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The role of diversification in dynamic small-scale fisheries: Lessons from Baja California Sur, Mexico

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ABSTRACT

Globally, small-scale fisheries are critical for livelihoods and food security yet face increasing uncertainty and variability from processes such as overfishing, globalization, and climate change. Enhancing the number of options for human response through increased access to marine resources, diverse livelihood approaches, and generalist fishing strategies may attenuate the negative effects of change and disturbance. My research explores the relative importance of diversification strategies for achieving resilient small-scale fishing communities and cooperatives of Baja California Sur, Mexico. Specifically, interview data and long-term catch and economic data were used to develop an economic metric of resilience, in addition to income diversification indices, for fishing cooperatives. Fishing cooperative characteristics and environmental conditions were then evaluated as possible predictors of cooperatives' relative ability to diversify. I found that while diversification was important for risk mitigation and stabilizing income, the ability of cooperatives to specialize during favorable conditions may be important for poverty reduction and wealth accumulation. Thus, the flexibility to move across fishing strategies given changing environmental conditions is important for the adaptive capacity of small-scale fishing cooperatives. My findings will contribute to a better understanding of the institutional arrangements that promote a resilient small-scale fishery, and therefore, will be invaluable for practitioners of small-scale fisheries.

1. Introduction

1.1. Resilient small-scale fisheries in a changing world

Small-scale fisheries (SSF) are ubiquitous and critically important around the world, and are diverse, decentralized and dynamic in nature. These fisheries are diverse because of the range of gear types used and species groups targeted, and the varied human communities from around the world that rely and depend on them. SSF are decentralized because of the sheer numbers of fishers, the many ports and points of access to the sea, and because these fisheries may operate in countries or regions with limited government presence where fishers must take decision-making into their own hands. Finally, these fisheries are dynamic because fishers often switch across species and gear types, or even livelihoods, depending on species availability and production in nearshore waters. While small- and large-scale fisheries each contribute to roughly half of global fisheries capture, SSF employ orders of magnitude more people than does the large-scale sector (Berkes et al., 2001). Thus, these fisheries are critical from an employment and livelihoods perspective. While important for livelihoods, these same characteristics of SSF (diverse, decentralized, dynamic) create significant challenges for effective governance. Furthermore, these fisheries often occur in regions and countries where governments lack capacity and resources to adequately manage and enforce fisheries policies (Berkes et al., 2001). Given the complexity of these fisheries as just described, historical governance efforts often have not been enough to curb the ecosystem effects of overfishing or to alleviate poverty for the communities that depend on them (Béné et al., 2010).

At the same time, SSF around the world are becoming increasingly connected across scales vis-a-vis processes such as climate change and globalization, and thus, becoming more vulnerable to external drivers of change (Adger et al., 2005; Armitage and Johnson, 2006; Berkes et al., 2006; Kittinger et al., 2013; Perry et al., 2011). For example, while trade liberalization and market integration may provide more economic opportunities

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for rural coastal communities, at the same time, these local economies become more vulnerable to price shocks and other market dynamics at higher scales. Likewise, while many SSF have learned to adapt to predictable or common environmental shocks and stresses, these fisheries are now facing disturbances with increasing intensity, frequency, and uncertainty. In sum, attempts to govern SSF at the local and regional level are undermined by processes occurring at higher scales.

Given the inadequacy of historical SSF management and increasing drivers of change facing fisheries generated by climate change and globalization, we need to redefine our current approach to conceptualizing and managing SSF. Specifically, scholars argue for the conceptualization of these fisheries as linked social–ecological systems, placing equal importance on ecological *and* human domains (Berkes and Folke, 1998; Berkes, 2003; McClanahan et al., 2008a,b; Ostrom, 2007; Wilson, 2006), and recognizing that these systems are intrinsically linked through a variety of feedback mechanisms (Kittinger et al., 2013). In addition, scholars suggest a redirection of fisheries management goals from a steady-state approach to managing for resilience (Berkes et al., 2003; Mahon et al., 2008; McClanahan et al., 2008a,b; Walker and Salt, 2002; Wilson, 2006). The resilience approach recognizes the complexity and uncertainty inherent in marine fisheries and emphasizes the need for flexible institutions with the capacity to adapt to changing conditions or environmental perturbations (Armitage, 2005; Berkes, 2003; Chapin et al., 2010; Hilborn et al., 2001; Holling, 1996; Ostrom, 2005). This is particularly true for SSF, which are inherently decentralized, diverse, and dynamic in character, and subject to extreme uncertainty and variability.

