
GS3.2.5 Multiple outcome recognition & planning	RU5 Cultural value
GS4 Rules & Regulations	RU5.1 Indigenous/ Subsistence Value
GS4.1 Constitutional Rules	RU5.2 Recreational value
GS4.2 Collective Choice Rules	RU6 Number of units (Harvestable Population)
GS4.3 Operational Rules	RU6.1 Legal Harvest Rate
GS4.4 Commercial Resource Regulations	RU6.2 Illegal, Unreported, Unregulated (IUU) fishing
GS4.4.1 Input controls	RU7 Distinctive Characteristics
GS4.4.1.1 Season	RU7.1 Molting
GS4.4.1.2 Licenses/Permits	RU7.2 Artificial female markings
GS4.4.1.3 Equipment/Gear allowed	RU7.3 Tail V-notch
GS4.4.1.4 Harvestable Size Limits	RU8 Seasonal and Temporal distribution
GS4.4.1.5 No berried females	RU8.1 Seasonal migration
GS4.4.1.5.1 V-Notch	**Actors**
GS4.4.2 Output controls	A1 Number of actors
GS4.4.2.1 Total Allowable Catch (TAC)	A1.1 Commercial
GS4.4.2.2 Individual Transferable Quotas (ITQ)	A1.2 Recreational
GS4.4.3 Access	A1.3 Non-consumptive recreational
GS4.4.3.1 Shared exclusive territory	A1.4 Indigenous peoples, subsistence harvesting
GS4.4.3.2 Individual spot ownership	A1.5 IUU actors
GS4.4.3.3 Open	A2 Socioeconomic attributes of actors
GS4.4.4 Decision Rules	A2.1 Socioeconomic resilience
GS4.5 Recreational Resource Regulations	A2.1.1 Insurance Availability
GS4.5.1 Input Control	A2.2 Operating Costs
GS4.5.1.1 Harvestable Size limits	A2.2.1 Replacement/ Renewal Rates
GS4.5.1.2 Licenses	A3 History of use
GS4.5.1.3 Trap soak time	A3.1 Crisis
GS4.5.1.4 Equipment/ Gear allowed	A3.2 Duration
GS4.5.1.5 Season	A4 Location

GS4.5.2 Output Controls GS4.5.2.1 Daily limit GS4.5.2.2 Season limit GS5 Monitoring GS5.1 Social GS5.2 Biophysical GS6 Sanctions GS6.1 Graduated Sanctions	A4.1 Ports/ Harbors/ Built Infrastructure A4.2 Beaches/ Non-built/ natural access A5 Leadership/entrepreneurship A6 Norms/social capital A6.1 Spatially based A6.1.1 Clubs/ Organizations/ Chapters A6.2 Non-spatially based A6.2.1 Online format, publications A7 Knowledge of SES/mental models A7.1 Traditional Ecological Knowledge (TEK) A7.2 Western Science & Management Knowledge (SMK) A7.3 Local Ecological Knowledge (LEK) A7.4 Knowledge Sharing/ Social Learning A8 Importance of resource A8.1 Economic dependence A8.2 Cultural dependence A9 Technology used A9.1 Homogeneity A9.2 SCUBA for commercial gear recovery

2.5 Survey design and implementation

The stakeholder representative group for the Southern California Spiny Lobster fishery, the Lobster Advisory Committee (LAC), was surveyed. The LAC is comprised of stakeholder representatives, shown in *Figure 7* (for a detailed list see *Appendix 7),* brought together in a delegative co-management structure to cooperate towards developing a sustainable management plan for the fishery. The survey was sent to all 12 primary committee members as well as the 6 additional alternate members for each stakeholder group through their official LAC email accounts. While only the 12 primary members have voting power on the committee, based on first hand experience, alternate members have the chance to and do participate as equally as primary members in committee meetings and decision making; for this reason all survey responses were considered equally. The survey consisted of 20 questions (see *Appendix 9*) regarding the social-institutional arrangement, functionality and the perceived effectiveness of the LAC to manage the fishery sustainably. All survey questions, except the initial representative group identification question, used a Likert scale for question responses. Survey responses were paired with voluntary comment responses to each question, linked to a specific LAC representative responses, to better give an indication of the reasoning for the Likert scale responses of each question. According to Maeda, (2014), vertically oriented and unidirectional response answers should be used with a Likert scale to best acquire absolute judgment; this method was used for the survey in this study. The survey was designed with the Likert scale to

contain less than 20 questions in aims to increase the response rate and accuracy. The five response options were: strongly disagree, disagree, neutral, agree, strongly agree. Survey results are shown in *Tables 8-12* (Likert responses) in the results section below and *Appendix 3* (comments). None of the questions were mandatory for submitting the survey, and an optional comment box followed all questions. The survey was created, designed and sent out through Google Drive as a 'Form'. Reponses were entered digitally and automatically into a Google Drive spreadsheet. An official statement regarding the purpose of the project and importance of participation to the project of all of the stakeholder representatives was included in the email. The survey was initially sent out on February 4th, followed by a 'reminder and thank you' email on February 24^{th,} for those who had not, or had taken the survey already.

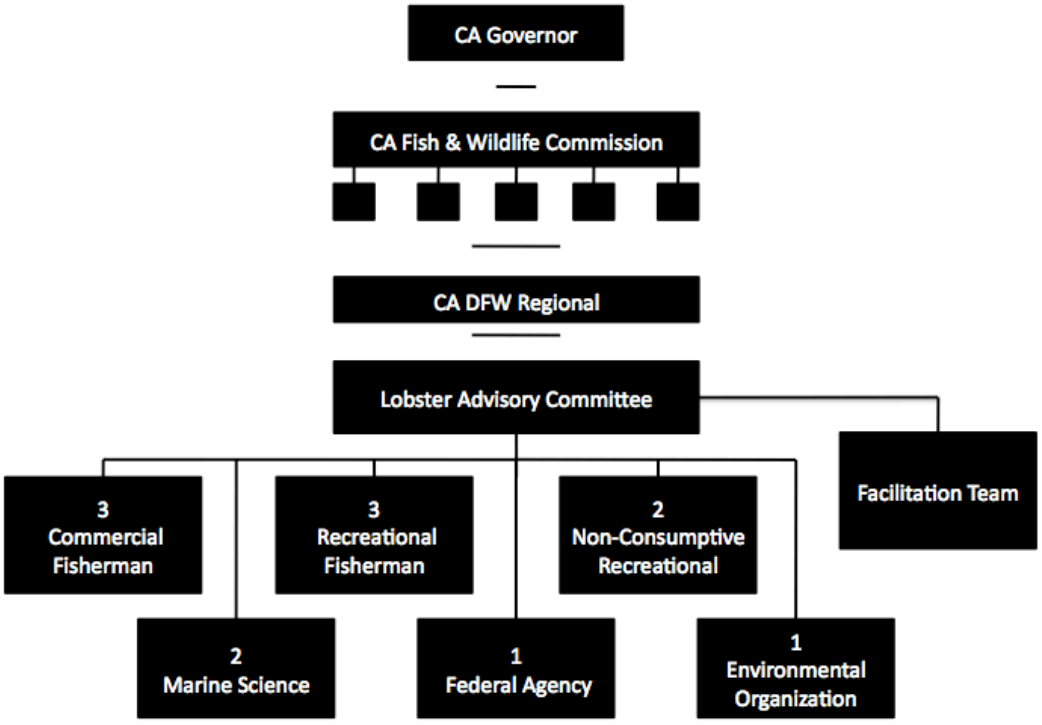


Figure 7. The Lobster Advisory Committee (LAC) internal and governance network structure. The LAC consists of 12 voting members and one alternate (not displayed) for each stakeholder group, making 18 total representatives. The number indicates the amount of representatives in each stakeholder group. The facilitation team organizes, facilitates discussion and consults decision-making on the LAC, but has no voting or authoritative power on decision-making. The LAC is overseen by the CADFW regional office, and recommendations for the Fishery Management Plan must ultimately be approved by the CADFW Commission. – Provided by the Author--

2.6 Applying the SES framework to the Southern California Spiny Lobster Fishery

To exemplify the use of the updated lobster fishery social-ecological system classification framework empirically, the updated framework was applied to the Southern California Spiny Lobster fishery. A case study was chosen to practically apply the theoretical methods (Flyvbjerg, 2011) of the SES and IAD frameworks as well as to implement a tangible sustainability assessment. This was done by indentifying and observing as many of the relevant variables in the framework that are present or identifiable as part of the fishery's social-ecological system as possible. This was accomplished through document analysis, survey responses and first-hand experience as an alternate LAC recreational non-consumptive member, shown in full in *Appendix 4* and selected results were used for the IAD framework analysis of the LAC in *Table 6*. Individual variables in the framework require different identification scales, inputs, and data as responses for classification in the framework. Classification responses for different variables were indentified in various ways and simplified. Classification of a variable may be 'Yes or No', or 'Low, Medium, or High', or specific data relevant to the framework variable. The classification depth or specificity was not exceeded beyond these metrics in this application.

2.7 Assessment of variable interactions

The framing of the internal and external interactions of the LAC action situation sets the stage for a discussion of its outcomes through defined evaluative criteria that associate with sustainability. This social-institutional interactions within the SES framework are theoretically derived from and can be assessed with the Institutional Analysis and Development (IAD) framework as an 'action situation', shown in *Figure 3* above, and presented by Ostrom & Cox (2010) as an embedded part of analyzing interactions in social-ecological systems. The survey data of the LAC along with the results of the framework classification of SCSLF are interacting sets of data, of which the dynamics within the LAC as a social-institutional 'action situation' between multiple variables in the framework were assessed. The interactions of the seven criteria in the LAC with internal and external variables for each of the seven criteria were identified. These are achieved through the survey data, SCSLF framework classification, and

document analysis. The LAC was analyzed at a singular point in time when this research was conducted, with the variables present at the time included. The changes to the fishery's management approach as a result of the LAC will not be implemented into the fishery until 2015, and were not included in this study.

2.8 Methodological considerations

Considerations and adjustments to the literature review methodology should be noted to express a reflective and transparent process. The term 'stakeholders' was added to the original search string in Scopus after reviewing a number of articles resulted in this necessary adjustment to include more papers relevant to the study focus. This resulted in an additional 16 articles, resulting in the total of 140 articles. In addition, the search string may have emphasized the identification of articles focusing on a governance perspective, reflected in the results, within social-ecological system research on lobster fisheries.

Utilizing an online survey as well as previous involvement with the case study analyzed, requires acknowledging certain methodological considerations. Analyzing the SCSLF and the LAC as a case study was in part due to personal engagement in aspects of the fishery prior to this research. All survey recipients, the LAC stakeholder representatives, had been collaborated with and approached prior to this study and some representatives were contacted individually for participation in the survey. The commercial lobster fishing season is ends in mid-March, surveys were sent out in the beginning of February. Only one commercial fishing representative completed the survey, this may have been due to the fact that many of the commercial representatives were occupied with completing the fishing season. While the possibility to get responses from every member would have been insightful, the purpose of the stakeholder groups is to collaborate and best make decisions for their constituent groups together, and one response can be considered to represent the views of the other representatives in the same group. Although this was mostly the case, the survey results indicated otherwise for certain stakeholder groups. Facilitators and those individuals managing the LAC from the CADFW were contacted for possible interviews and additional insights into the process but declined to

participate as the LAC is still an on-going process and the results of its undertakings are not finalized.

Using a Likert scale for a survey may indicate certain responses biases. In addition, how to best structure a Likert scale is still debated (Maeda, 2014). In fact, there is no common standard accepted in the scientific community for analyzing data from a Likert scale (Göb, McCollin, & Ramalhoto, 2007). Differences in responses cannot be assumed that they are linear in nature, giving the impression of interval spacing between responses in scale responses. This is exemplified in the assumption that the response difference between 'neutral' and 'agree' is the same as between 'agree' and 'strongly agree' (Robertson, 2012).

3 Results

The results presented in this section contribute specifically to the knowledge of lobster fisheries as social-ecological systems and the ability to classify them as such systems. The framing of the results through the IAD framework assesses the contextual situation of the SCSLF and LAC, while also demonstrating how various data can be grouped and analyzed to assess interactions in any general SES. Linking these results together provides an overview of how knowledge of a SES can be gained and then analyzed to assess outcomes associated with sustainability.

3.1 Social-ecological system characteristics by lobster fishery: Review results

3.1.1 Fishery characteristics and trends

The fishery characteristics, as a result of the conducted literature review, provides the first summarized guide to building an understanding of the various lobster fisheries and their characteristics across the world. While this information is not inclusive of all relevant data or lobster fisheries, achieving an overview of the many similarities and differences within the lobster fisheries sector added valuable data insights for updating the SES framework for lobster fisheries. Many fisheries have undertaken similar management approaches and achieved

drastically different fishery outcomes, and some have developed stable or healthy fisheries through entirely different approaches. The differences in fishery characteristics among all of the fisheries, expresses the need for contextualized assessments and management plans. These specifics, grouped by fishery, are shown in *Table 5.*

Table 5. Summarized lobster fishery characteristics from literature review, organized by fishery.

Fishery Name & Location, Sources	***Fishery Specifics*** *(Species, Class, Value, Status, Users, Primary purpose)*	***Management Type/ Organization***	***Management Tools***
Juan Fernandez Lobster Fishery Juan Fernandez Islands, Chile (Ernst et al., 2010, 2013b)	• *Jasus frontalis* • Classified as a recruitment fishery, geographically isolated. • ~US $3.92 million; ~80 metric tons yearly (2012) • Declared "fully exploited" and required to develop a formal management plan • ~57 commercial fishing boats • International export	Traditional informal tenure management; informal rules upheld by fisherman along with spot transferability. Formal national oversight and regulations by Under-secretary of Fisheries (SUBPESCA) and National Fisheries Service (SERNAPESCA)	• Closed Season (May 15 - Sept. 30) • Minimum Size (115mm antennae to end of carapace) • No egg-bearing females • Baited Traps only • Maximum boat size (18m) • MSC certification (in progress) & Slow Food promotion
Maine Lobster Fishery Maine, USA (Brewer, 2012a; Wilson, Hill, et al., 2013; Wilson, Yan, & Wilson, 2007)	• *Homarus americanus* • ~20 million lbs per year (2013) • Healthy • ~6000 commercial boats	Co-management; co-management zones empowered to establish industry-supported conservation rules at the zone level. Each of seven zones was divided into several districts made up of one or more harbor groups, and zone council elections are held so lobstermen can "regulate themselves." Two-thirds vote required in zone councils to pass new laws/ regulations.	• Traps only; trap limit (800) per boat • Size limit between (82.5-127mm) • No egg-bearing females • V-notch for caught and released egg-bearing females
Red Rock Lobster Fishery West Coast Mexico (Pérez-Ramírez, Ponce-Díaz, & Lluch-Cota, 2012)	• *Panulirus interruptus* • ~1500 metric tons per year • Healthy • ~1200 commercial fisherman • 90% Export	Co-management between National Fisheries Institute and Fishing cooperatives, includes: organizational incentives, participation of members in decision-making, profit-sharing, pension systems, self-management ability; investment in fixed and social capital, fishing equipment and infra-structure; profit-sharing from investment education, community	• MSC certified • Legal size • Closed seasons • Protection of egg-bearing females, • Traps only, • Limited access rights; • Mechanisms of coordination and

		improvements, such as maintenance of roads and supply of electricity. Fishery certification continued state funding for research and stakeholder involvement in the management. Most fishermen are unaware of the details of or for the MSC certification.	co-management among fishermen and INAPESCA technicians • Regulatory measures to protect recruitment
Torres Strait Rock Lobster Fishery Northern Australia; Papua New Guinea (Butler et al., 2012; I. van Putten, Deng, et al., 2013; I. van Putten, Lalancette, et al., 2013)	• *Panulirus ornatus* • Stable; not overfished • Export • Large indigenous populations from both Australia and Papua New Guinea reside and use resources within the fishery.	Participatory co-management. Informal co-management with formal advisory committee structure. The lobster fishery is managed in a joint effort with other fisheries in the region. Various fishery specific advisory and assessment committees comprised of delegated stakeholder positions report up the corresponding authority for decision making. The management seeks to further integrate traditional ecological knowledge (TEK).	• Pending quota management system (QMS) and individual transferable quotas (ITQs).
Tasmanian Lobster Fishery Tasmania, Australia (Nursey-Bray et al., 2012; Phillips, Kriwoken, & Hay, 2002; I. E. van Putten, Jennings, et al., 2013)	• *Jasus edwardsii; Jasus verreauxi* • Rec. harvest ~135t ; Commercial catch ~1523t (2008); ~AU$ 72 million (2013) • Ecologically stable, economically vulnerable; declining recruitment and avg. size	Participatory Co-management. The new management environment is one in which government and property rights holders and fisherman engage in a mixture of collaboration and contest.	• Recreational fishing licenses AU$31.50 plus an additional AU$5.25 for dive, pot or ring use • Size limit (carapace length) 110mm for male and 105mm for female • Primarily output controls • TAC based on annual stock assessment, 10% recreational. • ITQs and owned 'pots' or 'traps' as part of a total allowable • Season (majority of year; females Nov-Apr.)
Caribbean Lobster Fishery Caribbean Sea; Mexico, Guatemala, Honduras, Grenada	• *Panulirus argus* • Honduras (In, 1360 tons of lobster tails at ~ 30 million US dollars) • Belize (800 tones whole weight per year) • Guatemala (less	Consultive co-management (Grenada). Cooperative co-management (Mexico). ***Management Tools (extension)*** **Mexico** Closed season of 4 months (March–June) and a minimum size restriction of 13.5cm tail length) **Grenada** Minimum length and weight. Hand, loop-trap or pots only. No	**Honduras** Maximum 170 industrial vessels, a closed season of 3 months (April–June), minimum size of 14.5cm of tail length.) **Belize** Closed season (15 February–14 June), minimum size 7.6cm

(McConney & Baldeo, 2007; Seijo, 2007)	than 10 tonnes whole weight per year.) • Mexico (In 2005–2006, 1074 tons whole weight • ~2400 commercial fisherman (Mexico), ~3000 (Belize)	landing lobster not whole. No impaling of lobsters. Closed season (May–August). Trammel nets are prohibited.	carapace length. No fishing in MPAs, scuba diving or traps in coral reefs. **All countries**: No berried females or molting lobsters.
South African Lobster Fishery South Africa; Atlantic Coast (Pilling & Payne, 2008)	• *Jasus lalandii* • Stable, considered reasonably sustainable	Precautionary Stakeholder Management- Builds on the scientific, administrative and political will to develop and employ operational management procedures, developed and understood by most and transparent to all. Non-fishery users are not as included in participatory management as many would like.	• Total Allowable Catch (TAC) • Minimum size
South African (Wild Coast) Lobster Fishery South Africa; Indian Coast (Steyn, Fielding, & Schleyer, 2008)	• *Panulirus homarus rubellus* • Subsistence and recreational fishing only. (2008) • Commercial fishery pending based on development of management plan. • Local business and resident consumption	Top-down input controls; Rule enforcement is poor and undocumented.	• Min. size, 65 mm carapace length • Closed season (1 Nov. to end Feb.) • Daily bag limit of eight lobsters • No use of boats or artificial breathing apparatus • No berried or molting lobsters.
Galapagos Spiny Lobster Galapagos Islands, Ecuador (Hearn, 2008)	• *Panulirus penicillatus; Panulirus gracilis* • Declining yields; overfishing • 446 registered commercial vessels	A consensus-based stakeholder decision-making process. Galapagos Marine Reserve Management Board (GMRMB): tourism sector, naturalist guides, artisanal fishers, conservation and science sectors, and the Galapagos National Park Service (GNPS). Inter-institutional Management Authority (IMA): Ministers of Environment, Defense, Tourism and Fisheries, Galapagos Tourism and Fishing Sectors, and CEDENMA (Ecuadorian environmental groups).	• Divers using surface supply gear only. • No large-scale commercial, only local artisanal commercial fishing. • 4 month season • Minimum 26cm total length • No egg bearing females
New Zealand Rock Lobster Fishery New Zealand (Yandle, 2006)	• *Jasus edwardsii; Sagmariasus verreauxi* • NZ$ ~101.5million (2004) • Declining yields and CPUE	Dual top-down/bottom-up Co-management. Each regional stakeholder fisherman group (CRAMAC) elects a representative to the board of the national umbrella agency New Zealand Rock Lobster Industry Council (NZ RLIC). Funding is	• ITQ models based on TAC

	• Primarily Asian export	paid up to the national level. Management issues are mostly dealt with at the regional CRAMAC level while administration, representation and analysis and advocacy occur at the NZRLIC level. Commercial, recreational, Maori (indigenous), conservation groups, and governmental organizations are all involved.	