Given the need to implement a resilience approach to SSF management, our knowledge of SSF dynamics and interactions between natural and social systems is still limited (Berkes et al., 2001). Furthermore, conceptions of resilience are varied and the determinants of social versus ecological resilience are not well understood (Adger, 2000). As such, resilience is difficult to quantify or measure (Carpenter et al., 2001; Cumming et al., 2005), which further undermines meaningful attempts to increase the resilience of ecosystems and the communities that depend on them. The main goal of this research is to contribute to the growing body of literature that investigates how to govern SSF from a resilience perspective. In other words, what governance arrangements enable SSF to adapt to change over time?

1.2. Resilience as a multi-dimensional and multi-scale phenomenon

Conceptions of resilience are varied both across and within different bodies of literature. The resilience perspective first emerged in ecological literature in the 1960s (Holling, 1961), and has since been adopted in ecology as the amount of disturbance an ecosystem can withstand before undergoing a regime shift and occupying an alternate stable state. Thereafter, resilience was embraced in social science fields, such as anthropology, when scholars challenged the notion that culture was best characterized as an equilibrium-based system (Vayda and McCay, 1975). However, in the social sciences, resilience has been used less in the context of alternate stable states and regime shifts, as it is in ecology, and is more commonly conceptualized as the ability of human communities to withstand external shocks to their social infrastructure (Adger, 2000). Although the concept of social resilience is still being developed and refined (Berkes and Ross, 2013), recent scholarship has contributed to improved understanding, measurement, and fostering of social resilience. In particular, scholars have defined social resilience as the intersection of the various capitals that human communities are capable of mobilizing (i.e. natural, human, cultural, economic, political, social) (Magis, 2010; Wilson, 2012).

Some scholars have used a particular lens to study social resilience. For example, resilience from a livelihoods perspective describes livelihood diversification as important for increasing options and flexibility, buffering human communities from disturbance (Marschke and Berkes, 2006; Nayak et al., 2014). Under this framework, diversification can be understood vis-à-vis risk mitigation, coping behavior, or as a proactive strategy to increase options in a changing world (Marschke and Berkes, 2006). Resilience from an institutional perspective identifies the importance of institutions in mediating how people can access and interact with the environment, and thus is important in understanding the link between social and ecological resilience (Adger, 2000). From this perspective, resilience is defined at the collective level as the ability of institutions to cope with stresses and shocks (Adger, 2000). Importantly, social resilience embodies multiple dimensions, requiring analysis at various scales, using diverse methodologies (Adger, 2000).

In contrast, many studies, are concerned with measuring the *vulnerability* of nations, communities, and individuals to external drivers of change (Adger, 2006; Allison et al., 2009). Vulnerability is the degree to which a system is susceptible to, and is unable to cope with, adverse affects, and is influenced by the generation or erosion of resilience (Adger, 2006). Accordingly, some scholars view vulnerability at the opposite end of the spectrum from resilience (Wilson, 2012). Increasingly, vulnerability is used as a theoretical framework and a tool to study the well-being of small-scale fishers, in addition to their ability to cope with change in an increasingly dynamic world (Allison et al., 2009; Cinner et al., 2012; McClanahan et al., 2008a,b).

Across studies, the complex concept of vulnerability is distilled into three components: exposure, sensitivity, and adaptive capacity (Allison et al., 2009; Cinner et al., 2012; Gallopín, 2006; McClanahan et al., 2008a,b; Smit and Wandel, 2006). Exposure refers to the degree, duration, and extent to which a system experiences a disturbance, while sensitivity is the degree to which a system is *affected* by a disturbance (Gallopín, 2006). Adaptive capacity refers to a system's ability to anticipate, respond to, and recover from change (Cinner et al., 2012). Adaptive capacity is an important concept differentiating ecological resilience from social vulnerability (or resilience), because it describes the ability of human communities to *influence* their resilience (Berkes and Ross, 2013; Davidson, 2010; Nelson et al., 2007; Walker et al., 2004). Thus, it implies elements of human autonomy and agency. Some scholars perceive adaptive capacity as reflective of, or synonymous with the concept of social resilience (Gallopín, 2006). In the context of this study, the concept of social resilience is used interchangeably with adaptive capacity.

1.3. Diversification and income stability

Despite differences in conceptions across bodies of literature, there are important opportunities for empirical research by adopting concepts derived in one literature in the context of the other. For example, the concept of response diversity (distinct from species diversity) has been identified as a critical factor in ecological resilience (Elmqvist et al., 2003; Walker et al., 2006, 2004). Elmqvist et al. (2003) define response diversity as the diversity of responses to environmental change among species that contribute to the same ecosystem function. Thus, if response diversity within an ecological guild is high in the face of a major environmental perturbation, species able to cope with the disturbance will ensure the persistence of the specific ecological function (Elmqvist et al., 2003; Peterson et al., 1998). Although only recently explored in social systems (Folke, 2006), response diversity in humans could be equated to socio-economic and biological diversity enhancing the number of options for human response in a changing environment (Chapin et al., 2010). In other words, human response diversity could be enhanced or eroded by access to ecosystem services for communities dependent upon marine resources.