3.1.2 Trends in research on lobster fishery SES's

The trends in the research performed on lobster fisheries as social-ecological systems, and/ or their various incorporated social-institutional dynamics are displayed in this section with a rounded percentage and whole number (in parenthesis) of the total articles. The publication dates of the articles ranged from 2002 - 2013, with 47% (9) of the articles published in either 2012 or 2013. Sustainability is a universal topic addressed when researching SES components in lobster fisheries. All nineteen articles, 100% (19), mentioned the term 'sustainable' or 'sustainability' in relation to the fishery. This supports the link between research in social-ecological systems and research in sustainability science. However, use of the SES framework empirically in lobster fisheries is still very limited. In comparison only 37% (7) of the articles specifically used the term 'social-ecological system', 37% (7) used the term 'resilience', 32% (6) mentioned or addressed 'trade-offs' in management, and 16% (3) mentioned the term 'ecosystem services' in their articles. The number of articles mentioning the Ostrom (2009) SES framework was 32% (6), but only 10% (2) of the articles used the framework empirically. Use of these specific terms and concepts shows how the research field is linked to certain perspectives of system understandings. This shows that most articles mention the framework for theoretical backing or to justify research in social-ecological systems. Term use also indicates coherency in the research field, how analyses and evaluations are being conducted and framed in the context of social-ecological system research.

The main perspective (ecology, economics, governance, methods, social, or other; see *Table* 2 in methods) taken in each article was assessed. Nearly 75% (14) of the articles took a governance

perspective, with 16% (3) having social perspectives, methods and economics having 5% (1) each, and no papers took an ecological perspective. Along with these perspectives, more than 60% (12) of the articles used or collected qualitative data, 10% (2) quantitative, and 26% (5) used both. While the selection categories were mutually exclusive, there is a strong singular disciplinary governance focus in the field.

There is a presence of discussing how and why certain interactions negatively affect each fishery in research. 37% (7) of the articles mentioned specific threats to the fishery. All of these articles specifically mentioned either 'over-fishing', 'extreme or climatic weather events' and/or 'mismanagement' as current threats facing the fishery. The 47% (9) of articles that mentioned specific sustainability challenges to the fishery included: 'understanding the circumstances in which it is possible to learn from others experience'; 'overfishing'; 'knowledge communication and co-management'; 'economic resilience'; 'incorporating indigenous peoples components'; 'achieving sustainable harvesting'; 'national fishery policy impeding on local tenure management'; 'social equity, private vs. common access'; and 'climate change'.

Studies on SES components in lobster fisheries have occurred only in the last few years, and are focused almost entirely on commercial control rules and regulations or implementable management techniques. A centric focus on these aspects of a fishery limits the scope of SES knowledge available in each fishery over time scales and disciplinary perspective. Generalized definitions of management approaches such as 'co-management' are extensively discussed while rarely defined or described contextually. In addition, the research field in lobster fisheries focuses almost exclusively on commercial fisheries in SES's, creating limited knowledge of recreational impacts, their control mechanisms, as well as cultural and economic recreational values.

3.2 Updating the SES framework for the classification of lobster fisheries

The Ostrom (2009) social-ecological system framework was updated specifically for the classification of lobster fisheries, and is shown in *Table 4* above. The updated framework

includes 153 components, compared to the Ostrom (2009) framework containing 37 components and including only second-tier variables. The updated framework has been elaborated beyond second-tier variables to include third, fourth, fifth and sixth-tier variables that are relevant to at least one lobster fishery system, through the analyzed case studies within the articles. Definitions and/ or a lobster fishery case study containing and justifying each framework component are shown in *Appendix 1*. The Social, Economic, and Political Settings, Related Ecosystems, and Interactions and Outcomes were not changed from the original Ostrom (2007, 2009), framework, and therefore not included. Many of these aspects were included into the updated framework through one of the four first-tier variable sub-components. To increase clarity and avoid confusion, only updated framework components from this study were used to classify the SCSLF in *Table 6*. Additionally, a separate and more in-depth interaction analysis conducted in this study, negating the need for the original framework section. The related ecosystems remain the same, and while important as indicated by concerns in the literature review, they were beyond the scope of the study focus and not updated or used to classify the SCSLF.

3.3 Classifying the Southern California Spiny Lobster fishery as a SES

The updated SES framework for classifying lobster fisheries was applied to classify the Southern California Spiny Lobster fishery as a social-ecological system. The selected results are displayed below in *Table 6 (*full results are shown in *Appendix 4)*, with the classification data or indicator within the SCSLF displayed when present in the right column. The selected results are shown because they relate directly to the IAD framework interaction analysis in the following section. The classification shows that the SCSLF has a well-developed and defined governance system including complex decision making structures and defined rules and regulations. Focal governance of the system is given to the stakeholder-comprised Lobster Advisory Committee. The resource system of the fishery is extensive and not entirely well understood. Considerable influential factors in the resource system include Marine Protected Areas and its existence in international waters. The different interactions actors exhibit in the fishery are well understood, but except for the commercial sector, data on the amount of them and their impacts on the

system is not available. There is a diverse array of knowledge on the system of which is shared between stakeholders in varying degrees and settings. The resource unit, or lobster species, is fairly well understood and stable both ecologically and economically. Recruitment dynamics are not well understood. The classification of the SCSLF has additionally shown considerable data gaps regarding many interacting system components.

Table 6. Selected framework components and the classification data of the SCSLF, as well as those used within the subsequent IAD framework analysis.

Selected Framework Components	Southern California Spiny Lobster Fishery
Governance System	
GS3 Decision making structures	
GS3.1 Network structure	--
GS3.1.1 Vertical	Yes
GS3.1.2 Horizontal	Yes
GS3.1.3 Transparency	Medium
GS3.2 Management Strategy	--
GS3.2.1 Co-management	Yes
GS3.2.1.3 Delegative	Yes
GS 3.2.2 Adaptive management	Yes
GS3.2.3 Self-governance/ Community-based	--
GS3.2.4 Stakeholder Involvement	Yes
GS3.2.4.1 Committee/ Council	Yes
GS3.2.4.2 Open forum/ comment	Yes
GS3.2.4.3 Research Involvement	Yes
GS3.2.5 Multiple outcome recognition & planning	Unknown
GS4 Rules & Regulations	Yes
GS4.1 Constitutional Rules	Yes
GS4.2 Collective Choice Rules	Yes
GS4.3 Operational Rules	Yes
GS4.4 Commercial Resource Regulations	Yes
GS4.4.1 Input controls	Yes
GS4.4.1.1 Season	October-March
GS4.4.1.2 Licenses/Permits	Limited ~150, ~$50,000 - $100,00 USD each.
GS4.4.1.3 Equipment/Gear allowed	Baited Traps only
GS4.4.1.4 Harvestable Size Limits	Minimum 8.255 carapace length.
GS4.4.1.5 No berried females	Unofficial
GS4.4.3 Access	--
GS4.4.3.1 Shared exclusive territory	No
GS4.4.3.2 Individual spot ownership	Unofficial
GS4.4.3.3 Open	Yes
GS4.4.4 Decision Rules	No
GS4.5 Recreational Resource Regulations	Yes
GS4.5.1 Input Controls	Yes
GS4.5.1.1 Harvestable Size limits	Minimum 8.26 cm carapace length.
GS4.5.1.2 Licenses	Yes, no limit. ~$35 USD/yr. ~30,000 in 2011.
GS4.5.1.3 Trap soak time	Yes, 24 hours

GS4.5.1.4 Equipment/ Gear allowed	Hoop traps, out of water. Hands only, in water. SCUBA allowed.
GS4.5.1.5 Season	October-March
GS4.5.2 Output Controls	Yes
GS4.5.2.1 Daily limit	Yes, 7 per person per day.
Actors	
A1 Number of actors	--
A1.1 Commercial	~150
A1.2 Recreational	+30,000
A1.3 Non-consumptive recreational	Likely high but unknown.
A1.4 Indigenous peoples, subsistence harvesting	None
A1.5 IUU actors	Unknown
A2 Socioeconomic attributes of actors	--
A2.1 Socioeconomic resilience	Unknown
A2.1.1 Insurance Availability	Yes
A2.2 Operating Costs	Commercial costs, high. Recreational, low.
A2.2.1 Replacement/Renewal Rates	Yearly recreational license renewals. Case-based commercial license transfers.
A7 Knowledge of SES/mental models	
A7.1 Traditional Ecological Knowledge (TEK)	Low
A7.2 Western Science and Management Knowledge (SMK)	Medium, social and ecological.
A7.3 Local Ecological Knowledge (LEK)	High
A7.4 *Knowledge Sharing/ Social Learning*	Medium
A8 Importance of resource	High
A8.1 Economic dependence	High
A8.2 Cultural dependence	Unknown
Resource System	
RS2 Clarity of system boundaries	Not well understood.
RS2.1 Recruitment Sourcing	Not well understood.
RS2.1.1 Within governance system boundaries	Yes
RS2.1.2 Outside of governance system boundaries	Yes
RS2.2 Zoning Districts/ Marine Protected Areas	Yes, extensive MPA network within RS.
RS2.3 International Waters	Yes, USA and Mexico.
Resource Units	
RU4 Economic dynamics	Yes
RU4.1 Economic Value	High.
RU4.1.1 Live	~ $14.90 - $39.70 USD per kilogram
RU4.1.2 Frozen	--
RU4.2 Market Predictability	No data.
RU4.3 Market Diversity	Mostly export to Asian markets.
RU4.4 Recreational Value	Yes, but no data.

3.4 Interactions in complex SES's: Analysis of the LAC through the Institutional Analysis and Development framework

Action situations, analyzed with the Institutional Analysis and Development framework shown in *Figure 3,* are the social spaces where individuals interact, exchange goods and services, solve

problems, dominate one another, or even fight (Ostrom, 2011). Concurrently, an action situation is the 'black box' where policy choices are made (McGinnis, 2011). In relation to the social-ecological system framework, action situations can represent specific interactions between variables or components within the classified SES. In this study, the Lobster Advisory Committee demonstrates an action situation, where the fishery's policy choices are made, which also incorporates many identified variables in the SES classification framework (*Table 6)* that interact with each other, including but not limited to: the number of actors *A1*, delegative co-management *GS3.2.1.3*, stakeholder involvement *GS3.2.4*, knowledge of SES/mental modes *A7*, network structure *GS3.1*, rules and regulations *GS4*, socioeconomic attributes *A2*, importance of resource *A8*. While an action situation in a system may affect any number of components in a system, the variables mentioned in this case can be directly attributed to the seven criteria of an action situation identified by (Ostrom & Cox, 2010) with empirical data attained through the LAC survey and the SCSLF SES framework classification.

An action situation, as defined by (Ostrom & Cox, 2010), is defined by the seven criteria in the left column of *Table 7*. The identified variables pertaining to the seven criteria that frame the LAC as an action situation are in the right column.

Table 7. Definitions & summary of LAC criteria, as classified by the IAD framework.

'Action Situation' Structural Criteria	**Criteria represented in the LAC**
(1) Set of Actors	LAC is comprised of stakeholder representatives and the facilitation team within the existing governance structure. Shown in *Figure 6*.
(2) Sets of positions actors fill in the context of this situation	Stakeholder representatives represent the interests of their constituent interest groups. The facilitation team acts as an external moderator and communicator between representatives' discussion and action implementation, and the CADFW Commission.
(3) Set of allowable actions for actors in each position	Each of the stakeholder representatives are on the LAC because their stakeholders engage in actions impacting the fishery, each group has differing impacts. Internally the LAC uses a

	charter as a collective-choice based governing document stating the rules and democratic principles adopted by each representative on how discussions and decision-making will be carried out. The LAC will provide Fishery Management Plan (FMP) recommendations to the CADFW Commission, whom has final approval or denial rights.
(4) Level of control that an individual or group has over an action	Representatives have equal voting power on the LAC. The LAC has recommendation powers only to the CADFW Commission.
(5) Potential outcomes associated with each possible combination of actions	A sustainable social, economic and ecological outcome is unanimously desired on the LAC through implementing the FMP.
(6) Amount of information available to actors	Information regarding the SES is provided to the LAC through external research groups, internally supported CADFW researchers, the CADFW enforcement agency, as well as between stakeholder representatives from different interest groups.
(7) Costs and benefits associated with each possible action and outcome	Trade-offs and compromises among stakeholder groups as well as the perceptions and willingness of stakeholders to manage collectively.

3.4.1 Evaluating the LAC through the IAD framework criteria

Results are presented here from the interacting data of the LAC survey and the SCSLF SES classification, providing empirically identified interaction analyses and component identification. The results show the effectiveness and ability of the LAC, as an action situation in the SES, to achieve the desired sustainable fishery outcomes through its implementation. While presenting and analyzing these components, evaluating the LAC as an 'action situation' with the IAD framework requires defining the scope and depth of the variables to be included. In the case of the LAC, the internal interactions of the committee are primarily explored. Although the action situation is primarily defined by internal interactions, certain external variables also have a significant influence. Internal (within the LAC) and external variables (within the SES) are included for IAD framework assessment to exemplify this. Survey results are based on responses

from the following stakeholder representatives on the LAC (see methods Table 1), with the number of survey responses from each group as follows: 1 commercial, 2 recreational, 1 non-consumptive, 2 environmental, 1 governmental and 1 marine science. There were a total of 8 survey responses from a possible 12 voting members and 6 alternates. There was at least one response from each stakeholder group. At least one response from each stakeholder group was the goal of the survey, to provide insights regarding the LAC from all perspectives. Comment responses to individual survey questions are stated in *Appendix 3.*

The following section identifies and analyzes the LAC as an action situation through the seven criteria of the IAD framework:

(1) Sets of Actors:

External Variables: The number of actors *A1* actively engaged in harvesting and utilizing lobsters as the resource unit in the SCSLF are presented here. The number of commercial actors *A1.1* is relatively low compared to other fisheries in the review at ~150, recreational actors *A1.2* are high at +30,000 along with an unknown number of non-consumptive actors *A1.3*. There is no presence of an indigenous population *A1.4*, and there is an unknown amount of Illegal, Unregulated, and Unreported (IUU) *A1.5* lobster fishing. ***Internal Variables:*** The number of actors, as representatives of their associated stakeholder groups classified in the SES, on the LAC are displayed in *Figure 5 above*. This is displayed along with the institutional design of the delegative co-management *GS3.2.1.3* approach used by the CADFW to involve stakeholders to develop a Fishery Management Plan required by legislation from the CADFW Commission.

(2) Sets of positions actors fill in the context of this situation

***Internal Variables*:** The LAC representatives, shown in *Figure 5*, assume the role of communicating among and between stakeholders to make decisions in the best interest

of their stakeholders and the sustainability of the fishery (LAC Charter, 2012). Responses from the survey questions addressing the effectiveness of the LAC structure in achieving this goal through communicating, and the equity of stakeholder representation is shown in *Table 8* below.

Table 8. Survey questions and responses, addressing criteria (2).

Who Responded: Commercial C Recreational R Non-Consump. N Environmental E Govt. (Fed.) G Marine Science M	(1) "It is easy to communicate the decisions, as well as what happens at the LAC meetings to your constituents."	(2) "The LAC has allowed for easier engagement with other stakeholders."	(3) "Your stakeholder group is represented fairly on the LAC."	(4) "Other stakeholder groups are represented fairly on the LAC."
Strongly Disagree	0	0	0	0
Disagree	0	1 C	2 EC	0
Neutral	1 N	2 ER	3 NRM	1 R
Agree	5 REEGM	5 ENGRM	2 RE	7 CGREENM
Strongly Agree	2 CR	0	1 G	0

(3) Set of allowable actions for actors in each position

External Variables*:** Rules and regulations *GS4* of the actors harvesting or utilizing lobsters are classified in SES framework, *Table 6*. These are extensively defined and monitored for the commercial sector. The recreational and non-consumptive sectors are well defined but not well monitored. The recreational value *RU4.4,* cultural dependence *A8.2*, and the number of non-consumptive users *A1.3* are not well understood or have no data. ***Internal Variables: From the LAC Charter (2012), The LAC members' role is to provide advice, feedback, and recommendations regarding the issues and actions to develop the fishery management plan (FMP). Additionally to address and put forth key issues from the interested parties (stakeholders). The LAC does not author the contents of the FMP, but provides options and ideas for management.

(4) Level of control that an individual or group has over an action

External Variables*:** In relation to rules and regulations *GS4*, transparency of the network structure *GS3.1* and collective choice rules *GS4.2* are present within the fishery. ***Internal Variables: Stakeholder involvement *GS3.2.4* and the delegative co-management structure are present in the SES and control group actions inclusively. Survey responses are shown in *Table 9* below.

Table 9. Survey questions and responses, addressing criteria (4).

Who Responded: Commercial C Recreational R Non-Consump. N Environmental E Govt. (Fed.) G Marine Science M	(5) "It is difficult to work in a group the size of the LAC."	(6) "The LAC is too small and should incorporate more stakeholders and/or representatives."	(7) "Having representation on the LAC has helped your constituency better organize or communicate."	(8) "The LAC has the proper tools and organizational structure to adapt to future challenges the fishery may face."
Strongly Disagree	1 E	1 M	1 C	1 R
Disagree	4 GRNC	7 GRENECR	0	2 EE
Neutral	2 RM	0	3 GRE	1 G
Agree	1 E	0	4 ENRM	2 RM
Strongly Agree	0	0	0	2 CN

(5) Potential outcomes associated with each possible combination of actions

***External Variables*:** Adaptive management *GS3.2.2* and monitoring *GS5* are present. Multiple outcome recognition and planning *GS3.2.5* is unknown within the current fishery management efforts. ***Internal Variables*:** The amount of outcomes associated with different decision-making criteria on the LAC was not explored. The survey aimed to provide insights from stakeholder representatives on the ability to achieve sustainable outcomes with the LAC. The LAC serves the primary role of deciding future fishery

outcomes through management strategies. Corresponding responses are shown in *Table 10* below.

Table 10. Survey questions and responses, addressing criteria (5).

Who Responded: Commercial C Recreational R Non-Consump. N Environmental E Govt. (Fed.) G Marine Science M	(9) "It is clear how future fishery challenges will be handled with the LAC."	(10) "The long term sustainability of the fishery is a main concern."	(11) "Social issues are adequately taken into consideration on the LAC."	(12)"Environmental issues are adequately taken into consideration on the LAC."
Strongly Disagree	3 EEM	0	1 C	0
Disagree	2 CN	0	3 EGM	0
Neutral	1 G	1 R	0	3 NEM
Agree	2 RR	3 GCE	3 RRE	5 GRRCE
Strongly Agree	0	4 RRNM	1 N	0

(6) Amount of information available to actors

External Variables: Norms and social capital *A6* are available to commercial actors spatially and all actors non-spatially in the SES. There are organized commercial chapters at various harbor locations to discuss fishery issues. Online blogs and publications are open access for all actors and the general public. ***Internal Variables:*** Information available to stakeholder representatives on the LAC, as well as their support for the LAC structure is analyzed through survey questions shown in *Table 11*.

Table 11. Questions and responses, addressing criteria (6).

Who Responded: Commercial C Recreational R Non-Consump. N Environmental E Govt. (Fed.) G Marine Science M	(13) "Being a part of the LAC has helped you better understand the biology and/or ecology of the CA Spiny Lobster."	(14) "The LAC has helped you to understand the other stakeholder's viewpoints more thoroughly."	(15) "I would recommend using the stakeholder organizational structure of the LAC for the management of other fisheries."	(16) "Local, in-the-field, first hand knowledge is taken seriously on the LAC."
Strongly Disagree	0	0	1 C	0
Disagree	1 C	1 C	1 E	0
Neutral	0	1 R	0	2 CM
Agree	4 EEMR	3 REE	4 GREM	1 E
Strongly Agree	3 GRN	3 NGM	2 NR	5 GRRNE

(7) Costs and benefits associated with each possible action and outcome

Here the stakeholder representatives responded in their willingness or ability to weigh decisions between cost and benefits of certain actions. These actions effect both internal and external variables and how they interact to affect the outcomes within the fishery. These results are displayed in *Table 12.*

Table 12. Survey questions and results, addressing criteria (7).

Who Responded: Commercial C Recreational R Non-Consumptive N Environmental E Governmental (Fed.) G Marine Science M	(17)"Compromising, trade-offs, and/ or concessions of your stakeholder groups interests may be necessary to ensure the long-term sustainability of the fishery."	(18)"Compromising, trade-offs, and/ or concessions have occurred at the expense of your stakeholder groups interests."
Strongly Disagree	0	0
Disagree	2 CR	1 R
Neutral	2 GR	2 GM
Agree	4 EENM	5 REECN
Strongly Agree	0	0

4 Discussion

A diverse array of methodological approaches and data has been presented in this study that serves to cumulatively facilitate discussion on implications for how research is conducted utilizing the SES framework and how interaction analyses can assess system components that associate with sustainable outcomes. This research protocol aims to provide insights for researchers and practitioners that seek to develop sustainable SES management approaches through contextualized research methodologies. Through the following section, insights and concerns for how to make progress towards achieving such a vision are discussed.

4.1 Utilizing the social-ecological system framework in research

4.1.1 Applications of a SES framework for lobster fisheries and SES research

Depending on the desired analytical depth, the framework can be used and variables identified in varying ways, for different purposes in a fishery. Time sequences as demonstrated by Basurto et al., (2013) can provide valuable insights towards understanding specific system changes between two definitive points in time or in intervals. Selective event classification to analyze a system in response to a disturbance, such as a tsunami event as demonstrated by Ernst et al., (2013), can illustrate impacts as well as the resilience of a system (Schoon & Cox, 2012). Using the SES framework to analyze the presence of sustainability criteria for a fishery, as done by Hearn (2008), will aim to correlate sustainable outcomes to certain variables or interactions in a system. Although there is an absence of specific rules that typify any specific system as long-lasting or sustainable (Agrawal, 2001, 2003; Ostrom & Cox, 2010), research efforts that aim to collectively aggregate empirical data through uniformed frameworks, metrics and definitions may aid towards a better understanding of certain system characteristics and interactions that associate with sustainable outcomes between systems (Agrawal, 2003; Liu et al., 2007; Ostrom, 2007).

Use of the framework on lobster fisheries is almost exclusively limited to commercial-actor dominated systems. The implications of recreational actors in fisheries are poorly understood and far less frequently researched (Hunt, Sutton, & Arlinghaus, 2013). Applications of the framework to recreational-actor or indigenous peoples dominant fisheries may be limited with the existing framework due to differing system dynamics regarding governance and actors. Recreational catches may generally be lower in percentage than commercial catches in most fisheries, but may contain significantly more users that can attribute an unknown amount of cultural identity and value, economic impact, local ecological knowledge, and management challenges to the fishery (Hunt et al., 2013; Schuhbauer & Koch, 2013; Sharp, 2005).

4.1.2 Critical perspectives: Operationalization and coherency of the SES framework

While the recognition and use of the Ostrom (2007, 2009) SES framework has been widely accepted and incorporated into fisheries research (Basurto et al., 2013; Basurto & Nenadovic, 2012; Cinner, MacNeil, Basurto, & Gelcich, 2013), empirical application of the framework and the use of common metrics and definitions within research on comparable systems is largely absent. In social-ecological system research on lobster fisheries, only two studies from an initial 140 used the framework empirically as shown through the literature review in this study. Within fisheries as a larger sector Basurto et al, (2013) provides definitions and an updated framework for classifying benthic small-scale fisheries as SES's. Many of their definitions and framework components were relevant to lobster fisheries and provided very useful base component metrics in which specific sub-systems and sub-variables could be developed more specifically for lobster fisheries. Many systems may overlap with numerous applicable and relevant SES framework components, and research that aims to collectively aggregate these components between systems may aim to achieve coherency and comparable data between similar systems within SES research (Agrawal, 2003; Basurto & Nenadovic, 2012; Cinner et al., 2013; Hunt et al., 2013; Ostrom & Cox, 2010).

Operationalizing the SES framework in lobster fisheries seeks to shift the applicability of the framework beyond research and into use for the practical management of the fishery, as

visualized in *Figure 8* further below. However, there are many challenges and difficulties for practitioners in understanding and trying to implement social-ecological thinking (MacNeil & Cinner, 2013; Kittinger et al., 2013; Ostrom & Cox, 2010). Through this study, initial classification of the SCSLF revealed significant data gaps such as recruitment sourcing, the impacts of recreational users, market stability, and non-consumptive recreational impacts. Initial roadblocks for practitioners would be to address these data gaps, and the SES framework provides the means to help identify them (Cinner et al., 2013). While identifying data gaps is important, an understanding of the interactions between certain management techniques and tools may be necessary for attaining desired outcomes in the fishery. These interactions require an in-depth empirical understanding of interacting components (MacNeil & Cinner, 2013; Aswani, Gurney, Mulville, Matera, & Gurven, 2013). This study has provided an example of how to approach research on interacting SES components, looking into the LAC through the use of the IAD framework. Research providing well-supported correlations between management approaches and outcomes may provide more tangible references for practitioners to base fishery management decisions on (Aswani et al., 2013; Cinner et al., 2013; Degnbol & Mccay, 2007). Further insights from the literature review and interviews suggest the necessity for the development of a 'practitioners guide' for understanding and using the SES framework for practical applications in management. Insights for developing the foundations of a 'practitioners guide' may be aided through a more integrated SES understanding and consideration for research designed for operationalizing outcomes into practical management. This includes trans-disciplinary research designed to incorporate practitioners into research design and implementation.

4.2 An overview of lobster fisheries & research trends

4.2.1 Fishery characteristics

The lobster fishery characteristics show the need for contextual, place-based management solutions that involve practitioners. Although the Marine Stewardship Council (MSC) certification played a role in two of the reviewed fisheries through securing federal funding and management support as well as increasing economic market stability for the fisheries, the

contextual settings that enabled this to happen within these cases is not replicable in all other fisheries. In addition, similar control rules (e.g. season, size limits) in fisheries with similar ecological characteristics but differing social-institutional settings has created different outcomes, supporting the need to avoid panaceas in management approaches. As differing rule configurations and management approaches have demonstrated contrasting outcomes between fisheries, contextualized management approaches that involve stakeholders, rather than transferring a successful management approach from one fishery to another, is necessary. The generalization of management approach explanations may reflect a lack of in-depth contextual understanding of how and why the social-institutional settings have formed the given outcomes, or function accordingly.

4.2.2 Research trends

It is evident that the research field is over-looking and generalizing management approaches although it has become a normative natural resource policy model (Brewer, 2012b; Gelcich, Edwards-Jones, & Kaiser, 2007). This study further defined differing types of co-management based on fishery participation research from McConney & Baldeo (2007) (see *Appendix 6)*. While co-management can vary greatly in meaning, there is minimal focus on understanding the social-institutional structures and arrangements behind co-management approaches. These arrangements can contribute significantly to how and what degree stakeholders are included in the process (Crona & Hubacek, 2010; Lange et al., 2013). This also indicates that concerns that many generalized panacea type approaches still exist and that integrating stakeholders into management remains a challenge in many fisheries. Contextually defined, designed and researched management approaches need to be considered with the necessary practitioners and stakeholders in complex SESs in order to avoid social-ecological traps and aim towards achieving sustainable outcomes (Cinner, 2011; Kittinger et al., 2013; Steneck et al., 2011).

The percentage of articles that mentioned specific threats and sustainability challenges within a specific fishery is concerning in regards to achieving sustainability but they can also be seen as advisory signs for action oriented solutions. These threats and challenges are similar between

many fisheries and suggest that well recognized global drivers of environmental change impact local contexts in lobster fisheries. While there are many uniform threats, the additional presence of specific threats to any one fishery stresses the need to adapt place-based solutions that aim to mitigate the impacts of global environmental change drivers in a local context.

The use of various theoretical and conceptual approaches in research demonstrates how SES's can be widely interpreted and understood. The wide array of approaches exemplifies that there is no coherent way of assessing or evaluating how SES's interact and feedback, or how they can be managed more sustainably. Making inter-disciplinary connections within the research field will be necessary to address these challenges (Basurto & Ostrom, 2009; Checkley et al., 2013), and transdisciplinary collaborations when research is aimed at integrating into management (Kittinger et al., 2013). How we understand SESs and their interactions across disciplines will naturally be varying and create thorough system knowledge. However, how we communicate this knowledge and how it relates to managing sustainable outcomes should be collaboratively understood across disciplines.

4.3 Expert interviews & inter-disciplinary research

Conducting consultative research practices can contribute towards implementing trans- and interdisciplinary research principles, building research networks and supporting the coherency and integrity of research. The epistemological foundations of research in social-ecological systems requires trans- and interdisciplinary knowledge (Levin et al., 2012; Miller et al., 2008). Reaching out to and discussing with researchers and practitioners who had varying disciplinary backgrounds is an essential part towards gaining a complete understanding of the perspectives and knowledge in lobster fisheries (Steneck et al., 2011), as well as approaches to sustainability and social-ecological systems in general (Cinner, 2011; Kittinger et al., 2013). Moreover, for knowledge in sustainability science to be truly useful, it generally needs to be 'co-produced' through close collaboration between scholars and practitioners (Clark, Dickson, & Kennedy, 2003; Kates, 2011).

4.4 IAD framework considerations: In practice and theory

The Institutional Analysis and Development (IAD) framework has multiple purposes and can give variable insights dependent on its application. The framework can be applied at different scales and levels (Ostrom & Cox, 2010; Ostrom, 2005), and thus requires defining the system that it will be applied to. Further application of this framework could take a comparative timescale analysis in such a case. Analysis through the seven framework criteria allowed for the grouping of multiple data types and proliferated insights regarding interactions in the system. Evaluative criteria for outcomes in the framework vary dependent on the type of assessment, and in the case of sustainability, there are no well-supported evaluative criteria (Ostrom & Cox, 2010) but rather a need for recognizing multiple outcomes (Agrawal & Chhatre, 2011; Kittinger et al., 2013). The criteria data groupings allowed for multiple narrative interpretations of components and their interactions that associate with well-supported sustainability criteria. Through the classification process of a SES, the recognition of data gaps in system knowledge will limit the ability to initially conduct interaction analyses. Using more complete data, allowing for fully defined interaction criteria within the IAD framework, will provide more accurate evaluative outcomes.

4.5 Evaluating sustainability in the SCSLF through the IAD framework

There are many possible evaluative criteria to analyze sustainable outcomes, but there are no well supported, generalized or defined evaluative criteria that identify or assess certain causal characteristics that associate with sustainable outcomes in complex social-ecological systems (Agrawal, 2003; Ostrom & Cox, 2010). In aims to support the development of causal characteristics, the purpose of the following discussion is to group certain components and survey responses that define the seven IAD action situation criteria in the LAC into outcome characteristics associated with sustainability or sustainable outcomes. With the IAD framework, the LAC has been framed as an action situation from the classified component of delegative co-

management in the SCSLF SES, and grouped by seven criteria that effect outcomes within the fishery's SES. The primary outcome to be considered in this discussion is sustainability. To discuss and assess the interaction results of the LAC to sustainable outcomes within the complex SCSLF SES, this discussion takes into consideration various evaluative criteria associated with sustainability as proposed by McGinnis (2011), Ostrom (2011) and Gibson, Hassan, Holtz, Tansey, & Whitelaw (2005); Gibson (2006).

4.5.1 Equity

Defined as the distribution of outcomes and processes (McGinnis, 2011), and ensuring that sufficiency and effective choices for all are pursued in ways that reduce dangerous gaps in sufficiency and opportunity (and health, security, social recognition, political influence) between actors (Gibson, 2006).

Despite underlying social concerns, overall equity through these interactions is generally attained and may aid towards achieving sustainable outcomes in the SCSLF. The LAC enabled equitable environmental considerations and interactions at the organizational level. In concern, the results through characterizing the LAC with the IAD framework criteria indicate that considerations for social and inter-stakeholder group conflicts were often perceived as inadequately addressed. The presence of stakeholder involvement, delegative co-management, collective choice rules and 'medium' network transparency in the SES classification, gives a strong indication of organizational equity for decision making in the SES. Survey responses indicated overall support for environmental considerations and the ability to easily communicate decisions and what happened at the LAC meetings to their stakeholder groups. Addressing social considerations there were polarized responses, with comments citing inter-stakeholder group conflicts and inadequate or too much attention given to the issue.

4.5.2 Adaptability and precaution

Defined as the ability to respect uncertainty, plan to learn, design for surprise, and manage for adaptation (Gibson, 2006). From a resilience perspective, the capacity to incur a disturbance and continue to function without losing structural or functional integrity (McGinnis, 2011).

The current adaption and precaution characteristics are unlikely to aid in solving future challenges that may be necessary for achieving sustainable outcomes in the SCSLF. There is a clear indication that the long-term sustainability of the fishery is a main concern on the LAC and in the SES, however it is unclear how these concerns and future challenges will be dealt with and what it will mean for the different stakeholder groups. According to the SES framework classification of the fishery, there is a presence of adaptive management, extensive rules and regulations, and input controls that indicate precaution towards resource use and efforts as well as the type of management system. However, there is economic dependence, a high economic value with low market diversity and no market predictability data. One key factor may be an unknown adherence to multiple outcome recognition & planning. Recreational impacts and cultural value are not well understood. Survey results indicate that there is nearly unanimous acknowledgement that the sustainability of the fishery is a main concern but a majority of responses indicated that it is unclear how future challenges will be handled. Polarizing responses and comments indicated serious concerns and/ or content regarding the LAC's organizational structure and tools to adapt to future challenges. Only the commercial and recreational responses 'disagreed' that trade-offs from their sector may be necessary for the long-term sustainability of the fishery. These are the only two sectors that remove resource units (lobsters) from the SES, and these viewpoints may present concerns if future adaptations are necessary in those sectors to achieve sustainable outcomes. While the unwillingness to be adaptive is problematic in achieving sustainability (Folke et al., 2005), there is no indication that complacency among representatives will be an issue as there are extensive comments indicating a willingness to address concerns in general. Overall, while the fishery remains economically and productively stable with current precautions and management, the ability to adapt to future

challenges while maintaining this stability is largely unknown, and not understood by numerous key stakeholder groups.

4.5.3 Participation and democratic governance

The integrative qualities, organizational structure and implementation of the SCSLF governance system, including the LAC, provides a solid democratic foundation and an inclusive participatory approach. Integrating stakeholders in management can bridge-the-gap between traditional top-down governance approaches while increasing government legitimacy and the ability to manage conflicts (Folke et al., 2005). The governance structure and purpose of the LAC and CADFW, shown in *Figure 7* above, is organized to delegate top-down management authority with a bottom-up stakeholder decision-making committee. This is facilitated through regional CADFW management, linking the governance structure and aiding transparency through cooperation. This facilitation includes that of the LAC meetings and organization, additionally supported in cohesion with a lead professional facilitator. There was nearly unanimous agreement that the 'other stakeholder groups' on the LAC were represented fairly, but when asked about the fairness of their own stakeholder groups' representation, responses varied. Comments addressed concerns of economically oriented representative selection and focus, and while there are many environmentally engaged and non-consumptive stakeholders, measuring enjoyment and the benefits of a healthy habitat is less tangible against financial figures. Such benefits and enjoyment, often considered cultural ecosystem services, are difficult to define and contentious to value in monetary terms and have consequently been rendered invisible in most planning and management (Chan et al., 2012; Satz et al., 2013). Six representatives were in agreement that the LAC allowed them to understand other stakeholder group's viewpoints more thoroughly. Comments generally supported the idea that bringing together the stakeholders was more effective than not, and increased understandings of the other stakeholder viewpoints would not have happened otherwise. The ability to make well-informed decisions in fisheries management, is derived from the opportunity for stakeholders to engage in dialogue, reflection, a shared vision and a process of collective decision making (Garrett et al., 2012). While a degree of state regulation and control may be necessary in the co-management

of marine resources, integrated governance institutions and marine ecological systems have the potential to evolve towards ecological resilience and increased stakeholder cooperation through inter-connected benefits (Jones, Qiu, & De Santo, 2013).