In the context of fisheries, a "generalist" strategy, or exploitation of multiple species using multiple gear types, exemplifies an important method of coping with variability and uncertainty and could be important for human response diversity. Compared to a specialist strategy, generalists participate in many activities and fisheries and thus have low switching costs enabling flexibility (Smith and McKelvey, 1986). In contrast, increased specialization of economic activities or limited access to alternative employment opportunities can increase risk to major system disturbances for fishers (Adger, 2000; Marshall and Marshall, 2007). According to Adger (2000), "stresses and variability associated with resource dependency [specialization] are manifest in instability and increased variance in income" (p. 351), and thus he suggests stability and distribution of income as one important indicator of social resilience. Recent work by Kasperski and Holland (2013) tests this theory empirically in the context of west coast United States fisheries, and demonstrates the link between fisheries specialization and increased variance in income.

While recognizing that no single indicator is capable of measuring the many dimensions of resilience, I use income stability over time as a proxy for the economic dimension of social resilience or adaptive capacity (Adger, 2000). In other words, I am interested in when and how income may fluctuate or stabilize in the face of change and disturbance confronting small-scale fisheries. As such, my first research objective is to understand the link between diversification and income stability in SSF. Based on previously published theoretical and empirical evidence, I hypothesize that diversification is related to greater inter-annual stability in income, as the ability to switch across species can help to maintain income as environmental or market changes occur.

1.4. Institutional factors mediating access to environmental resources

If the concept of response diversity is applied to human systems, then it would follow that ecological resilience would promote social resilience because ecosystem diversity increases the number of available options for human responses in a changing environment (Adger, 2000). However, ecosystem diversity is a necessary but not sufficient condition for human resilience. If communities do not have the means or rights (defined as authorized actions: Ostrom, 1976, as cited in Schlager and Ostrom, 1992) to access a diversity of natural resources, then social resilience or adaptive capacity would not be improved by ecosystem diversity alone. Instead, greater access to the marine environment mediated by institutions has the potential to foster social resilience (Adger, 2000; Carpenter et al., 2001; Wilson, 2006). In addition to having diverse access, local institutions must also have a given level of autonomy and agency to make decisions about when and how to switch among ecosystem uses. Leach et al. (1999) refer to the combination of access and agency as "environmental entitlements," and provide a cogent framework linking access to environmental resources with human well-being. In particular, their framework suggests that environmental access is mediated by (1) the resources possessed by humans, (2) the suite of rights conferred to humans, and (3) a "legitimate effective command" to mobilize these resources and rights (Leach et al., 1999). Likewise, a lack of environmental entitlements has been proposed to increase vulnerability of human systems, rendering them unable to cope with disturbance and change (Adger, 2006). Using the environmental entitlements framework, the second objective of my research is to understand what institutional factors enable fishers to access the marine environment and diversify, in order to better understand an institutional perspective of social resilience or adaptive capacity. I hypothesize that diversification is enabled by greater access to, and command over, the resources and rights possessed by humans.

1.5. Environmental conditions and the relative importance of diversification

Most fishing communities have a combination of generalist and specialist behaviors (Salas and Gaertner, 2004), but their relative proportions fluctuate with changes in the environment and market (Smith and McKelvey, 1986). Fisheries with high variability and uncertainty, or in open-access conditions, will likely have a higher proportion of generalist fishers (McCay, 1981; Salas and Gaertner, 2004; Smith and McKelvey, 1986). In contrast, stable fisheries or fishing communities with a longer presence in the region tend to favor a higher proportion of specialists (Salas and Gaertner, 2004). Given the mounting uncertainty and external drivers of change faced by SSF, diversification may become an increasingly important strategy. My third research objective is to understand under what conditions diversification becomes a dominant strategy, and if this strategy's relative importance has increased over time. I hypothesize that diversification is a dominant strategy under conditions of uncertainty and system variability, and will increase in importance over time.

These three research objectives: (1) understanding the link between income stability and diversification, (2) understanding what institutional characteristics are important for diversification, and (3) understanding the conditions under which diversification becomes a dominant strategy, were achieved by doing a comparative case study across small-scale fishing cooperatives in Baja California Sur, Mexico. Through this approach, I attempted to operationalize social resilience in small-scale fisheries through an economic and institutional lens, providing a multi-dimensional (albeit not complete) perspective. As resources and rights are commonly distributed to fishing cooperatives in Mexico, I viewed the fishing cooperative as the institutional mechanism enabling or constraining access to the environment. Thus, by focusing my analysis on fishing cooperatives, I examined measures of collective or aggregate adaptive capacity.