4.5.4 Social-ecological system knowledge

The classification of the Southern California Spiny Lobster fishery is extensive and well defined although many data gaps exist. Knowledge within the fishery is also fairly well developed with a need for more integrated knowledge sharing. With Local Ecological Knowledge (LEK) well established in the recreational and commercial sectors, and Western Science & Management Knowledge (SMK) also present, the LAC aimed to integrate these two perspectives for managing the fishery. While local ecological knowledge may be both practical and scientific, how this knowledge is transferred into management systems is very important for sustainably managing fisheries (Hammer, Holmlund, & Almlöv, 2003). This may also be achieved through applying the conceptual model, represented in *Figure 8*, within research. Co-management efforts and organizations, such as the LAC and CADFW, can provide critical boundary or bridging functions between knowledge and action when managing marine resources (Österblom & Folke, 2013). This was achieved through the LAC, although there were concerns expressed regarding emphasis given to particular viewpoints. In a study conducted by Martin, McCay, Murray, Johnson, & Oles (2007), scientists greatly appreciated fishermen's knowledge but had little use for it compared to larger assessments and recognized a profound cultural and communication gap between each other. The LAC largely succeeded in minimizing these gaps, although the future science and management of fisheries will need to consider stakeholder knowledge and experience in much more depth (Garrett et al., 2012).

4.5.5 Components associated with sustainability within the SCSLF SES

In order to succinctly summarize certain SES components in the SCSLF that may associate with sustainable outcomes through this discussion analysis above, the following components are presented. This study has identified five components that may positively identify with achieving sustainability and sustainable outcome characteristics in the SCSLF, including: (i) delegative co-

management with the LAC, (ii) stakeholder involvement, (iii) the accumulated and shared knowledge within the SES, (iv) an interlinked and semi-transparent governance structure, and (v) extensive control rules that are regulated with high compliance.

These components in the SCSLF indicate a strong positive association with the sustainability criteria defined by Gibson (2005, 2006), Ostrom (2011), and McGinnis (2011). While there are no direct causal characteristics associated with sustainability in SES's, this discussion has attempted to further associate certain system characteristics with defined sustainability criteria. These identified components do not implicate sustainable outcomes within the fishery, but rather provide a guide for reevaluation of the current management structure within the SCSLF and for management practitioners in other fisheries. Continuous monitoring, management reevaluation, stakeholder involvement, and SES reclassification of the SCSLF should occur through applying the steps presented in the conceptual model for operationalizing SES research in management (see Figure 8 below). Utilizing these steps, a conceptual model will help guide researchers and practitioners towards achieving sustainable outcomes in fisheries.

4.6 The LAC's structure as a unique approach to fisheries co-management

As co-management occurs when stakeholders and managers work together to improve the regulatory process (Gutiérrez, Hilborn, & Defeo, 2011), the evaluated effectiveness of this process in the LAC has demonstrated its ability to raise the many collective concerns regarding the fishery and provide the means for productive discussion through facilitated dialogue. Continuous evaluation and adaption of a stakeholder involved management plan is necessary to adjust to feedbacks and continually updated social-ecological knowledge (Folke et al., 2005). Although there was considerable critical and often negative feedback from this study's survey regarding the approach the LAC uses to manage the fishery, the ability of the LAC to bring these discussions to a public format with facilitated dialogue has arguably significantly benefitted the fishery. It is unlikely any fishery management committee will be successful without initial challenges, but rather can contextually adapt and work with the stakeholders to continuously improve the social-ecological sustainability of the fishery. The potential of the LAC's structure to

facilitate the link towards avoiding traditional top-down management panaceas and rather provide a transparent collaboration leading to a contextually adaptive management plan is positive.

4.7 A protocol and heuristic conceptual model for research

A research protocol for analyzing a social-ecological system to understand management procedures for achieving sustainable outcomes is exemplified in this study and can be represented as an integral part of a more holistic conceptual model represented in *Figure 8*. This heuristic conceptual model illustrates a holistic approach for structuring research aimed at operationalizing the use of the Ostrom (2007, 2009) framework for practical fisheries management. Just as the Ostrom (2007, 2009) social-ecological system framework provided a workable and interpretive framework for conceptualizing complex social-ecological systems, this research model exemplifies a holistic approach and leaves an adaptive template for guiding social-ecological system research designed for practical management implementation. While this study does not intend to develop further management recommendations or monitoring protocols, the model elaborates on the further steps that are crucial for guiding the operationalization of research into practical management.

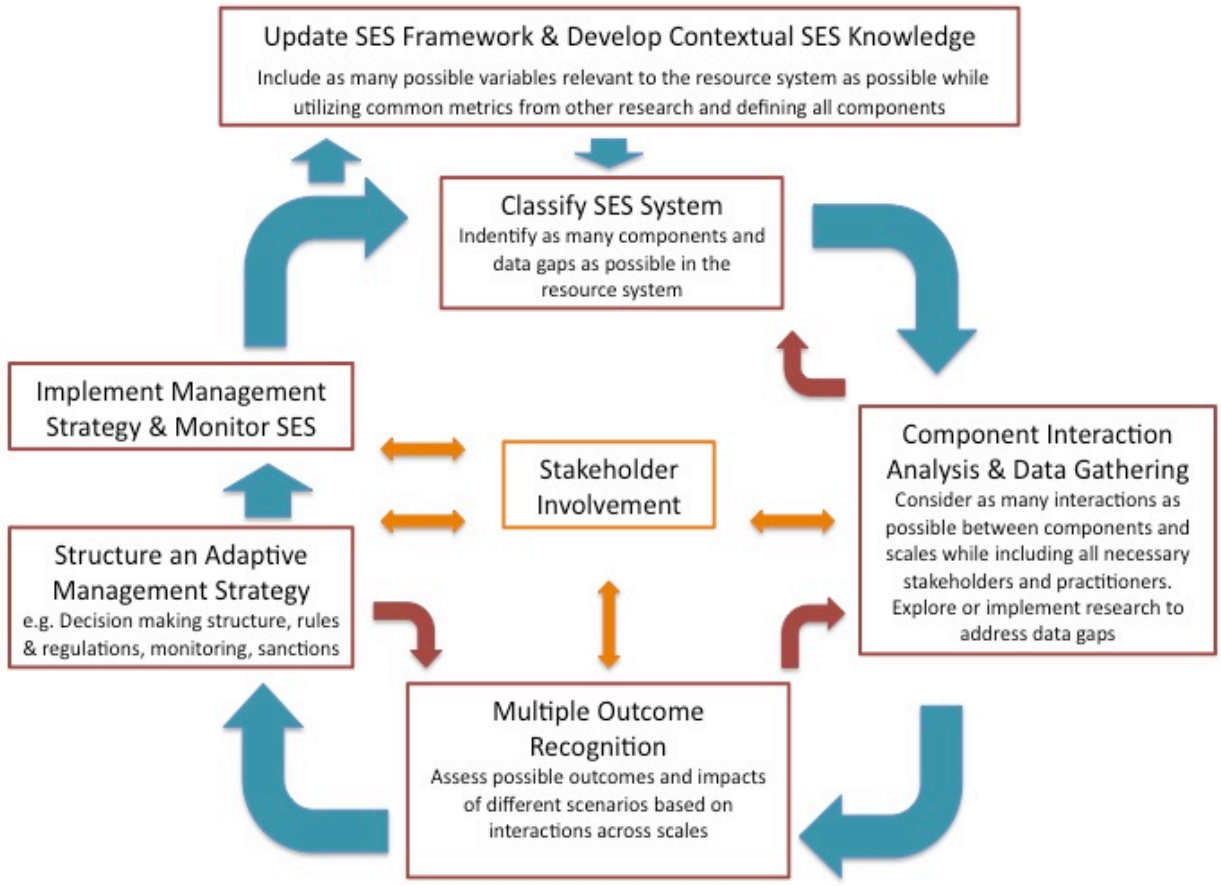


Figure 8. Illustrative conceptual model for research aimed at utilizing the Ostrom (2009) framework for operationalizing research into management. Red boxes represent each step, and flows between steps are shown with the larger blue arrows. Smaller red arrows represent system feedbacks between steps. Involvement of stakeholders in certain steps is indicated with orange arrows in the center of the model.

4.7.1 Model steps and overview

The heuristic conceptual model was developed over a reflective process of extensively evaluating current literature and critiquing the methodological approach and implications of this study and other peer-reviewed research. The illustrative model includes the following six steps for using the SES framework to gain comprehensive SES knowledge and analysis for management: (1) Update the SES framework to the resource sector or system in focus with comprehensive contextual knowledge, (2) Classify the specific SES in focus with the contextually updated framework to identify specific system components and data gaps, (3) Identify and

analyze as many system component interactions as possible while addressing and exploring data gaps, (4) Recognize the possibility for multiple system outcomes through component interaction analysis, (5) Design an adaptive management strategy based on the recognition of multiple outcomes and the knowledge acquired from related systems, (6) Implement management strategy and monitor the SES.

There are many ways of approaching or conducting each step within the model. Development of system knowledge can be done empirically through a literature review or first hand knowledge acquisition, shown in *Table 1* above. Identifying components or sub-systems within the system is the next step, which can be achieved through using classification frameworks such as the Ostrom (2009) SES framework, as demonstrated in *Table 4* above. Understanding interactions between SES variables requires an extensive empirical analysis of a system and requires multiple methodological approaches and research considerations (Ostrom & Cox, 2010; Ostrom, 2007). This may include but is not limited too: transdisciplinarity (Cundill, Fabricius, & Marti, 2005; Levin et al., 2012), stakeholder involvement (Garrett, MacMullen, & Symes, 2012; Reed, 2008), ecological and economic assessments (Berkes et al., 2006; van Putten, Lalancette, et al., 2013), extensive document and data analysis (Cox & Arnold, 2010; Halpern et al., 2008), social and institutional analysis (Agrawal, 2003; Ostrom & Cox, 2010; Ostrom, 2011), and multiple theoretical approaches (Miller et al., 2008). Multiple outcome recognition is an additional integral aspect of enhancing the potential for sustainably operationalizing research into management (Kittinger et al., 2013). Evaluating sustainability criteria should be included in monitoring through implementation. Continual reevaluation of the SES sustainability characteristics completes the loop within the model for then re-classifying the SES within future time and spatial scales.

While the model is structured around these focal steps, model feedbacks and stakeholder involvement are also included. Understanding system feedback drivers that create social-ecological stability are crucial for understanding how to manage the system sustainably through addressing causes rather than symptoms (Hughes, Carpenter, Rockström, Scheffer, & Walker,

2013; Österblom et al., 2013). Feedbacks between steps in the model allow for continual system reevaluation and the research consultation to understand these drivers. While these feedbacks occur in the SES, they also need to occur in the management that regulates the SES. These feedback considerations in the model may involve system modeling, stakeholder consultation, or various other predictive or experimental research methods. As the model steps are implemented over a time scale, considerations will need to feedback current assessments and data back into previous steps. Stakeholder involvement is incorporated into multiple steps, as prescribed as an integral aspect of operationalizing research to achieve sustainable outcomes (Folke et al., 2005; Kittinger et al., 2013). The involvement of stakeholders in management also reflects the core foundations of sustainability science (Kerkhoff, 2013; Miller et al., 2013), which is problem driven through consulting the affected stakeholders, and action oriented by engaging with stakeholders to best create contextual solutions.

4.8 Insights for future research

Drawing on insights from the methodological approaches, interviews and literature used in this study, four key recommendations for future research are presented. These four key recommendations for further research on SESs in lobster fisheries and related natural resource systems include: (i) further in-depth contextual interaction analysis of social-institutional settings, (ii) further expansion and defining of common metrics, common definitions, and case specific SES framework components, (iii) inter- & transdisciplinary research collaborations that aim to embrace multiple epistemological approaches for understanding interactions between as many variables and scales as possible in a SES, and (iv) comprehensive multiple methodological approaches to gaining information, analyzing interactions and assessing outcomes in SES's. These insights are represented in the heuristic conceptual model for operationalizing SES framework research into practical management, presented in *Figure 8.*

4.9 Implications for research in sustainability science

The foundations of this research have been to structure and analyze contextualized solutions in order to sustainably manage SESs. This has been in part response to ineffective governance panaceas and non-collaborative singular research perspectives that have neglected the complexity of integrated SESs. This has undoubtedly caused sustainability challenges, leaving practitioners and researchers with very few cases (fisheries) that can attribute a current 'sustainable' system state to certain components (drivers and feedbacks) of that system. As sustainability science aims to address these challenges through facilitating inter- and trans-disciplinary collaborations that find solutions through action-oriented research, this study has aimed to contribute to that vision. Finding contextualized solutions within SESs that address the sustainability of all relevant components will better suit a system rather then transferring a 'sustainable' solution from one system to another. However, aggregating the components from successfully managed systems will provide insights on how to contextually approach management between similar SESs. This study has demonstrated that research practices such as stakeholder involvement, trans-disciplinary collaborations and multiple methodological approaches will continue to advance the ability of sustainability science research to find contextually derived sustainable solutions to managing SESs.

5 Conclusion

A social-ecological system framework for the classification of lobster fisheries has been developed and thoroughly defined through a systematic literature review on social-ecological system research in lobster fisheries, expert interviews and prior knowledge of the SCSLF. Through defining each new framework variable with literature review data and incorporating existing components and their definitions from other SES research frameworks, incremental steps were made towards utilizing common metrics for inter-fishery or related SES research and data comparisons. The literature review indicated that there are many differing research

approaches, focal areas, social-institutional settings, and management techniques used concerning lobster fisheries. There is a strong emphasis on addressing sustainability and taking governance perspectives in the research. Application of the lobster fishery social-ecological system framework was implemented on the SCSLF to demonstrate how classifying the fishery's system components identifies data gaps and illustrates the complexity of interactions and the necessity for understanding them to implement management that aims to achieve sustainable outcomes.

The contributions and insights from this study have cumulated into the development of a heuristic conceptual model for utilizing the Ostrom (2009) SES framework for operationalizing research into practical management in lobster fisheries and related marine natural resource systems. These contributions include the first summarized review of lobster fishery characteristics and lobster fishery SES research, an updated and defined SES framework for classifying a lobster fishery as a SES, contextual interaction and outcome analysis of the LAC for improved management, and a demonstrated holistic methodological approach for research in social-ecological systems. In addition, key recommendations for further research are presented for research focused on social-ecological systems in lobster fisheries and related natural resource systems. In final reflection, marine fisheries are the last natural resources that we have to hunt as a modern society, but have the potential to be some of the first resources that we manage sustainably.

Appendix. 1- 10

Appendix 1. Updated lobster fishery SES framework definitions and references.

Components	Definitions	References
GS Governance System		° Definition source(s) ∞ Lobster fishery case study including attribute(s) ϕ Source includes subsequent tier attribute definitions and/or examples
GS1 Governance Policies		
GS1.1 Marine Protection Area (MPA) policies	Policies surrounding districts with different, clearly defined permitted or not permitted, activities.	(Center for Ocean Solutions, 2009)°(Hearn, 2008)∞
GS1.2 National sanctions	National penalty, rule enforcement or regulation policies.	(Brewer, 2012) ∞
GS1.2.1 Endangered species policies	Specie(s)and/or habitat may become protected or unharvestable due to declining population. Usually a 'trigger' or decision rule.	(Butler, Tawake, Skewes, Tawake, & Mcgrath, 2012)∞
GS1.3 Spatial Zoning	National spatial use/ permitting/ restriction laws	(Brewer, 2012) ∞
*GS2 Organizations/Institutions**	Institutions recognized by external actors/ authorities facilitating formal structured interactions among actors affected by them.	(Basurto et al., 2013; Kittinger et al., 2013)°
GS2.1 Government organizations	Institutions with governmental authority mandated to protect the public trust.	(Basurto et al., 2013)°
GS2.1.1 National Level	Institutions mandated to protect and communicate with local level and national level	NA
GS2.1.2 Regional level	Institutions mandated to protect and most directly involved in a specific area. Report and communicate mostly to regional level.	NA
GS2.1.3 Local Level	Institutions mandated to protect and most directly involved in a specific area. Report and communicate mostly to local level.	NA
GS2.1.4 Support Enforcement	Institutions with a mandate for monitoring and enforcement of rules to access and use the resource.	(Basurto et al., 2013)
GS2.1.5 Support Funding	Institutions with a mandate to provide subsidies or credit.	(Basurto et al., 2013)
GS2.1.6 Restoration efforts	Institutions with a mandate to address provision problems such as the restocking of natural populations.	(Basurto et al., 2013)
GS2.2 Nongovernment organizations	Institutions without government authority mandated to protect public trust.	(Basurto et al., 2013)
GS2.2.1 Environmental Organizations	Nongovernmental organization advocating for science and/ or policies in regarding lobster or the resource system.	NA
GS2.2.2 Research Organizations	Nongovernmental organization conducting research on lobster or the resource system.	NA
GS2.2.3 Social/ Welfare Organizations	Nongovernmental organization involved in social dynamics surrounding fishery.	NA

GS2.2.4 Restoration efforts	Nongovernmental organization conducting ecological restoration for lobsters or the resource system.	NA
GS3 Decision making structures	How decisions are made within a given institution(s), in which there may be varying levels of interactions.	(Hilborn, Orensanz, & Parma, 2005)°
GS3.1 Network structure		
GS3.1.1 Vertical	Link actors with other organizations or the state across levels.	(Basurto et al., 2013; Marin, Gelcich, Castilla, & Berkes, 2012) °
GS3.1.2 Horizontal	Link actors with each other to act collectively for a common purpose.	(Basurto et al., 2013; Marin et al., 2012) °
*GS3.1.3 Transparency**	Degree of open access to information.	(Gilman & Kingma, 2013)°∞
GS3.2 Management Strategy	Meta-level decisions on the objectives, implementation framework, and the relevant knowledge base for decisions and implementation.	(Degnbol & Mccay, 2007)°
GS3.2.1 Co-management	A range of institutional arrangements often depicted as a scale based on the relative proportions of responsibility and authority shared between state and stakeholders.	(McConney & Baldeo, 2007)°∞ϕ
GS.3.2.1.1 Consultive	Government interacts often but makes all of the decisions.	*See Appendix 6*
GS.3.2.1.2 Collaborative	Government and stakeholders work closely and share decisions.	(Pérez-Ramírez, Ponce-Díaz, & Lluch-Cota, 2012) ∞ (LAC, See Figure 7)
GS.3.2.1.3 Delegative	Government let formally organized users/ stakeholders make decisions.	(Brewer, 2012)∞
*GS3.2.2 Adaptive management**	Where ecological knowledge and institutional arrangements are tested and revised in a dynamic, ongoing, self-organized process of learning-by-doing.	(McConney & Baldeo, 2007)°∞ (Castilla & Defeo, 2001) ∞
*GS3.2.3 Self-governance/ Community-based**	Community or user organized management.	(Ernst et al., 2013)∞ (Wilson, Yan, & Wilson, 2007) ∞
*GS3.2.4 Stakeholder Involvement**	Where individuals, groups and organizations have a, formal or informal, active role in making decisions that affect them.	(Reed, 2008)° (Garrett, MacMullen, & Symes, 2012)∞ (Butler et al., 2012) ∞
GS3.2.4.1 Committee/ Board/ Council	Stakeholders are organized, often with elected representatives, through a formally organized decision making or consulting group	(LAC see Figure 7)∞ (Butler et al., 2012)∞
GS3.2.4.2 Open forum/ Public comment	Stakeholders are involved through open, public engagement.	(Garrett et al., 2012) ∞
GS3.2.4.3 Research Involvement	Stakeholder knowledge or insights is conducted through official research mechanisms rather than direct inclusion in management.	NA
*GS3.2.5 Multiple outcome recognition and planning**	Management strategies recognize and plan for the possibility of multiple outcomes within the system.	(Garrett et al., 2012) ∞ (Kittinger et al., 2013) °
GS4 Rules & Regulations	Formal and informal rules in practice shaping human behavior and governing social interactions. Usually there is a formal sanctioning mechanism if not followed.	(Basurto et al., 2013)°
GS4.1 Constitutional Rules	Process in which collective-choice procedures are defined and legitimized, usually results in a state or federal fisheries guideline/ law	(Basurto et al., 2013) ° (McGinnis, 2011)°
GS4.2 Collective Choice Rules	The processes through which institutions are constructed and policy decisions made by actors authorized (or allowed) to do so.	(Basurto et al., 2013) ° (McGinnis, 2011)°

GS4.3 Operational Rules	Implementation of practical decisions by individuals authorized (or allowed) to take these actions.	(Basurto et al., 2013) ° (McGinnis, 2011)°
*GS4.4 Commercial Resource Regulations**	Rules & regulations governing the commercial use sector.	NA
GS4.4.1 Input controls	Regulations limiting efforts and access put into harvesting the resource system.	(Wilson, Acheson, & Johnson, 2013) ∞(van Putten et al., 2013) ∞
GS4.4.1.1 Season	Yearly time frame(s) during which harvesting is allowed.	(Wilson et al., 2013) ∞
GS4.4.1.2 Licenses/Permits	Official permission pertaining to harvesting and/ or gear usage.	(Gourguet et al., 2013)∞
GS4.4.1.3 Equipment/Gear allowed	Tools used to harvest or access resource system.	(Ernst et al., 2010)∞
GS4.4.1.4 Harvestable Size Limits	Minimum and/ or maximum size limit of a harvestable lobster.	(Wilson et al., 2013) ∞
GS4.4.1.5 No berried females	No harvesting of actively reproductive females, or females with visible eggs attached.	(Wilson et al., 2013) °∞
GS4.4.1.5.1 V-Notch	Intentionally marked and released reproductive females. Marked by cutting a V-notch in the tail for future identification as a reproductive female.	(Wilson et al., 2013) °∞
GS4.4.2 Output controls	Regulations limiting what is taken out of the resource system	(Punt et al., 2012) °∞
GS4.4.2.1 Total Allowable Catch (TAC)	Fishery, zone, or individually allocated catch amounts during a given time duration	(van Putten et al., 2013) °∞
GS4.4.2.2 Individual Transferable Quotas (ITQs)	Individually owned and transferable harvestable amount limits	(Bradshaw, 2004) °∞
GS4.4.3 Access	Who has the right to access or harvest in specific areas of the resource system	NA
GS4.4.3.1 Shared exclusive territory	Specific groups or multiple individuals share access and/ or catch amounts in a given area.	(Wilson et al., 2007) ∞
GS4.4.3.2 Individual spot ownership	Specific individuals own the right to access specific areas and /or catch amounts within them.	(Ernst et al., 2013)°∞
GS4.4.3.3 Open	No access restrictions in access or effort.	(Martinet, Thébaud, & Doyen, 2007)° (Castilla & Defeo, 2001) ∞
GS4.4.4 Decision Rules	Specifies what data will be examined, what will "trigger" the rule, and what will then happen.	(Bentley, Breen, Kim, & Starr, 2005)°∞
GS4.5 Recreational Resource Regulations	Rules and regulations governing the recreational use sector.	(Sharp, 2005)∞ϕ
GS4.5.1 Input controls	Regulations limiting efforts and access put into harvesting the resource system.	(Eggleston, Parsons, Kellison, Plaia, & Johnson, 2008)∞ϕ
GS4.5.1.1 Harvestable Size limits	Minimum and/ or maximum size limit of a harvestable lobster.	NA
GS4.5.1.2 Licenses	Official permission pertaining to harvesting and/ or gear usage.	NA
GS4.5.1.3 Trap soak time	Time duration allowed to implement lobster traps or catching devices.	NA
GS4.5.1.4 Equipment/ Gear allowed	Type of gear allowed when catching lobster.	NA
GS4.5.1.5 Season	Yearly time frame(s) during which harvesting is allowed.	NA
GS4.5.2 Output Controls	Regulations limiting what is taken out of the resource system.	NA
GS4.5.2.1 Daily limit	Total amount of lobsters allowed to harvest per day.	NA

GS4.5.2.2 Season limit	Amount of lobsters allowed to harvest per season.	NA
GS5 Monitoring	Local actors or those legitimized by them are responsible to observe and report changes in the SES.	(Basurto et al., 2013) °
GS5.1 Social	Local actors, or outsiders legitimized by them, observe that other actors comply with agreed-upon behavior in the use of the resource system and units	(Phillips, Kriwoken, & Hay, 2002)∞
GS5.2 Biophysical	Local actors, or outsiders legitimized by them, observe the condition of the resource system and units	(Hearn, 2008) ∞ (Basurto et al., 2013) °
GS6 Sanctions	Penalty or condition for disobeying rules or regulations	NA
GS6.1 Graduated Sanctions	Actors who violate operational rules are given a sanction coherent with its seriousness and the times the offense has been committed	(Basurto et al., 2013) °
	[Adapted from (Ostrom, 2009) & (Basurto et al, 2013)]	° Definition source(s) ∞ Lobster fishery case study including attribute(s) ϕ Source includes subsequent tier attribute definitions and/or examples

Components	**Definitions**	**References**
RS1 Sector	Characteristic(s) of a resource system that distinguishes it from other resource systems	(Basurto, Gelcich, & Ostrom, 2013; Ostrom, 2007)°
RS1.1 Lobsters (Species)	Specific specie(s) of lobster within the system	
RS2 Clarity of system boundaries	Biophysical characteristics that make feasible for actors to determine where the resource system starts or ends	(Basurto et al., 2013)°
*RS2.1 Recruitment Sourcing**	Origin and transport mechanisms of larval stage lobster	(Bruce, Griffin, & Bradford, 2007; Gaughan, 2007; Nursey-Bray et al., 2012) ϕ∞°
RS2.1.1 Within governance system boundaries		NA
RS2.1.2 Outside of governance system boundaries		NA
RS2.2 Zoning Districts/ Marine Protected Areas	Districts in which different activities, permitted or not permitted, are clearly defined	(Center for Ocean Solutions, 2009)° (Hearn, 2008)∞
RS2.3 International Waters	RS is within, shares, or overlaps in international waters	(Seijo, 2007) ∞
RS3 Size of resource system	Absolute or relative descriptions of the spatial extent of a resource system	Basurto et al., 2013)
RS3.1 Carrying capacity	The maximum number of resource units that the biophysical setting can sustain indefinitely	Basurto et al., 2013)
RS4 Human-constructions	Human built or placed objects or structures in the RS	NA
RS4.1 Human access structures	Structures built to access, or interacting with the RS	NA
RS4.2 Artificial Habitat	Structures intentionally deployed on the seafloor to influence biological or physical processes	(Briones-Fourzán et al., 2007)° ∞

RS5 Productivity of system	Rate of generation of units of biomass determined by production-consumption rates per unit of time, surface, or volume	(Basurto et al., 2013)ϕ
RS5.1 Stock Status	Rate of generation of units of biomass as determined by production in a given year	NA
RS5.2 Biophysical Properties	Upwelling, biogeographic or geomorphological factors affecting the generation of units of biomass	NA
RS6 Equilibrium properties	Characterization of the type of attractor of a resource system along a range from one to multiple (chaotic) attractors	Basurto et al., 2013)
*RS7 Predictability of system dynamics**	Degree to which actors are able to forecast or identify patterns in environmentally driven variability?	(Kittinger et al., 2013; Ostrom, 2009)
RS8 Storage characteristics	Degree to which the resource units can be held captive until harvested	Basurto et al., 2013)
RS9 Location	Spatial and temporal extent where resource units are found by actors	Basurto et al., 2013)
	[Adapted from (Ostrom, 2009) & (Basurto et al, 2013)]	° Definition source(s) ∞ Lobster fishery case study including attribute(s) ϕ Source includes subsequent tier attribute definitions and/or examples

Components	Definitions	References
RS Resource Units		
*RS1 Resource unit mobility**		
RS1.1 Recruitment	Open-water larval-stage settlement to bottom-dwelling adulthood habitat.	(California Department of Fish & Wildlife, 2011) °∞
RS1.2 Nocturnal movement	Nightly movement patterns.	(California Department of Fish & Wildlife, 2011) °∞
RS2 Growth or replacement rate	Absolute or relative descriptions of changes in quantities (x) of resource units over time (t)	(Basurto, Gelcich, & Ostrom, 2013) °
RS3 Interaction among resource units	Interactions among resource units during different life stages affecting the future structure of the population.	(Basurto et al., 2013)°
RS3.1 Reproduction	Spawning, the transfer of a sperm packet from a male to female lobster.	(California Department of Fish & Wildlife, 2011) °∞
RS4 Economic dynamics	Economic factors associated with lobsters.	NA
RS4.1 Economic Value	Value of resource units in relation to the portfolio of resources available to actors	(Basurto et al., 2013)°
RS4.1.1 Live	Value of a lobster transported and sold live.	NA
RS4.1.2 Frozen	Value of a frozen lobster tail.	NA
RS4.2 Market predictability	Predictability of economic dynamics effecting demand and value.	NA
RS4.3 Market diversity	Number and distribution of buyers or demand potential.	NA
*RS 4.4 Recreational value**	Value of industry surrounding, or goods derived from recreational and subsistence harvesting.	NA

RS5 Cultural value	Attributed social value to the fishery.	NA
RS5.1 Indigenous/ Subsistence Value	---	(van Putten et al., 2013) ∞
RS 5.2 Recreational value	---	(Sharp, 2005) ∞
RS6 Number of units (Harvestable Population)	Number of lobsters harvested or that could be potentially harvested.	(Basurto et al., 2013)°
RS6.1 Legal Harvest Rate	Allowed, legally permitted and reported harvest rate.	NA
RS6.2 Illegal, Unreported, Unregulated (IUU) fishing	Rate and/ or social-ecological system implications of illegal fishing.	(Österblom & Folke, 2013) ° (Brill & Raemaekers, 2013) ∞
RS7 Distinctive Characteristics	Markings and/or behavioral patterns that can be identified in resource units and affect actors' behavior toward them.	(Basurto et al., 2013)°
RS7.1 Molting	The process of shedding the exoskeleton, preceded by the growth of a new soft shell, eventually hardening and replacing the previous shell.	(California Department of Fish & Wildlife, 2011) °
RS7.2 Artificial Female Markings	Artificially marked reproductive female lobsters.	NA
RS7.2.1 Tail V-notch	V-shaped notch cut into a caught, and then released, female lobster for future identification as a reproductive female.	(Wilson, Acheson, & Johnson, 2013) °
RS8 Spatial and temporal distribution	Allocation patterns of resource units across a geographic area in a particular time period	(Basurto et al., 2013)°
RS8.1 Seasonal distribution	Seasonal movement or migration patterns	(Seijo, 2007) ∞ (Eggleston, Parsons, Kellison, Plaia, & Johnson, 2008) ∞
	[Adapted from (Ostrom, 2009) & (Basurto et al, 2013)]	° Definition source(s) ∞ Lobster fishery case study including attribute(s) ϕ Source includes subsequent tier attribute definitions and/or examples

Components	**Definitions**	**References**
A Actors		
A1 Number of actors*	Number of actors affecting decision-making processes related to harvesting in the fisher	(Basurto, Gelcich, & Ostrom, 2013) °
A1.1 Commercial	Actors harvesting the resource as part of their economic livelihood.	NA
A1.2 Recreational	Actors harvesting the resource for social and/ or recreational benefit.	NA
A1.3 Non-consumptive recreational	Actors utilizing the resource for social and/ or recreational benefit without consuming the resource.	NA
A1.4 Indigenous peoples, subsistence harvesting	Harvesting of the resource by those who are dependent on it for survival or for maintaining cultural tradition.	NA

A1.5 IUU actors	Illegal, unreported, or unregulated (IUU) harvesting of the resource.	(Brill & Raemaekers, 2013) ∞ (Österblom & Folke, 2013) ˚
A2 Socioeconomic attributes of actors	Characteristics of actors related to social and economic dimensions affecting fishing dynamics.	(Basurto et al., 2013) °
A2.1 Socioeconomic resilience	Ability to cope financially with stress and changes in the social-ecological system, while retaining structure, functioning, self-organization.	(van Putten et al., 2013) °∞
A2.1.1 Insurance Availability	The ability to redistribute and manage the costs of financial risks and shocks.	(Sethi, 2010) °
A2.2 Operating Costs	Costs of Gear or Equipment, license, access and/ or costs necessary for harvesting the resource.	(van Putten et al., 2013) ∞
A2.2.1 Replacement Rates	Cost of maintaining operation over time.	NA
A3 History of use	Past interactions that affect current actor's behavior and fisheries dynamics.	(Basurto et al., 2013) ° ϕ
A3.1 Crisis	Current use patterns triggered by a human or biophysically caused off- patterned event.	(Ernst et al., 2013) ∞ (Martinet, Thébaud, & Doyen, 2007)
A3.2 Duration	Determined as the length of time the resource has been in use.	NA
A4 Location	Physical place where the actors are in relation to the resource itself and the market.	(Basurto et al., 2013) °
A4.1 Ports/ Harbors/ Built Infrastructure	Artificial constructions built, and usually controlled, to access the resource system.	NA
A4.2 Beaches/ Non-built/ natural access	Natural access to the resource system.	NA
A5 Leadership/entrepreneurship	Actors who have skills useful to organize collective action and are followed by their peers.	(Basurto et al., 2013) °
A6 Norms/social capital	Degree by which one or several individuals can draw upon or rely on others for support or assistance in times of need.	(Basurto et al., 2013) °
A6.1 Spatially based	Dependent on location.	NA
A6.1.1 Clubs/ Organizations/ Chapters	Social organization(s) based at a physical location.	(Brewer, 2012) ∞
A6.2 Non-spatially based	Not dependent on location.	NA
A6.2.1 Online format, blogs, social media, publications	Digitally or print based social organization.	NA
A7 Knowledge of SES/mental models	Degree to which stakeholders understand and make sense of the characteristics and/or dynamics of the SES.	(Basurto et al., 2013) ° (Castilla & Defeo, 2001) ∞
A7.1 Traditional Ecological Knowledge (TEK)	Practical skills and wisdom developed at a local scale through earning livelihoods from the environment, usually over successive generations.	(Butler et al., 2012) ° ∞
A7.2 Western Science and Management Knowledge (SMK)	--	(Martin, McCay, Murray, Johnson, & Oles, 2007) °
A7.3 Local Ecological Knowledge (LEK)	Knowledge based on personal, shared and inherited experience; also including social aspects embedded in the social-ecological system.	(Basurto et al., 2013) ˚
A7.4 Knowledge Sharing/ Social Learning*	Actors' fishing practices allow them to learn characteristics of the resource at sufficiently rapid rates leading to behaviors affecting the state of the resource.	(Basurto et al., 2013) ° ϕ
A8 Importance of resource		NA
A8.1 Economic dependence	The resource constitutes a source of monetary income and plays a major role in fishers' ability to sustain their livelihoods.	NA

A8.2 Cultural dependence	The resource constitutes a source of cultural values, practices, and services, and plays a major role in the fishers' ability to sustain their livelihoods.	NA
A9 Technology used		(Basurto et al., 2013) °
A9.1 Homogeneity	Degree by which fishers use the same harvesting technology.	NA
A9.2 SCUBA allowed for commercial gear recovery	Lost or damaged gear can be recovered through SCUBA diving.	
	[Adapted from (Ostrom, 2009) & (Basurto et al, 2013)]	° Definition source(s) ∞ Lobster fishery case study including attribute(s) ϕ Source includes subsequent tier attribute definitions and/or examples

Appendix 2. SCOPUS – Database search string

TITLE-ABS-KEY ((lobster* AND fisher*) AND (management OR system* OR platform* OR framework* OR committee* OR governance OR board* OR stakeholder*) AND (social OR ecological) OR (SES))

Appendix 3. Survey response comments.