1.6. Study area

Marine resource extraction is of primary economic and cultural importance along the peninsula of Baja California and Baja California Sur, Mexico (Brusca et al., 2004; Lluch-Cota et al., 2007). Representing 99% of registered fishing vessels on the peninsula (INEGI, 2008), SSF rely on the extraction of myriad resources such as bony fishes, elasmobranchs, mollusks, and crustaceans using a wide variety of fishing gears, such as traps, hook and line, nets, and diving (Cudney-Bueno and Turk-Boyer, 1998; Table 1). This is particularly true for the study region of Golfo de Ulloa, Baja California Sur (Table 1; Fig. 1) where catch diversity is the highest in Northwest Mexico (Erisman et al., 2011). As such, the health of marine ecosystems and the fisheries they support are vital to the well-being of rural coastal communities in Northwestern Mexico. However, it is increasingly evident that Mexican SSF and associated ecosystems are in decline (Lluch-Cota et al., 2007; OECD, 2006; Peckham et al., 2007; Saenz-Arroyo et al., 2005; Sagarin et al., 2008; Sala et al., 2004). And furthermore, these fisheries are subject to extreme spatial and temporal fluctuations in productivity due to El Niño Southern Oscillation-driven inter-annual changes in oceanographic conditions (Collins et al., 2002; Pérez-Brunius et al., 2006). Due to this variability in the ocean environment, many fishers in the region distribute their risk by

Table 1
Common permits in Golfo de Ulloa. Permit names in Spanish, and their corresponding scientific name, English common name, and associated gear type. Gear types vary based on particular regulations for different species. For example, gillnets often vary in mesh size and where they are suspended in the water column for certain species selectivity.

Permit/concession	Scientific name	English common name	Gear type
Abulon[a]	*Haliotis spp.*	Abalone	Hookah diving
Almeja Catarina	*Argopecten ventricosus*	Pacific scallop	Hookah diving
Almeja Chocolata	*Megapitaria squalida*	Chocolate clam	Hookah diving
Almeja Generosa	*Panopea generosa*	Geoduck	Hookah diving
Almeja Pata de Mula	*Anadara tuberculosa*	Black ark	Hookah diving
Almeja Ronosa	*Chione califomiensis*	Clam	Hookah diving
Calamar	*Dosidicus gigas*	Squid	Jigging
Callo de Hacha	*Atrina spp.*	Pen shell	Hookah diving
Camaron	*Farfantepenaeus californiensis, Litopenaeus stylirostris*	Shrimp	Artisanal trawls
Caracol Chino	*Phyllonotus erythrostoma*	Murex snail	Traps, hookah diving
Escama	Many species	Bony fishes	Gillnets, hook and line, traps
Jaiba	*Callinectes spp.*	Swimming crab	Traps
Langosta[a]	*Panulirus spp.*	Lobster	Traps
Lisa	*Mugil spp.*	Mullet	Gillnets
Pulpo	*Octopus spp.*	Octopus	Traps
Tiburon	Many species	Elasmobranchs	Artisanal longline, gillnets

[a] Issued via concession, not permit.

engaging in a variety of fisheries using different gears and traveling to different locations, and maintaining multiple livelihoods.

Among other factors, fishers' ability to access different fisheries is contingent upon availability of resources, seasonal closures issued by the federal government, and possession of fishing rights. The National Fisheries Commission, CONAPESCA, distributes fishing rights to fishers in several ways. Most commonly, permits are issued for 2–5 year periods, and dictate the species or species groups, gear types, seasons, and geographic delineation that fishers can legally access (Table 1). Rights conferred by permits are often overlapping and not exclusive. Permits can either be issued to individuals (*permisionarios*), who contract fishers to work under their permits, or to collective groups of fishers organized into cooperatives. In 2010, in the study region's municipality of Comondu, 68 *permisionarios* with a labor force of 235 fishers, and 112 cooperatives with a labor force of 1435 fishers were legally registered as permit holders.

Less commonly, concessions have been issued to cooperatives on the Baja Peninsula for lucrative benthic species, such as lobster (*Panulirus sp.*) and abalone (*Haliotis sp.*, Table 1). Only four of the 112 cooperatives in Comondu have concessions. Unlike permits, this type of fishing right is issued for 20-year periods, and gives fishing cooperatives exclusive and non-overlapping access to designated species. The renewal of a concession is contingent upon fishers' participation in stock assessments and adequate self-governance of their resources. As such, concessioned cooperatives have evolved internal decision-making, enforcement, monitoring, and conflict resolution mechanisms. These cooperatives tend to be much larger in size (up to 137 members) with respect to non-concessioned cooperatives. In fact, the average size cooperative in the region has only 12 members. Many of these smaller cooperatives are formed by family members as a way to access permits, and thus may function much differently than do larger cooperatives with concession rights. In either case, all fishing cooperatives are designated a certain level of autonomy as they have the capacity to develop internal by-laws, so long as they are in compliance with legal restrictions dictated by permits.

2. Methods

2.1. A comparative case study approach

Using a comparative case-study approach, I collected data across 22 fishing cooperatives (4 with concessions and 18 without) in the Golfo de Ulloa region of Baja California Sur, Mexico (Fig. 1). Comparative case studies allow the researcher to examine each case "as a whole, as a total situation resulting from a combination of conditions" and "by examining differences and similarities in context it is possible to determine how different combination of conditions have the same causal significance and how similar causal factors can operate in opposite directions" (Ragin, 1987, p. 49). I selected fishing cooperatives by purposive sampling, which allows the researcher to maximize variation across the variable(s) of interest, while minimizing variation in other confounding variables (Agrawal, 2003, 2002), and is common in studying social–ecological systems (Agrawal, 2003, 2002; Evans et al., 2011; McClanahan et al., 2008a,b). Based on preliminary research and communication with key informants in the region, I selected fishing cooperatives in an effort to maximize variation in their relative ability to diversify. Following the suggestion of many SES scholars (Adger, 2000; Marshall and Marshall, 2007; McClanahan et al., 2008a,b), I collected data at the collective level (cooperative) and individual level (fishers within each cooperative) in order to examine how social resilience manifests at multiple scales. This paper reports on analysis at the collective level, and thus only considers aggregate measures of adaptive capacity.

For each fishing cooperative ($n = 22$), I considered 12 years (1997–2008) of income and catch data from the CONAPESCA federal database due to availability and reliability. Catch and income data were collated and cleaned for each cooperative prior to analysis (Supplemental material). I adjusted all income data for inflation, and standardized the data with the last year in the dataset (2008; Supplemental material). I collected interview and participant observation data in the field between June 2012 and December 2013. Although interview data were collected outside of the timeframe of the catch and economic data series, interview questions explored past disturbances experienced by fishers, in addition to the strategies they employed to overcome them, which in large part correspond temporally with the time-series data.

I conducted semi-structured interviews (following the methods of Bernard, 2013) with a representative from each fishing cooperative sampled, in addition to every obtainable member of that cooperative ($n = 171$). Interview questions were intended to provide detailed information on the suite of economic activities each cooperative partakes in, including fishing gear types, species groups, and opportunities in ecotourism, and to elucidate the degree of autonomy each cooperative has, by investigating the cooperatives' roles in decision-making and rule-making processes