(1) "It is easy to communicate the decisions, as well as what happens at the LAC meetings to your constituents."	**Commercial**: Very easy, unfortunately the (commercial) representatives did not. It is much easier for one to push ones agenda if one keeps others in the dark. I kept 40 guys apprised throughout the LAC nonsense even though I was an alternate. **Recreational**: It's a very straightforward process, and my constituents spend a lot of time conversing on the issues related to the lobster fishery. So it went well for us. **Non-consumptive**: I struggled with this. It was hard to summarize the many complicated factors we discussed each time. **Environmental**: The meeting notes made this particularly helpful. **Governmental**: Facilitators, meeting summaries and CDFW accessibility supported constituent outreach.
(2) "The LAC has allowed for easier engagement with other stakeholders."	**Recreational:** Some LAC Appointees were very receptive to collaboration, some were seemingly reticent to contribute and others were indifferent. Fortunately, my experience with the LAC (few exceptions) was favorable. We had very good interaction with the scientists, and with other user groups. There will always be a separation of the groups to a point, but we had a great understanding of the entire groups' overall desires: To keep the lobster fishery open, and viable. **Non-consumptive:** Groups that demonstrated engaged commitment to collaboration became more understandable. **Environmental:** It provided a forum for discussions to happen across stakeholders, where folks may not have the time or willingness to get together and discuss lobster management issues otherwise. **Marine Science**: Certainly the LAC made

	it far easier to engage with others about lobster use, by bringing us together. Apart from that the discussions were kept on track allowing everyone to participate.
(3) "Your stakeholder group is represented fairly on the LAC."	**Commercial:** Two of the three commercial reps only represented their interests and the third is/was to green to make moves. **Recreational:** I felt we had good representation. Only my constituency can answer this question. I did emphasize being balanced with my personal perspectives and was receptive to offer perspectives to the LAC by divers with grossly different viewpoints. **Non-consumptive:** Financial interests have greater clout in these discussions even though their numbers are smaller then the number of non-consumptive recreational users of the ocean. Active hunting interests have a greater voice than conservation minded recreational users (whose enjoyment of a healthy habitat cannot me measured.) **Environmental:** With just one environmental representative and one alternate, it made negotiations on contentious areas challenging, especially when I had a divergent viewpoints from other LAC members and if my alternate was absent. **Marine Science**: The LAC administration seemed to rely mostly on one source of information for scientific advice, and did little to solicit it from other sources.
(4) "Other stakeholder groups are represented fairly on the LAC."	**Commercial:** I feel that no other groups can comment on the commercial side of things as we are the only group that can participate in all facets**. Recreational:** Those who stuck it out did a good job. A few left the process early, and they were going to be less influential and less knowledgeable, so their was no great loss in them not being at the table. Interpretation of "fairly" is deeply subjective.
(5) "It is difficult to work in a group the size of the LAC."	**Commercial:** The size of the group was fine **Recreational:** We worked together very well. I was able to find some common ground with each and every person on the LAC. maybe not on everything, but we did well. I was pleased with the number of LAC Appointees and the diversity of representation. **Non-consumptive:** 12 representatives, with professional facilitation, we're usually able to work well. Non-collaborative individuals can derail any group if they decide to, whether the grounded is larger or smaller than 12. It was challenging when alternates were present and highly active as this made up to 20 in the working group. **Environmental:** I think the size was great - enough folks to represent viewpoints across sectors (with the exception of the environmental seat). It was much more manageable than large stakeholder groups that I've previously served on, like the South Coast Regional Stakeholder Group in the MLPA. And, I've also been part of smaller stakeholder groups for State Water Resources Control Board policy implementation, where members had to take on a lot of work because of the small group size and areas of expertise seemed to be missing. **Marine Science**: There are some difficulties (e.g. allowing everyone a chance to speak their mind) but overall the group worked well together.
(6) "The LAC is too small and should incorporate more stakeholders and/or representatives."	**Commercial:** The more folks on a given panel the more difficult the process and agreements become, smaller is better. **Recreational:** See above question referencing LAC**.** It was the right size group to sit down and work together. Half the reason the MLPA was a disaster in its' implementation was the sheer size and the volume of stakeholders who had little real understanding of the coastal ecosystem and its' resiliency,

	and even more importantly how bad decisions on MPA boundaries hurt many fishermen and took key public access from the elderly and children, and curtailed a lot of handicapped access. The LAC was MUCH BETTER. **Environmental:** I think the size was fine, but felt there should have been two-three environmental representatives. **Marine Science:** The LAC should not be bigger, but could develop a program to assist with public comment so that more stakeholders in each group could communicate with the representatives.
(7) "Having representation on the LAC has helped your constituency better organize or communicate."	**Commercial:** Not in any way, see above. We are more divided now than before the start of this thing. **Recreational:** We have good communication and support from our constituency. We overall tend to be very understanding of the lobster fishery, as it means a lot to us. **Environmental:** We were already well-organized and in regular communication, but without representation on the LAC, we would have been less tuned into the discussion/planning.
(8) "The LAC has the proper tools and organizational structure to adapt to future challenges the fishery may face."	**Commercial:** Absolutely not. The make up of the current LAC will not be able to accomplish anything moving forward. Its widely understood that the environmental interests and universities wield a large stick in this forum, and have the funding to further their views **Recreational:** Especially pleased with the flexible and adaptive nature of the LFMP framework. The members of the LAC worked together and recognized certain strong points in the lobster fishery, and places in which we could strengthen the fishery for the long term future. The LAC worked well in this regard, there would be no reason to believe it would not work together in the future well also. All the stakeholders who really put forth proposals and worked to find common ground understand the fishery and the people tied to it very well. The knowledge base was excellent overall. **Non-consumptive:** With professional facilitation I believe more can be accomplished. **Environmental:** The LAC seems to be structured as an advisory group, but not a decision-making group. As such, we have to rely on tools and resources provided by DFW and other experts. Therefore, I'm not sure we are structured appropriately to continue gathering in the future. There also was no clear expectation laid out by DFW that we could continue to function as a group after our meetings were completed. However, I think there is likely interest among many LAC members to continue collaboration, even if it's just informally. **Governmental:** Not sure if this means the LAC will remain an active body into the future of the fishery.
(9) "It is clear how future fishery challenges will be handled with the LAC."	**Recreational:** We KNOW lobster. There would be some disagreements on how to move forward if there was a serious need to alter the fishery. At this time, with the changes we have already agreed upon, the chances of a failure of any kind in the fishery is highly unlikely. Agree... with the caveat that, the LFMP does not include references to predetermined management actions. Instead, the LFMP references indicators and options. The adaptive review process, with some basic controls set aside for possible fishery protections if needed will work much better than the MLPA result of closed areas, which are not as reactive and adaptive. **Environmental:** We were provided many options for future lobster fishery management by DFW, but it seemed clear that DFW and the Fish and Game Commission would make any relevant decisions to advance the sustainability of the fishery when that time

	comes. The LAC seemed more structured to deal with immediate challenges that could be changed before or as the FMP is adopted (not adaptive management challenges in the future). **Governmental:** Again, unsure if the LAC was ever envisioned as a future advisory body. I think the future roles of the Fish and Game Commission and CDFW with respect to the fishery are clear.
(10) "The long term sustainability of the fishery is a main concern."	**Recreational:** NO-NO-NO-NO-NO! Fisheries management plans should never consider one reference to sustainability as a main concern. All references to time trends should be factored into the plan with equal significance. Marine ecosystems are historically dynamic and unpredictable... and "apparently predictable" by our perceived anecdotal or current scientific understanding. We are not that good (be humble). Reference fisheries the embryonic management ideologies from thirty years ago. Forty years into the future, society will likely chuckle our lack of understanding just the same. No one wants an empty ocean. Everyone wants lots of lobster; either lots to catch, or lots to buy and eat. **Environmental:** It seemed to be a primary concern of most of the stakeholders participating in the LAC. For one constituency, the priority concern seemed to be access to recreational opportunities over the long-term sustainability of the fishery. **Marine Science:** I'm not certain if the discussions and recommendations will amount to change in the regulations that are necessary to ensure sustainability.
(11) "Social issues are adequately taken into consideration on the LAC."	**Commercial:** As it relates to commercial interests this couldn't be further from the truth. The Dept. may have sent out their survey but if that was the plan it should have been done from the beginning. There are many different operations that will be adversely impacted by this 300 trap/stacking nonsense and the public will not see the so-called benefits the Dept. has preached. Compaction on the beach will grow significantly I'd suspect. **Recreational:** While nothing is perfect, and more time may have been beneficial, there was already some time not utilized well, so overall, we did very well with the time allotted in the end. User group outreach and education was good, and worked within the timeframe given. **Environmental:** The meetings were very adaptable, and DFW was open to feedback, especially from the fishing community. DFW improved as the LAC progressed with meeting notice and preparation - sometimes early on, busy schedules of the non-consumptive community were not considered when planning for meetings. **Governmental:** Too much time on the commercial sector and not enough on the sport harvest sector - lots of unresolved social aspects.
(12)"Environmental issues are adequately taken into consideration on the LAC."	**Commercial:** Of course they are. Who in the hell came up with 'non-consumptive recreational?' **Recreational:** The FIRST thing established was that the lobster fishery was very sound and robust. This truth was never upended, and the environmental concerns which could be directly addressed by the LAC were taken seriously, and we got good consensus on making some positive changes; ie removal of lost traps via scuba for the commercial fishermen. **Non-Consumptive:** It's easier to quantify the sport and commercial hunting than environmental goals and challenges. We like numbers and the numbers involved with environmental concerns are complicated. **Environmental:** Environmental issues were integrated to most of the consumptive community discussion areas, but they were not given specific areas on the agenda for discussion.

(13) “Being a part of the LAC has helped you better understand the biology and/or ecology of the CA Spiny Lobster.”	**Commercial:** I've learned nothing new. **Recreational:** Matt Kay did an excellent job of presenting his research and findings. Appreciated. Additionally, I was pleased that his discoveries often paralleled my anecdotal/ practical understandings. I am what one would consider a 'lobster whisperer'. Anything to learn a bit more about my local lobster, I welcome that information. **Environmental:** I was very familiar with the biology & ecology of spiny lobster before this process, but it helped me understand that management processes and challenges on both DFW's and stakeholders ends of the spectrum. **Marine Science:** There are always things to learn from others, particularly those that spend so much time on the water.
(14) “The LAC has helped you to understand the other stakeholder’s viewpoints more thoroughly.”	**Commercial:** I have been very involved for over 5 years now in terms of representing commercial lobster interests, nothing new regarding the other interested parties. **Recreational:** Ultimately, every LAC Appointee came to the table with the common desire for a healthy fishery and enhanced interactive opportunities. We learned a few VERY IMPORTANT things from the LAC: 1. There is no such thing as a non-consumptive user. Either people utilize lobster, or they do not. But those who interact with lobster- they ALL utilize lobster.2. 'Non-Consumptives' wanted nothing to do with paying a fair share for lobster research studies. They wanted the recreational and commercial fishermen to foot the bill thru higher fees, whilst they reap the benefits of closed areas to take.3. The least productive part of the entire LAC process was the presentation from the Center for Ocean Solutions. A nice catalog, with zero specifics, and a complete lack of the specific knowledge required to make informed policy decisions on the lobster fishery. Their funding was a waste of taxpayer funds. All the general protocols and methodology they proposed was already being utilized by folks with a much more in depth specific knowledge of the lobster fishery as a whole, and its' impact to the people of the state; fishermen, non fishermen, and lobster connoisseurs. **Non-consumptive:** Facilitated meetings over 18 months allowed me the see the complexity of each stakeholder group. Even years of reading about it could not do that. **Environmental:** I think the LAC served to bring together diverse stakeholders and helped folks discuss various viewpoints. It was hard to get a sense of whether the viewpoints brought by LAC members were tempered by the individuals serving on the committee, or whether they truly reflected the perspectives of the individual constituencies. We may have just received majority stakeholder viewpoints, not those of the minority. **Marine Science:** Effective discussions allowed me to understand the positions of the stakeholders. Good organization for meetings.
(15) “I would recommend using the stakeholder organizational structure of the LAC for the management of other fisheries.”	**Commercial:** Absolutely not. I would suggest having meetings open to the public with public input allowed by county in which the fishery operates**. Recreational:** BEST THING THE DF&W HAS DONE IN MANY YEARS. It was MUCH better than the MLPA process. It improved on the management programs of the past iterations. **Environmental:** With some tweaks for equability and clear direction from the management agency on the type of input the stakeholder advisory group would be providing, and things that are outside of the area of the management agency's interest for the group to provide. Stakeholders need to be focused on the areas where they can be expected to have important

	input. Primarily on regulations that will come out of the process.
(16) "Local, in-the-field, first hand knowledge is taken seriously on the LAC."	**Commercial:** Yes and no. **Recreational:** Yes. Yes; the science proposed in the beginning went under scrutiny, and much to their credit, the scientists worked VERY HARD to get better and more complete data. Their expanded data recognized a lot of what the fishermen, both recreational and commercial were expressing. **Governmental:** Too much so sometimes. **Marine Science**: While there was a lot of useful insight provided by those with extensive field experience, it was not always valued as highly as theoretical models that were not always completely applicable.
(17)"Compromising, trade-offs, and/ or concessions of your stakeholder groups interests may be necessary to ensure the long-term sustainability of the fishery."	**Commercial:** If the health of the fishery was in question, which per the Dept. it is not Id say yes. The NGO's have received everything their hearts desire in terms of the MPA's, I'm finished compromising. **Recreational:** We worked to find compromises and solutions to mostly rapid growth related concerns within the fishery. I hope this question does not reference an eye-for an-eye type fisheries management mentality. We all benefit from sound decisions, everybody looses when we base management on sacrifice, concession or trade off. If a specific problem is recognized within user/ group or industry, address it. **Environmental:** It also helps build cross-interest buy-in to the fishery management plan, as everyone participating in the LAC gained support in some areas of negotiation and had to concede in others. It creates more stakeholder connectedness to the process and outcome. **Marine Science**: I would say this is true of all groups, though not all are willing to readily agree to compromise.
(18)"Compromising, trade-offs, and/ or concessions have occurred at the expense of your stakeholder groups interests."	**Recreational:** We are not thrilled with some aspects of the LAC proposals, but in the interest of strengthening the fishery in the face of potential growth in the recreational sector, it was necessary. The hoop netters however would not compromise. **Marine Science**: I am not a recreational or commercial user so this question is not as applicable to me.
Additional Comments:	**Commercial:** Having been one of three fishermen that sat down with Kristine, Tom B. and Huff M. w/EDF back in June of 09 to discuss how the FMP may look and what the DFG was looking to accomplish, personally lobbied the OPC to fund this FMP on behalf of the now defunct lobster association and subsequently sat down with Kristine and 7 other fishermen at Los Alamitos in Sept of 10 I am disgusted! The DFG would not discuss Santa Monica Bay and how it is closed to commercial lobster take, the little supposed credit given for the MPA's, this process was a fucking joke! Things are going to change moving into the future and it will be interesting to see how some adjust to those changes. I suspect future collaboration with commercial fishermen will continue to diminish in harbors below SB. **Recreational:** Please select your stakeholder or representative group on the LAC: I was appointed to represent recreational divers. However, my position was not singular in representation. My goal was to encourage LFMP decisions that benefit all user groups favorably. As I stated in our first LAC meeting, when a

	stakeholder group comes to the table with the common goal of producing a quality fisheries management plan and works collectively towards that goal, we succeed-- if the stakeholder group members are selfish and argue for what is best for their individual constituency, we fail. Fisheries management plans drafted by the influence of stakeholder debate and lobbing skills are a complete failure. I'm pleased with the LFMP framework and satisfied with the proactive environment of the LAC members. That said... the LAC was not perfect and mistakes were made. Hopefully the Department, facilitators and LAC Appointees will learn from this experience and work to improve future Advisory Council opportunities. **Non-consumptive:** Selection of Representatives was 90% successful in gathering people invested in collaboration to meet mutual goals. **Marine Science:** The proactive nature of the process is refreshing. Hopefully the effort will result in changes to the fishery that promote sustainability. The shift in focus from making a fishery management plan (i.e planning for future problems) to discussing at length the current fishing regulations and how/ whether they should change was confusing. It was unclear why we went in with one clear purpose, and wound up focusing on another.

Appendix 4. Full SCSLF SES classification.

Governance System	**Southern California Spiny Lobster Fishery**
GS1 Governance Policies	
GS1.1 Marine Protection Area (MPA) policies	Present, MPA network exists in the RS
GS1.2 National sanctions	Yes
GS1.2.1 Endangered species policies	Yes, currently not effecting spiny lobster.
GS1.3 Spatial Zoning	Yes
GS2 Organizations/Institutions	--
GS2.1 Government organizations	Yes
GS2.1.1 National Level	National Oceanic & Atmospheric Association (NOAA)
GS2.1.2 Regional level	California Department of Fish & Wildlife (CADFW)
Gs2.1.3 Local Level	CADFW- Regional, Southern California
GS2.1.4 Support Enforcement	CADFW
GS2.1.5 Support Funding	CADFW
GS2.1.6 Restoration efforts	--
GS 2.2 Nongovernment organizations	--
GS2.2.1 Environmental Organizations	Yes
GS2.2.2 Research Organizations	Yes
GS2.2.3 Social/ Welfare Organizations	No
GS2.2.4 Restoration efforts	Yes
GS3 Decision making structures	
GS3.1 Network structure	--
GS3.1.1 Vertical	Yes
GS3.1.2 Horizontal	Yes
GS3.1.3 Transparency	Medium
GS3.2 Management Strategy	--
GS3.2.1 Co-management	Yes
GS3.2.1.1 Consultive	--

GS3.2.1.2 Collaborative	--
GS3.2.1.3 Delegative	Yes
GS 3.2.2 Adaptive management	Yes
GS3.2.3 Self-governance/ Community-based	--
GS3.2.4 Stakeholder Involvement	Yes
GS3.2.4.1 Committee/ Council	Yes
GS3.2.4.2 Open forum/ comment	Yes
GS3.2.4.3 Select engagement	--
GS3.2.4.4 Research Involvement	Yes
GS3.2.5 Multiple outcome recognition & planning	Unknown
GS4 Rules & Regulations	Yes
GS4.1 Constitutional Rules	Yes
GS4.2 Collective Choice Rules	Yes
GS4.3 Operational Rules	Yes
GS4.4 Commercial Resource Regulations	Yes
GS4.4.1 Input controls	Yes
GS4.4.1.1 Season	October-March
GS4.4.1.2 Licenses/Permits	Limited to ~150, (~$50,000 - $100,00 USD) each.
GS4.4.1.3 Equipment/Gear allowed	Baited Traps only
GS4.4.1.4 Harvestable Size Limits	Minimum 8.255 carapace length.
GS4.4.1.5 No berried females	Unofficial
GS4.4.1.5.1 V-Notch	No
GS4.4.2 Output controls	No
GS4.4.2.1 Total Allowable Catch (TAC)	No
GS4.4.2.2 Individual Transferable Quotas (ITQs)	No
GS4.4.3 Access	--
GS4.4.3.1 Shared exclusive territory	No
GS4.4.3.2 Individual spot ownership	Unofficial
GS4.4.3.3 Open	Yes
GS4.4.4 Decision Rules	No
GS4.5 Recreational Resource Regulations	Yes
GS4.5.1 Input Controls	Yes
GS4.5.1.1 Harvestable Size limits	Minimum 8.26 cm carapace length.
GS4.5.1.2 Licenses	Yes, no limit. ~$35 USD/yr. ~30,000 in 2011.
GS4.5.1.3 Trap soak time	Yes, 24 hours
GS4.5.1.4 Equipment/ Gear allowed	Hoop traps. Hands only, in water. SCUBA ok.
GS4.5.1.5 Season	October-March
GS4.5.2 Output Controls	Yes
GS4.5.2.1 Daily limit	Yes, 7.
GS4.5.2.2 Season limit	No
GS5 Monitoring	Yes
GS5.1 Social	No
GS5.2 Biophysical	Yes
GS6 Sanctions	Yes
GS6.1 Graduated Sanctions	Yes
Resource System	
RS1 Sector	Marine Fishery - Lobster
RS1.1 Lobster (Species)	Panulirus interruptus

RS2 Clarity of system boundaries	Not well understood.
RS2.1 Recruitment Sourcing	Not well understood.
RS2.1.1 Within governance system boundaries	Yes
RS2.1.2 Outside of governance system boundaries	Yes
RS2.2 Zoning Districts/ Marine Protected Areas	Yes, extensive MPA network within RS.
RS2.3 International Waters	Yes, USA and Mexico.
RS3 Size of resource system	Monterey, California, USA to Bahía Magdalena, Baja California, Mexico. Adult habitat from 0 to 73 meters. Larva appear up to 217 km off the coast.
RS3.1 Carrying capacity	Data Needed
RS4 Human-constructions	Yes
RS4.1 Human access structures	Numerous large harbors and piers within RS.
RS4.2 Artificial Habitat	Likely but unknown.
RS5 Productivity of system	High
RS5.1 Stock Status	Stable
RS5.2 Biophysical Properties	Unknown
RS6 Equilibrium properties	Unknown
RS7 Predictability of system dynamics	Lack of larval recruitment and recreational use data.
RS8 Storage characteristics	--
RS9 Location	Monterey, California, USA to Bahía Magdalena, Baja California, Mexico.
Resource Units	
RU1 Resource unit mobility	--
RU1.1 Recruitment	Variable and not well understood.
RU 1.2 Nocturnal movement	Adults average +600 meters nightly movement, commonly not returning to the location.
RU2 Growth or replacement rate	7-13 years to reach legal harvest size (8.26 cm carapace)
RU3 Interaction among resource units	Yes
RU3.1 Reproduction	Male to female sperm transfer during the summer months. Lobsters usually spawn 2-3 times before reaching legal harvest size.
RU4 Economic dynamics	**--**
RU4.1 Economic Value	Yes
RU4.1.1 Live	~ $14.90 - $39.70 USD per kilogram
RU4.1.2 Frozen	--
RU4.2 Market Predictability	No data.
RU4.3 Market Diversity	Mostly export to Asian markets.
RU4.4 Recreational Value	Yes, but no data.
RU5 Cultural value	Yes
RU5.1 Indigenous/ Subsistence Value	No
RU5.2 Recreational value	No data
RU6 Number of units (Harvestable Population)	Unknown
RU6.1 Legal Harvest Rate	316 metric tons (2010-11 season)
RU6.2 Illegal, Unreported, Unregulated (IUU) fishing	No data
RU7 Distinctive Characteristics	Yes
RU7.1 Molting	Yes
RU7.2 Artificial female markings	No
RU7.3 Tail V-notch	No
RU8 Seasonal and Temporal distribution	--