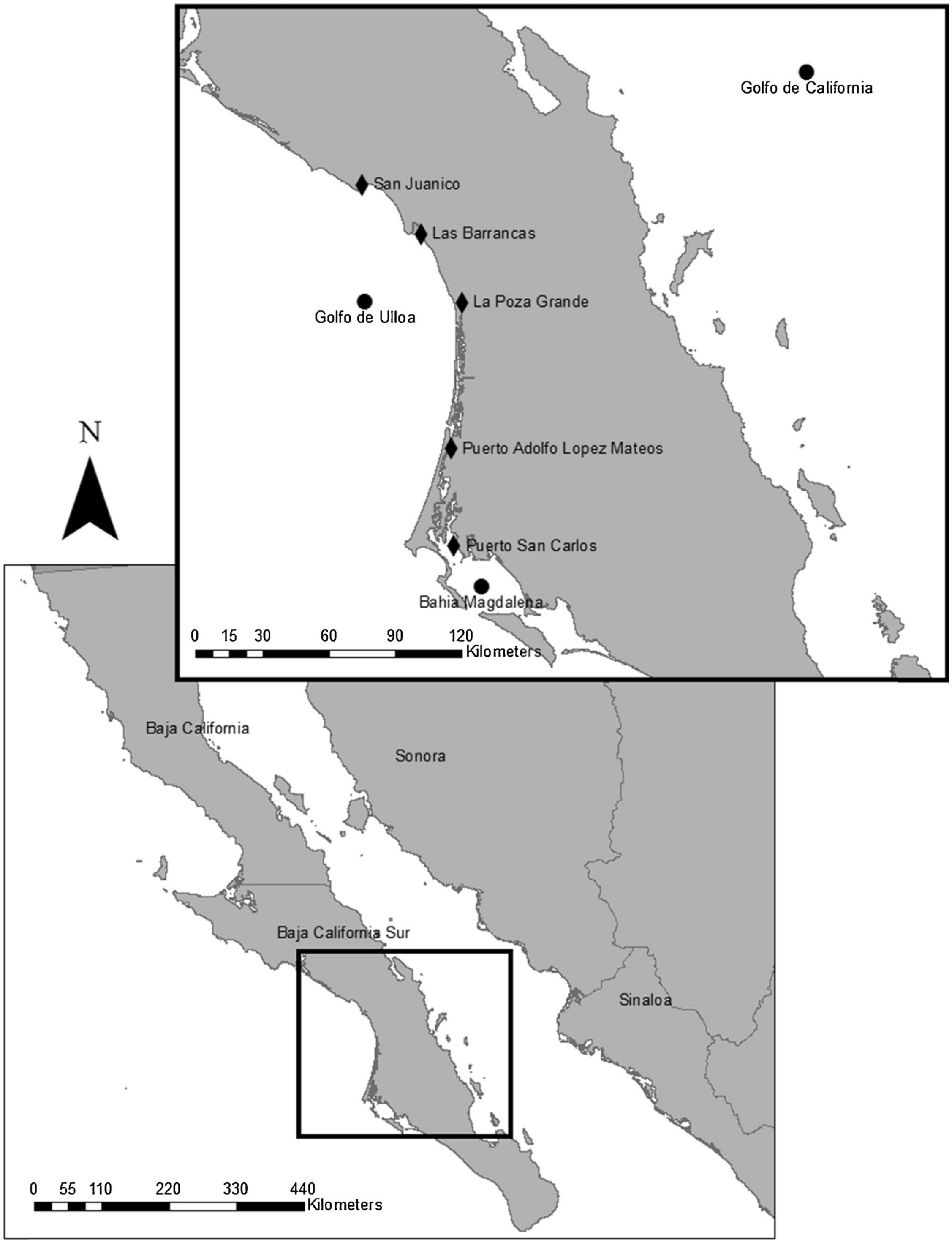

Fig. 1. Study Region. Golfo de Ulloa, Baja California Sur, Mexico. Cooperatives were sampled from San Juanico, Las Barrancas, La Poza Grande, Puerto Adolfo Lopez Mateos, Puerto San Carlos, and surrounding communities and fishing camps.

(Agrawal and Gibson, 1999; VanLaerhoven, 2010). Interviews also intended to investigate coping strategies used by cooperatives during major environmental, political, and economic perturbations. I pre-tested all interview instruments with key informants, and in a focus group with fishers, before use in the local context. With the interviewees' permission, some interviews were digitally recorded for future coding of responses. While in the field, I employed local research assistants helping to access cooperatives, generate trust, coordinate logistics, administer interviews, and overcome potential language and cultural barriers. Upon return from the field, all digitally recorded interviews were transcribed, coded, and entered into a database for analysis (Supplemental material).

2.2. Data analysis: diversification and income stability

In order to measure each cooperative's relative ability to withstand and adapt to change, I used inter-annual cooperative income change as a metric of the economic dimension of social resilience. Adjusted income data were first transformed using a natural log function as income is usually log-normally distributed, and because change in log income between years is essentially a way to measure percent change. With the log-transformed income data, I derived an index of income change by differencing income in the present year from income in the previous year. The resulting values were used as the dependent variable for the first part of the analysis:

$$\text{Inter-annual change in income} = \ln(x_i) - \ln(x_{i-1})$$

where x, cooperative-level annual income; i, current year in dataset.

The primary independent variable of interest for the first part of the analysis, is a measure of cooperative income diversification, the Simpson index used in biological sciences, or the Herfindahl–Hirschman Index (HHI) used in economics. This index is a measure of dominance; larger values represent specialization, and smaller values represent diversification:

$$\text{Income diversification(HHI)} = \sum_{i=1}\left(x_i/\sum_{i=1}^{n}x_i*100\right)^2$$

where x, annual value (landings × price/kilo) for each permitted species group; i, permitted species group; n, total # of species groups in cooperative portfolio for each year.

To test the hypothesis that income diversification (lower value on the HHI scale), is related to smaller inter-annual changes in income (more income stability), I fit a non-linear regression model to examine the relationship between each change in income between subsequent years, and the corresponding HHI value for the resulting year. However, processes driving positive changes in income between subsequent years are likely different than the processes driving negative changes in income between subsequent years. As a result, I divided income data into two different datasets for separate analyses: values associated with negative and positive changes in income.

Changes in inter-annual income could also be mediated by exposure to environmental and market disturbances and fluctuations, not just by a cooperative's ability to diversify income. To account for these important missing variables in the model, I considered oceanographic and market change proxies in the next round of regression analysis in addition to income diversification. Pacific Decadal Oscillation values were calculated as annual averages from the JISAO Index (Joint Institute for the Study of the Atmosphere and Ocean of the University of Washington), and El Niño Southern Oscillation indices were calculated as annual averages from the MEI (Multivariate ENSO Index of NOAA Earth Systems Research Laboratory; Supplemental material). To avoid co-linearity of independent variables in the multivariate model, use of either PDO or ENSO indices was determined a priori based on strength of uni-variate relationships with the dependent variable.