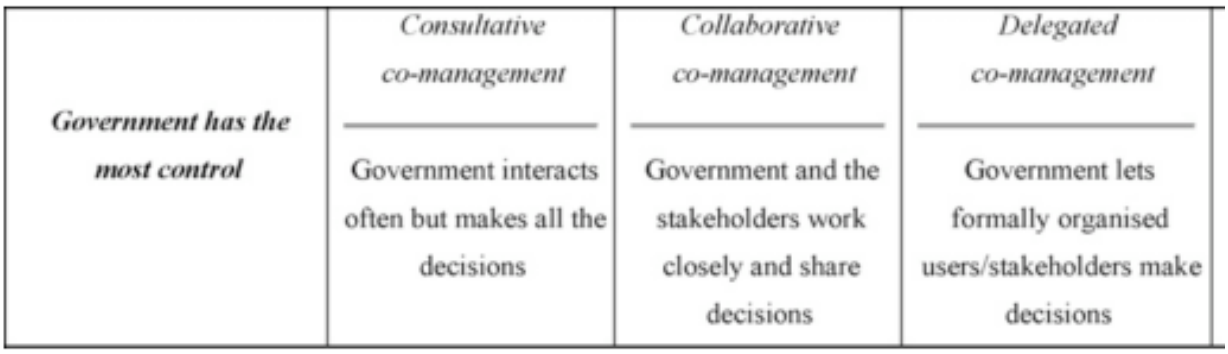
RU8.1 Seasonal migration	Observed but unsure seasonal movement to more shallow waters in the spring and summer.
Actors	
A1 Number of actors	--
A1.1 Commercial	~150
A1.2 Recreational	+30,000
A1.3 Non-consumptive recreational	Likely high but unknown.
A1.4 Indigenous peoples, subsistence harvesting	None
A1.5 IUU actors	Unknown.
A2 Socioeconomic attributes of actors	--
A2.1 Socioeconomic resilience	Unknown
A2.1.1 Insurance Availability	Yes
A2.2 Operating Costs	Commercial costs, high. Recreational, low.
A2.2.1 Replacement/Renewal Rates	Yearly recreational license renewals. Case-based commercial license transfers.
A3 History of use	--
A3.1 Crisis	El Nino Southern Oscillation (ENSO) cycles
A3.2 Duration	Fished since at least 1872. +100 years commercial.
A4 Location	South of Point Conception, California to the USA –Mexican border.
A4.1 Ports/ Harbors/ Built Infrastructure	Numerous harbors and piers.
A4.2 Beaches/ Non-built/ natural access	Public coastal access throughout RS.
A5 Leadership/entrepreneurship	Unknown
A6 Norms/social capital	--
A6.1 Spatially based	Yes
A6.1.1 Clubs/ Organizations/ Chapters	Commercial fishing regional (by port of entry) organizations/ chapters.
A6.2 Non-spatially based	Yes
A6.2.1 Online format, publications	Commercial and recreational online discussion boards and groups.
A7 Knowledge of SES/mental models	--
A7.1 Traditional Ecological Knowledge (TEK)	Low
A7.2 Western Science and Management Knowledge (SMK)	Medium, social and ecological.
A7.3 Local Ecological Knowledge (LEK)	High
A7.4 *Knowledge Sharing/ Social Learning*	Medium
A8 Importance of resource	High
A8.1 Economic dependence	High (commercial)
A8.2 Cultural dependence	Yes, but unknown.
A9 Technology used	--
A9.1 Homogeneity	Yes
A9.2 SCUBA allowed for commercial gear recovery	No
Information Sourcing	
(Neilson & Barsky, 2011) (Kay et al., 2012) (Kay, 2011) (California Department of Fish & Wildlife, 2013)	

Appendix 5. Bibliography of 19 articles in the literature review, as a result of the systematic search and selection criteria.

Author(s)	Title	Journal	Year
Ernst B., Chamorro J., Manriquez P., Orensanz J.M.L., Parma A.M., Porobic J., Roman C.	Sustainability of the Juan Fernv°ndez lobster fishery (Chile) and the perils of generic science-based prescriptions	Global Environmental Change	2013
Wilson J.A., Acheson J.M., Johnson T.R.	The cost of useful knowledge and collective action in three fisheries	Ecological Economics	2013
Van Putten I., Deng R., Dennis D., Hutton T., Pascoe S., Plaganyi E., Skewes T.	The quandary of quota management in the Torres Strait rock lobster fishery	Fisheries Management and Ecology	2013
van Putten I.E., Jennings S., Frusher S., Gardner C., Haward M., Hobday A.J., Nursey-Bray M., Pecl G., Punt A., Revill H.	Building blocks of economic resilience to climate change: A south east Australian fisheries example	Regional Environmental Change	2013
van Putten I., Lalancette A., Bayliss P., Dennis D., Hutton T., Norman-Lopez A., Pascoe S., Plaganyi E., Skewes T.	A Bayesian model of factors influencing indigenous participation in the Torres Strait tropical rocklobster fishery	Marine Policy	2013
Butler J.R.A., Tawake A., Skewes T., Tawake L., McGrath V.	Integrating traditional ecological knowledge and fisheries management in the torres strait, Australia:The catalytic role of turtles and dugong as cultural keystone species	Ecology and Society	2012
Perez-Ramirez M., Ponce-Diaz G., Lluch-Cota S.	The role of MSC certification in the empowerment of fishing cooperatives in Mexico: The case of red rock lobster co-managed fishery	Ocean and Coastal Management	2012
Brewer J.F.	Don't fence me in: Boundaries, policy, and deliberation in Maine's lobster commons	Annals of the Association of American Geographers	2012
Ernst B., Manriquez P., Orensanz J.M., Roa R., Chamorro J., Parada C.	Strengthening of a traditional territorial tenure system through protagonism in monitoring activities by lobster fishermen from the Juan Fernandez Islands, Chile	Bulletin of Marine Science	2010
Wilson J., Yan L., Wilson C.	The precursors of governance in the Maine lobster fishery	Proceedings of the National Academy of Sciences of the United States of America	2007
Yandle T.	Sharing natural resource management responsibility: Examining the New Zealand rock lobster co-management experience	Policy Sciences	2006
Phillips G., Kriwoken L., Hay P.	Private property and public interest in fisheries management: The Tasmanian rock lobster fishery	Marine Policy	2002

Nursey-Bray M., Pecl G.T., Frusher S., Gardner C., Haward M., Hobday A.J., Jennings S., Punt A.E., Revill H., van Putten I.	Communicating climate change: Climate change risk perceptions and rock lobster fishers, Tasmania	Marine Policy	2012
Steyn E., Fielding P.J., Schleyer M.H.	The artisanal fishery for East Coast rock lobsters Panulirus homarus along the Wild Coast, South Africa	African Journal of Marine Science	2008
Seijo J.C.	Considerations for management of metapopulations in small-scale fisheries of the Mesoamerican barrier reef ecosystem	Fisheries Research	2007
Davis A., Wagner J.	A right to fish for a living? The case for coastal fishing people's determination of access and participation	Ocean and Coastal Management	2006
Hearn A.	The rocky path to sustainable fisheries management and conservation in the Galv°pagos Marine Reserve	Ocean and Coastal Management	2008
Pilling G.M., Payne A.I.L.	Sustainability and present-day approaches to fisheries management - are the two concepts irreconcilable?	African Journal of Marine Science	2008
McConney P., Baldeo R.	Lessons in co-management from beach seine and lobster fisheries in Grenada	Fisheries Research	2007

Appendix 6. Co-management figure.



(McConney & Baldeo, 2007) Figure showing the scale of co-management, included into the updated lobster fishery SES framework.

Appendix 7. List of LAC members. All were contacted to participate in the survey.

Rodger Healy (Commercial Fishing Member)
Jim Colomy (Commercial Fishing Member)
Shad Catarius (Commercial Fishing Member)
Josh Fisher (Commercial Fishing Alternate Member)
Jim Salazar (Recreational Fishing Member)
Michael Gould (Recreational Fishing Member)

Al Stasukevich (Recreational Fishing Member)
Paul Romanowski (Recreational Fishing Alternate Member)
Lia Protopapadakis (Marine Science Member)
Kevin Hovel (Marine Science Member)
Jono Wilson (Marine Science Alternate Member)
Sarah Sikich (Environmental Organization Member)
Huff McGonigal (Environmental Organization Alternate Member)
Sean Hastings (Federal Agency Member)
David Kushner (Federal Agency Alternate Member)
Claudette Dorsey (Non-consumptive Recreational Member)
Chris Grossman (Non-consumptive Recreational Member)
Stefan Partelow (Non-consumptive Recreational Alternate)

Appendix 8. Expert Interview contacts and relevant details

Jack Kittinger PhD *Social Science Fellow.* Center for Ocean Solutions. Stanford University.
Ingrid van Putten PhD Research Fellow. CSIRO. University of Tasmania, Australia.
Michael Cox PhD Assistant Professor. Environmental Studies. Dartmouth College.
Sarah Sikich MSc Science & Policy Director. Heal the Bay (Environmental NGO). Los Angeles, California, USA. Environmental representative. Lobster Advisory Committee.
Xavier Basurto PhD Assistant Professor. Sustainability Science. Duke University

Appendix 9. LAC representative survey. (online only)

https://docs.google.com/forms/d/1K7wLiepeuFgj0z3fluxDORLmFPNj7mrOaO8hFx-8bFE/viewform?sid&c=0&w=1&token&usp=mail_form_link

Appendix 10. Review categories table

Data Extraction Categories from review literature
1. Research Funding
2. Reference point for research
3. Ocean; Region
4. Fishery Name
5. Species Name
6. Relevant Fishery Details (Management notes)
7. Associated Fisheries
8. SES Y(1)/N
9. Ecosystem Services Y/N
10. Sustainability Y/N
11. Mentioned sustainability challenges
12. Resilience Y/N
13. Trade-offs addressed in Management Y/N
14. If yes, then what?
15. Type of Management System used/ mentioned
16. Fishery regulations/ management techniques (trap limits, certifications, Seasons, permits,…)
17. National Government Policy (Policy based) Y/N
18. Who primarily governs the fishery?
19. Stakeholders (who) involved in research/ study
20. Stakeholders (who) involved in the fishery management
21. How were stakeholders involved in management?
22. Perspective of Article (ecology 1, economics 2, governance 3, methods 4, social 5, other 6)
23. State/ Health of Fishery
24. Size of fishery (# of fisherman/ boats, # of recreational users, other)

25. Physical Area of Fishery sqkm
26. Value of fishery $ or total landings
27. threats to fishery mentioned
28. Type of data in article (Quant. (1) Qual.(2) both (3))
29. Concluding recommendations Y/N
30. If yes, then what?
31. Primary consumer of lobsters caught?
32. Ostrom SES components mentioned or used for analysis Y/N

References

Aaron MacNeil, M., & Cinner, J. E. (2013). Hierarchical livelihood outcomes among co-managed fisheries. *Global Environmental Change*, *23*(6), 1393–1401. doi:10.1016/j.gloenvcha.2013.04.003

Abson, D. J., & Termansen, M. (2011). Valuing ecosystem services in terms of ecological risks and returns. *Conservation Biology : The Journal of the Society for Conservation Biology*, *25*(2), 250–8. doi:10.1111/j.1523-1739.2010.01623.x

Agrawal, A. (2001). Common Property Institutions and Sustainable Governance of Resources. *World Development*, *29*(10), 1649–1672. doi:10.1016/S0305-750X(01)00063-8

Agrawal, A. (2003). SUSTAINABLE GOVERNANCE OF COMMON-POOL RESOURCES : Context, Methods, and Politics. *Annual Review of Anthropology*, *32*(1), 243–262. doi:10.1146/annurev.anthro.32.061002.093112

Agrawal, A., & Chhatre, A. (2011). Against mono-consequentialism: Multiple outcomes and their drivers in social–ecological systems. *Global Environmental Change*, *21*(1), 1–3. doi:10.1016/j.gloenvcha.2010.12.007

Aswani, S., Gurney, G. G., Mulville, S., Matera, J., & Gurven, M. (2013). Insights from experimental economics on local cooperation in a small-scale fishery management system. *Global Environmental Change*, *23*(6), 1402–1409. doi:10.1016/j.gloenvcha.2013.08.003

Basurto, X., & Coleman, E. (2010). Institutional and ecological interplay for successful self-governance of community-based fisheries. *Ecological Economics*, *69*(5), 1094–1103. doi:10.1016/j.ecolecon.2009.12.001

Basurto, X., Gelcich, S., & Ostrom, E. (2013). The social–ecological system framework as a knowledge classificatory system for benthic small-scale fisheries. *Global Environmental Change*, *23*(6), 1366–1380. doi:10.1016/j.gloenvcha.2013.08.001

Basurto, X., & Nenadovic, M. (2012). A Systematic Approach to Studying Fisheries Governance. *Global Policy*, *3*(2), 222–230. doi:10.1111/j.1758-5899.2011.00094.x

Basurto, X., & Ostrom, E. (2009). The Core Challenges of Moving Beyond Garrett Hardin. *Journal of Natural Resources Policy Research*, *1*(3), 255–259. doi:10.1080/19390450903040447

Bentley, N., Breen, P. A., Kim, S. W., & Starr, P. J. (2005). New Zealand Journal of Marine and Freshwater Research Can additional abundance indices improve harvest control rules for New Zealand rock lobster (Jasus edwardsii) fisheries ?, (January 2014), 37–41.

Berkes, F., Hughes, T. P., Steneck, R. S., Wilson, J. a, Bellwood, D. R., Crona, B., … Worm, B. (2006). Ecology. Globalization, roving bandits, and marine resources. *Science (New York, N.Y.)*, *311*(5767), 1557–8. doi:10.1126/science.1122804

Bradshaw, M. (2004). A combination of state and market through ITQs in the Tasmanian commercial rock lobster fishery: the tail wagging the dog? *Fisheries Research*, *67*(2), 99–109. doi:10.1016/j.fishres.2003.11.007

Brewer, J. F. (2012a). Don't Fence Me In: Boundaries, Policy, and Deliberation in Maine's Lobster Commons. *Annals of the Association of American Geographers*, *102*(2), 383–402. doi:10.1080/00045608.2011.641889
Brewer, J. F. (2012b). Revisiting Maine ' s lobster commons : rescaling political subjects, *6*(2), 319–343.
Bryman, A. 2008. Social research methods. NewYork: Oxford Unviersity Press.
Butler, J. R. A., Tawake, A., Skewes, T., Tawake, L., & Mcgrath, V. (2012). Integrating Traditional Ecological Knowledge and Fisheries Management in the Torres Strait , Australia : the Catalytic Role of Turtles and Dugong as Cultural Keystone Species, *17*(4).
California Department of Fish & Wildlife. (2001). *The Master Plan : A Guide for the Development of Fishery Management Plans*.
California Department of Fish & Wildlife. (2013). http://www.dfg.ca.gov/marine/lobsterfmp/. Retrieved from http://www.dfg.ca.gov/marine/lobsterfmp/
CADFW. (2014). MPA guidebooks, brochures and maps. https://www.dfg.ca.gov/marine/mpa/guidebooks.asp
Castilla, J. C., & Defeo, O. (2001). Latin American benthic shellfisheries : emphasis on co-management and experimental practices. *Reviews in Fish Biology and Fisheries*, (c), 1–30.
Center for Ocean Solutions. (2009). *Pacific Ocean Synthesis*.
Chan, K. M. A., Guerry, A. D., Balvanera, P., Klain, S., Satterfield, T., Basurto, X., … Tam, J. (2012). Where are Cultural and Social in Ecosystem Services? A Framework for Constructive Engagement. *BioScience*, *62*(8), 744–756. doi:10.1525/bio.2012.62.8.7
Checkley, D., Alheit, J., Oozeki, Y., Roy, C., Ommer, R. E., Jarre, A. C., … Moloney, C. (2013). Human dimensions of the fisheries under global change. In *Climate Change and Small Pelagic Fish* (pp. 275–284). Cambridge University Press.
Cinner, J. E. (2011). Social-ecological traps in reef fisheries. *Global Environmental Change*, *21*(3), 835–839. doi:10.1016/j.gloenvcha.2011.04.012
Cinner, J. E., MacNeil, M. A., Basurto, X., & Gelcich, S. (2013). Looking beyond the fisheries crisis: Cumulative learning from small-scale fisheries through diagnostic approaches. *Global Environmental Change*, *23*(6), 1359–1365. doi:10.1016/j.gloenvcha.2013.11.001
Clark, W. C., & Dickson, N. M. (2003). Sustainability science: the emerging research program. *Proceedings of the National Academy of Sciences of the United States of America*, *100*(14), 8059–61. doi:10.1073/pnas.1231333100
Clark, W. C., Dickson, N. M., & Kennedy, J. F. (2003). Sustainability Sustainability science, *100*(14), 8059–8061.
Cox, M., & Arnold, G. (2010). A Review of Design Principles for Community-based Natural Resource Management, *15*(4).
Crona, B., & Hubacek, K. (2010). The Right Connections : How do Social Networks Lubricate the Machinery of Natural Resource Governance ? *Ecology and Society, 15*(4), 18 [online].
Cundill, G. N. R., Fabricius, C., & Marti, N. (2005). Foghorns to the Future : Using Knowledge and Transdisciplinarity to Navigate Complex Systems, *10*(2).
Davis, A., & Wagner, J. (2006). A right to fish for a living? The case for coastal fishing people's determination of access and participation. *Ocean & Coastal Management*, *49*(7-8), 476–497. doi:10.1016/j.ocecoaman.2006.04.007
Degnbol, P., & Mccay, B. J. (2007). Unintended and perverse consequences of ignoring linkages in fisheries systems. *ICES - Journal of Marine Science*, 64, 793-797.
Eggleston, D. B., Parsons, D. M., Kellison, G. T., Plaia, G. R., & Johnson, E. G. (2008). Functional response of sport divers to lobsters with application to fisheries management. *Ecological Applications : A Publication of the Ecological Society of America*, *18*(1), 258–72. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/18372571
Ernst, B., Chamorro, J., Manríquez, P., Orensanz, J. M. L., Parma, A. M., Porobic, J., & Román, C. (2013a). Sustainability of the Juan Fernández lobster fishery (Chile) and the perils of generic science-based prescriptions. *Global Environmental Change*, *23*(6), 1381–1392. doi:10.1016/j.gloenvcha.2013.08.002
Ernst, B., Chamorro, J., Manríquez, P., Orensanz, J. M. L., Parma, A. M., Porobic, J., & Román, C. (2013b). Sustainability of the Juan Fernández lobster fishery (Chile) and the perils of generic science-based prescriptions. *Global Environmental Change*. doi:10.1016/j.gloenvcha.2013.08.002
Ernst, B., Manríquez, P., Orensanz, J. M. L., Roa, R., Chamorro, J., & Parada, C. (2010). STRENGTHENING OF A TRADITIONAL TERRITORIAL TENURE SYSTEM THROUGH PROTAGONISM IN MONITORING ACTIVITIES BY LOBSTER FISHERMEN FROM THE JUAN FERNÁNDEZ ISLANDS , CHILE. *Bulletin of Marine Science*, *86*(2), 315–338.