I chose annual averages of shrimp and finfish prices for market change proxies for several reasons. Both are the most common permits held by the cooperatives in this sample, and have the longest time-series data (back to 1997). Shrimp is an important export product for the region and may have signals associated with the export market and global economy. Finfish is relatively important for the local economy, and finfish prices tend to vary a lot corresponding with product volume. As such, finfish price data may have important signals associated with the local economy and price/supply dynamics. I considered annual averages in price per kilo of shrimp and finfish, in addition to the coefficient of variation (CV) in annual prices for the two species groups (Supplemental material). To avoid co-linearity of independent variables in the multivariate model, use of one market change proxy was determined a priori based on strength of uni-variate relationships with the dependent variable.

Using the R package "glm" (Generalized Linear Models), I fit regression models separately for negative and positive inter-annual changes in cooperative income, as a function of cooperative income diversification (HHI values), while controlling for environmental and market change. Additionally, using the R package "nlme" (Non-linear Mixed Effects), I added fishing cooperative to the model as a random factor (allowing the intercept to vary by fishing cooperative). As this did not improve model fit according to AIC values, I used the standard GLM regression instead.

2.3. Data analysis: institutional factors mediating access to environmental resources, and environmental conditions and the relative importance of diversification

If diversification is an important strategy for minimizing inter-annual changes in income, then it is necessary to evaluate the institutional conditions that mediate a cooperative's ability to access and mobilize these different resources. In the next part of the analysis, I used annual cooperative diversification indices as the dependent variable and cooperative level characteristics as independent or explanatory variables. Environmental entitlements literature suggests that environmental access is mediated by the (1) resources possessed by humans, (2) the rights conferred to humans, and (3) "legitimate effective command" to mobilize these resources and rights to ultimately achieve greater well-being (Leach et al., 1999). Using data from cooperative interviews and the federal fishing database, I operationalized these three concepts to include in the analysis (Table 2). Specifically, I operationalized "resources" by (1) proportion of gear ownership by cooperative (boats, motors and fishing gear), (2) reported external support from government and NGOs, and (3) the presence of a savings fund. "Rights" were operationalized by (1) the presence of a concession, (2) proportion of species groups, gear types, fishing zones each coop is legally authorized to access, and (3) number of permits per member. Finally, I operationalized "legitimate effective command" by (1) the level of internal rules, (2) level of enforcement, (3) and proportion of members from each cooperative that report having a strategy during difficult times (Table 2, Supplemental material).

When I constructed indices (i.e. in the case of the Cooperative gear ownership index, and the Authorized rights index), I used reliability analyses to corroborate that each component of the index was significantly correlated with the corresponding index values. Using income diversification now as the dependent variable and proxies for cooperative resources, rights, and command as the independent variables I fit a "glm" regression model to the data in R. Region and year were both added to the model, as a factor and interval variable respectively, to control for differences in space and time. In an effort to understand the system conditions under which diversification or generalist behavior becomes the dominant strategy, I also considered the same environmental and market parameters from the first model in this model. Again, I added fishing cooperative to the model as a random factor (allowing the intercept to vary by fishing cooperative), using the "nlme" package in R. The StepAIC function in R was then used to choose the most parsimonious model, or the model explaining the most variance without over-fitting with the addition of new variables. Finally, I used relevant findings from interview data to contextualize model results in the discussion.

3. Results

3.1. Diversification and income stability

There is a significant non-linear relationship between income diversification and inter-annual changes in income (Fig. 2). The

Table 2
Access Indices. In this model resources are operationalized by (1) proportion of gear ownership by cooperative (boats, motors and fishing gear), (2) reported external support from gov't and NGOs, and (3) the presence of a savings fund. Rights are operationalized by (1) the presence of a concession, (2) proportion of species groups, gear types, fishing zones each coop is legally authorized to access, and (3) number of permits per socio. Legitimate effective command is operationalized by (1) the level of internal rules, (2) level of enforcement, (3) and proportion of members from each cooperative that report having a strategy during difficult times.