Flyvbjerg, B. (2011). "Case Study." in Norman K. Denzin and Yvonna S. Lincoln eds., *The Sage Handbook of Qualitative Research*, 4th Edition. (Thousand Oaks, CA: Sage, 2011) Chapter 17 pp. 301-316

Folke, C., Hahn, T., Olsson, P., & Norberg, J. (2005). Adaptive Governance of Social-Ecological Systems. *Annual Review of Environment and Resources*, *30*(1), 441–473. doi:10.1146/annurev.energy.30.050504.144511

Fox, E., Poncelet, E., Connor, D., Vasques, J., Ugoretz, J., McCreary, S., … Gleason, M. (2013). Adapting stakeholder processes to region-specific challenges in marine protected area network planning. *Ocean & Coastal Management*, *74*, 24–33. doi:10.1016/j.ocecoaman.2012.07.008

Garrett, A., MacMullen, P., & Symes, D. (2012). Fisheries as learning systems: Interactive learning as the basis for improved decision making. *Fisheries Research*, *127-128*, 182–187. doi:10.1016/j.fishres.2012.01.014

Gelcich, S., Edwards-Jones, G., & Kaiser, M. J. (2007). Heterogeneity in fishers' harvesting decisions under a marine territorial user rights policy. *Ecological Economics*, *61*(2-3), 246–254. doi:10.1016/j.ecolecon.2006.02.017

Gibson, R. B. (2006). Sustainability assessment : basic components of a practical approach. *Impact Assessment and Project Appraisal, 24*(3), 170–182.

Gibson, R. B., Hassan, S., Holtz, S., Tansey, J., & Whitelaw, G. (2005). *Sustainability Assessment: Criteria, Processes, and Applications* (pp. 1– 269). London, UK: Earthscan.

Gilman, E., & Kingma, E. (2013). Standard for assessing transparency in information on compliance with obligations of regional fisheries management organizations: Validation through assessment of the Western and Central Pacific Fisheries Commission. *Ocean & Coastal Management*, *84*, 31–39. doi:10.1016/j.ocecoaman.2013.07.006

Göb, R., McCollin, C., & Ramalhoto, M. F. (2007). Ordinal Methodology in the Analysis of Likert Scales. *Quality & Quantity*, *41*(5), 601–626. doi:10.1007/s11135-007-9089-z

Gourguet, S., Macher, C., Doyen, L., Thébaud, O., Bertignac, M., & Guyader, O. (2013). Managing mixed fisheries for bio-economic viability. *Fisheries Research*, *140*, 46–62. doi:10.1016/j.fishres.2012.12.005

Haines-Young, R., & Potschin, M. (2010). The links between biodiversity, ecosystem services and human well-being. In D. G. Raffaelli & C. L. J. Frid (Eds.), *Ecosystem Ecology: A New Sysnthesis* (pp. 110–139). Cambridge University Press.

Halpern, B. S., Walbridge, S., Selkoe, K. a, Kappel, C. V, Micheli, F., D'Agrosa, C., … Watson, R. (2008). A global map of human impact on marine ecosystems. *Science (New York, N.Y.)*, *319*(5865), 948–52. doi:10.1126/science.1149345

Hammer, M., Holmlund, C. M., & Almlöv, M. Å. (2003). Social–ecological feedback links for ecosystem management: a case study of fisheries in the Central Baltic Sea archipelago. *Ocean & Coastal Management*, *46*(6-7), 527–545. doi:10.1016/S0964-5691(03)00033-4

Hearn, A. (2008). The rocky path to sustainable fisheries management and conservation in the Galápagos Marine Reserve. *Ocean & Coastal Management*, *51*(8-9), 567–574. doi:10.1016/j.ocecoaman.2008.06.009

Hilborn, R., Orensanz, J. M. L., & Parma, A. M. (2005). Institutions, incentives and the future of fisheries. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *360*(1453), 47–57. doi:10.1098/rstb.2004.1569

Hughes, T. P., Carpenter, S., Rockström, J., Scheffer, M., & Walker, B. (2013). Multiscale regime shifts and planetary boundaries. *Trends in Ecology & Evolution*, *28*(7), 389–95. doi:10.1016/j.tree.2013.05.019

Hunt, L. M., Sutton, S. G., & Arlinghaus, R. (2013). Illustrating the critical role of human dimensions research for understanding and managing recreational fisheries within a social-ecological system framework. *Fisheries Management and Ecology*, *20*(2-3), 111–124. doi:10.1111/j.1365-2400.2012.00870.x

Jerneck, A., Olsson, L., Ness, B., Anderberg, S., Baier, M., Clark, E., … Persson, J. (2010). Structuring sustainability science. *Sustainability Science*, *6*(1), 69–82. doi:10.1007/s11625-010-0117-x

Jones, P. J. S., Qiu, W., & De Santo, E. M. (2013). Governing marine protected areas: Social–ecological resilience through institutional diversity. *Marine Policy*, *41*, 5–13. doi:10.1016/j.marpol.2012.12.026

Kates, R. W. (2011). What kind of a science is sustainability science? *Proceedings of the National Academy of Sciences of the United States of America*, *108*(49), 19449–50. doi:10.1073/pnas.1116097108

Kay, M. C. (2011). *Community Based Fisheries Research on California Spiny Lobster (Panulirus interruptus) at the Santa Barbara Channel Islands*. University of California, Santa Barbara.

Kay, M. C., Lenihan, H. S., Guenther, C. M., Wilson, J. R., Miller, C. J., & Shrout, S. W. (2012). Collaborative assessment of California spiny lobster population and fishery responses to a marine reserve network. *Ecological Applications : A Publication of the Ecological Society of America*, *22*(1), 322–35. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/22471093

Kerkhoff, L. (2013). Developing integrative research for sustainability science through a complexity principles-based approach. *Sustainability Science*. doi:10.1007/s11625-013-0203-y

Kittinger, J. N., Finkbeiner, E. M., Ban, N. C., Broad, K., Carr, M. H., Cinner, J. E., … Crowder, L. B. (2013). Emerging frontiers in social-ecological systems research for sustainability of small-scale fisheries. *Current Opinion in Environmental Sustainability*, *5*(3-4), 352–357. doi:10.1016/j.cosust.2013.06.008

LAC Charter. 2012. California Spiny Lobster Fishery Management Plan Advisory Committee Charter. *California Department of Fish and Wildlife*. 1-10.

Lang, D. J., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., … Thomas, C. J. (2012). Transdisciplinary research in sustainability science: practice, principles, and challenges. *Sustainability Science*, *7*(S1), 25–43. doi:10.1007/s11625-011-0149-x

Lange, P., Driessen, P. P. J., Sauer, A., Bornemann, B., & Burger, P. (2013). Governing Towards Sustainability—Conceptualizing Modes of Governance. *Journal of Environmental Policy & Planning*, *15*(3), 403–425. doi:10.1080/1523908X.2013.769414

Levin, S., Xepapadeas, T., Crépin, A.-S., Norberg, J., de Zeeuw, A., Folke, C., … Walker, B. (2012). Social-ecological systems as complex adaptive systems: modeling and policy implications. *Environment and Development Economics*, *18*(02), 111–132. doi:10.1017/S1355770X12000460

Liu, J., Dietz, T., Carpenter, S. R., Alberti, M., Folke, C., Moran, E., … Taylor, W. W. (2007). Complexity of coupled human and natural systems. *Science (New York, N.Y.)*, *317*(5844), 1513–6. doi:10.1126/science.1144004

Maeda, H. (2014). Response option configuration of online administered Likert scales. *International Journal of Social Research Methodology*, (March), 1–12. doi:10.1080/13645579.2014.885159

Marin, A., Gelcich, S., Castilla, J. C., & Berkes, F. (2012). Exploring Social Capital in Chile ' s Coastal Benthic Comanagement. *Ecology and Society*, *17*(1).

Martin, K. St., McCay, B. J., Murray, G. D., Johnson, T. R., & Oles, B. (2007). Communities, knowledge and fisheries of the future. *International Journal of Global Environmental Issues*, *7*(2/3), 221. doi:10.1504/IJGENVI.2007.013575

Martinet, V., Thébaud, O., & Doyen, L. (2007). Defining viable recovery paths toward sustainable fisheries. *Ecological Economics*, *64*(2), 411–422. doi:10.1016/j.ecolecon.2007.02.036

McConney, P., & Baldeo, R. (2007). Lessons in co-management from beach seine and lobster fisheries in Grenada. *Fisheries Research*, *87*(1), 77–85. doi:10.1016/j.fishres.2007.06.011

McGinnis, M. D. (2011). An Introduction to IAD and the Language of the Ostrom Workshop: A Simple Guide to a Complex Framework. *Policy Studies Journal*, *39*(1), 169–183. doi:10.1111/j.1541-0072.2010.00401.x

Miller, T. R., Baird, T. D., Littlefield, C. M., Kofinas, G., Iii, F. S. C., & Redman, C. L. (2008). Epistemological Pluralism : Reorganizing Interdisciplinary Research. *Ecology and Society*, *13*(2).

Miller, T. R., Wiek, A., Sarewitz, D., Robinson, J., Olsson, L., Kriebel, D., & Loorbach, D. (2013). The future of sustainability science: a solutions-oriented research agenda. *Sustainability Science*. doi:10.1007/s11625-013-0224-6

Neilson, D., & Barsky, K. (2011). *State of the Fishery: California Spiny Lobster* (pp. 1–9). Retrieved from http://www.dfg.ca.gov/marine/lobsterfmp/lit.asp

NOAA. (2013). *National Coastal Population Report* (pp. 1–22).

Nursey-Bray, M., Pecl, G. T., Frusher, S., Gardner, C., Haward, M., Hobday, a. J., … van Putten, I. (2012). Communicating climate change: Climate change risk perceptions and rock lobster fishers, Tasmania. *Marine Policy*, *36*(3), 753–759. doi:10.1016/j.marpol.2011.10.015

Österblom, H., & Folke, C. (2013). Emergence of Global Adaptive Governance for Stewardship of Regional Marine Resources. *Ecology and Society*, *18*(2).

Österblom, H., Merrie, A., Metian, M., Boonstra, W. J., Watson, J. R., Rykaczewski, R. R., … Blenckner, T. (2013). Modeling Social–Ecological Scenarios in Marine Systems. *BioScience*, *63*(9), 735–744. doi:10.1525/bio.2013.63.9.9

Ostrom, E. (2005). *Understanding Institutional Diversity*. Princeton, NJ, USA: Princeton Universty Press.

Ostrom, E. (2007). A diagnostic approach for going beyond panaceas. *Proceedings of the National Academy of Sciences of the United States of America*, *104*(39), 15181–7. doi:10.1073/pnas.0702288104

Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science (New York, N.Y.)*, *325*(5939), 419–22. doi:10.1126/science.1172133

Ostrom, E. (2011). Background on the Institutional Analysis and Development Framework. *Policy Studies Journal*, *39*(1), 7–28.

Ostrom, E., & Cox, M. (2010). Moving beyond panaceas: a multi-tiered diagnostic approach for social-ecological analysis. *Environmental Conservation*, *37*(04), 451–463. doi:10.1017/S0376892910000834

Pérez-Ramírez, M., Ponce-Díaz, G., & Lluch-Cota, S. (2012). The role of MSC certification in the empowerment of fishing cooperatives in Mexico: The case of red rock lobster co-managed fishery. *Ocean & Coastal Management*, *63*, 24–29. doi:10.1016/j.ocecoaman.2012.03.009

Perrings, C. (2007). Future challenges. *Proceedings of the National Academy of Sciences of the United States of America*, *104*(39), 15179–80. doi:10.1073/pnas.0701957104

Phillips, G., Kriwoken, L., & Hay, P. (2002). Private property and public interest in fisheries management: the Tasmanian rock lobster fishery. *Marine Policy*, *26*(6), 459–469. doi:10.1016/S0308-597X(02)00026-X

Pilling, G., & Payne, A. (2008). Sustainability and present-day approaches to fisheries management — are the two concepts irreconcilable? *African Journal of Marine Science*, *30*(1), 1–10. doi:10.2989/AJMS.2008.30.1.1.446

Punt, A. E., McGarvey, R., Linnane, A., Phillips, J., Triantafillos, L., & Feenstra, J. (2012). Evaluating empirical decision rules for southern rock lobster fisheries: A South Australian example. *Fisheries Research*, *115-116*, 60–71. doi:10.1016/j.fishres.2011.11.010

Raheem, N., Colt, S., Fleishman, E., Talberth, J., Swedeen, P., Boyle, K. J., … Boumans, R. M. (2012). Application of non-market valuation to California's coastal policy decisions. *Marine Policy*, *36*(5), 1166–1171. doi:10.1016/j.marpol.2012.01.005

Raymond, C. M., Singh, G. G., Benessaiah, K., Bernhardt, J. R., Levine, J., Nelson, H., … Chan, K. M. A. (2013). Ecosystem Services and Beyond. *BioScience*, *63*(7), 536–546. doi:10.1525/bio.2013.63.7.7

Reed, M. S. (2008). Stakeholder participation for environmental management: A literature review. *Biological Conservation*, *141*(10), 2417–2431. doi:10.1016/j.biocon.2008.07.014

Robertson, J. (2012). Likert-type scales, statistical methods, and effect sizes. *Communications of the ACM*, *55*(5), 6. doi:10.1145/2160718.2160721

Satz, D., Gould, R. K., Chan, K. M. a, Guerry, A., Norton, B., Satterfield, T., … Klain, S. (2013). The challenges of incorporating cultural ecosystem services into environmental assessment. *Ambio*, *42*(6), 675–84. doi:10.1007/s13280-013-0386-6

Schoon, M. L., & Cox, M. E. (2012). Understanding Disturbances and Responses in Social-Ecological Systems. *Society & Natural Resources*, *25*(2), 141–155. doi:10.1080/08941920.2010.549933

Schuhbauer, A., & Koch, V. (2013). Assessment of recreational fishery in the Galapagos Marine Reserve: Failures and opportunities. *Fisheries Research*, *144*, 103–110. doi:10.1016/j.fishres.2013.01.012

Seijo, J. C. (2007). Considerations for management of metapopulations in small-scale fisheries of the Mesoamerican barrier reef ecosystem. *Fisheries Research*, *87*(1), 86–91. doi:10.1016/j.fishres.2007.06.016

Sharp, W. C. (2005). Long - term trends in the recreational lobster fishery of Florida , United States : Landings , effort , and implications for management. *New Zealand Journal of Marine and Freshwater Research*, *39*, 733–747.

Steneck, R. S., Hughes, T. P., Cinner, J. E., Adger, W. N., Arnold, S. N., Berkes, F., … Worm, B. (2011). Creation of a gilded trap by the high economic value of the Maine lobster fishery. *Conservation Biology : The Journal of the Society for Conservation Biology*, *25*(5), 904–12. doi:10.1111/j.1523-1739.2011.01717.x

Steyn, E., Fielding, P., & Schleyer, M. (2008). The artisanal fishery for East Coast rock lobsters Panulirus homarus along the Wild Coast, South Africa. *African Journal of Marine Science*, *30*(3), 497–506. doi:10.2989/AJMS.2008.30.3.5.639

Van Putten, I., Deng, R., Dennis, D., Hutton, T., Pascoe, S., Plagányi, E., & Skewes, T. (2013). The quandary of quota management in the Torres Strait rock lobster fishery. *Fisheries Management and Ecology*, *20*(4), 326–337. doi:10.1111/fme.12015

Van Putten, I. E., Jennings, S., Frusher, S., Gardner, C., Haward, M., Hobday, A. J., … Revill, H. (2013). Building blocks of economic resilience to climate change: a south east Australian fisheries example. *Regional Environmental Change*, *13*(6), 1313–1323. doi:10.1007/s10113-013-0456-0

Van Putten, I., Lalancette, A., Bayliss, P., Dennis, D., Hutton, T., Norman-López, A., … Skewes, T. (2013). A Bayesian model of factors influencing indigenous participation in the Torres Strait tropical rocklobster fishery. *Marine Policy*, *37*, 96–105. doi:10.1016/j.marpol.2012.04.001

Wiek, A., Ness, B., Schweizer-Ries, P., Brand, F. S., & Farioli, F. (2012). From complex systems analysis to transformational change: a comparative appraisal of sustainability science projects. *Sustainability Science*, *7*(S1), 5–24. doi:10.1007/s11625-011-0148-y

Wilson, J., Acheson, J., & Johnson, T. (2013). The cost of useful knowledge and collective action in three fisheries. *Ecological Economics*, *96*, 165–172. doi:10.1016/j.ecolecon.2013.09.012

Wilson, J., Hill, J., Kersula, M., Wilson, C. L., Whitsel, L., Yan, L., … Wilson, C. J. (2013). Costly information and the evolution of self-organization in a small, complex economy. *Journal of Economic Behavior & Organization*, *90*, S76–S93. doi:10.1016/j.jebo.2012.12.019

Wilson, J., Yan, L., & Wilson, C. (2007). The precursors of governance in the Maine lobster fishery. *Proceedings of the National Academy of Sciences of the United States of America*, *104*(39), 15212–7. doi:10.1073/pnas.0702241104

Worm, B., Barbier, E. B., Beaumont, N., Duffy, J. E., Folke, C., Halpern, B. S., … Watson, R. (2006). Impacts of biodiversity loss on ocean ecosystem services. *Science (New York, N.Y.)*, *314*(5800), 787–90. doi:10.1126/science.1132294

Yandle, T. (2006). Sharing natural resource management responsibility: Examining the New Zealand rock lobster co-management experience. *Policy Sciences*, *39*(3), 249–278. doi:10.1007/s11077-006-9023-6

Zellmer, a. J., Allen, T. F. H., & Kesseboehmer, K. (2006). The nature of ecological complexity: A protocol for building the narrative. *Ecological Complexity*, *3*(3), 171–182. doi:10.1016/j.ecocom.2006.06.002