Variable	Concept	Definition	Numeric values	Source
Cooperative Gear Ownership Index	Resources	Proportions of interviewed cooperative members who reported the cooperative had ownership of their (1) boat, (2) motor and (3) fishing gear, then averaged across all three material components	Continuous scale; 1 = cooperative owned all gear for all members interviewed, 0 = cooperative owned no gear for all members interviewed	Interviews
External support	Resources	Reported presence or absence of external support each cooperatives has received from governmental and/or non-governmental organizations	Ordinal scale; 1 = governmental and non-governmental support, 0.5 = support from either/or, 0 = no support	Interviews
Savings fund	Resources	Reported presence or absence of a savings fund within the cooperative	Binary; 1 = savings fund, 0 = none	Interviews
Concession	Rights	Reported presence or absence of a 20-year concession (place-based, exclusive access) for abalone and lobster, verified by federal information	Binary; 1 = concession, 0 = none	Interviews/Federal Database
Authorized Rights Index	Rights	Proportion of legally authorized access to (1) species groups, (2) gear types, (3) fishing zones, averaged across all three components	Continuous; 1 = full legal access to all species groups, gear types, and fishing zones, 0 = no legal access	Federal Database
Permits/socio	Rights	Number of permits legally issued to each cooperative, divided by the number of cooperative members during the time period	Continuous; Range: 0.3–3.18	Federal Database
Internal rules	Command	Reported level of internal rules decided upon by cooperative assembly	Ordinal; 1 = Well-developed internal rules, 0.5 = Few internal rules in place, 0 = none	Interviews
Enforcement	Command	Reported level of enforcement each cooperative participated in, considering (1) if one or more cooperative member participated in enforcing fishery laws, and (2) if the cooperative had material assets to do so (enforcement boat or enforcement tower)	Ordinal; 1 = Member participation and material assets, 0.5 = Member participation, 0 = Neither	Interviews
Reported strategies	Command	Proportion of interviewed cooperative members who reported having a strategy to get them through the hardest fishing year in their memory	Continuous; 1 = all cooperative members interviewed reported a strategy, 0 = none	Interviews

model curve is highest at medium values of the HHI, suggesting that positive changes in inter-annual income are maximized when income diversification is at a medium level. As the model intercept is not significant, highest levels of diversification (lowest values of the HHI) occur when income variation is zero, suggesting that inter-annual income stability is maximized at the highest values of diversification. In other words, when fishing cooperatives are able to diversify their income (lower HHI score) they experience smaller fluctuations in income between years.

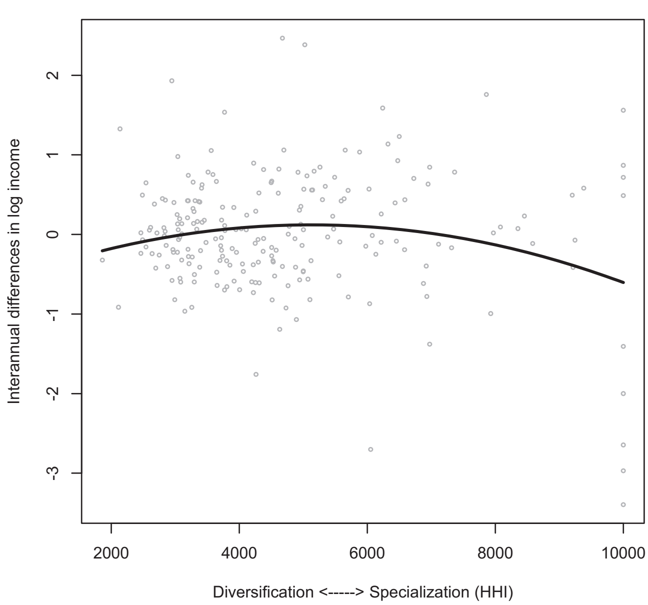

Fig. 2. Income diversification (HHI) and interannual differences in cooperative income. Cooperative income $\Delta \sim -6.828\text{e}{-01} + 3.134\text{e}{-04}(\text{HHI})^{*} + -3.056\text{e}{-08}(\text{HHI}^2)^{**} + \varepsilon$. Significance levels: $^{***}p$-value < 0.001, $^{**}p$-value < 0.01, $^{*}p$-value < 0.05.

After dividing the larger dataset into two separate datasets associated with either positive or negative inter-annual changes in income, I found a significant linear relationship between positive inter-annual changes in income and income diversification, with higher HHI scores (increased specialization) associated with greater positive changes in income between years (Fig. 3a). After controlling for oceanographic and market changes simultaneously, positive inter-annual changes in income are still significantly associated with greater specialization. Additionally, the intercept is no longer statistically different from zero, suggesting that with highest income diversification (or the lowest values of HHI), cooperatives experience smallest inter-annual changes in income (Table 3).

I found a significant non-linear relationship between negative inter-annual changes in income and income diversification, with greater diversification (lower HHI scores) associated with less severe negative changes in income between years (Fig. 3b). While controlling for export market dynamics and ENSO-related oceanographic changes simultaneously, greater income diversification still buffers negative inter-annual changes in cooperative level income and results in greater income stability (Table 4).

3.2. Factors mediating access to environmental resources

A greater suite of authorized rights, internal rules, and savings funds were significantly related to lower HHI scores, or a more diverse fishing portfolio (Table 5, Model A). External support from governmental and non-governmental organizations and reported strategies for dealing with difficult years were associated with higher HHI scores, or a more specialized fishing portfolio (Table 5, Model A). Both the northern region (from La Poza Grande northward) and Puerto San Carlos had significantly greater income

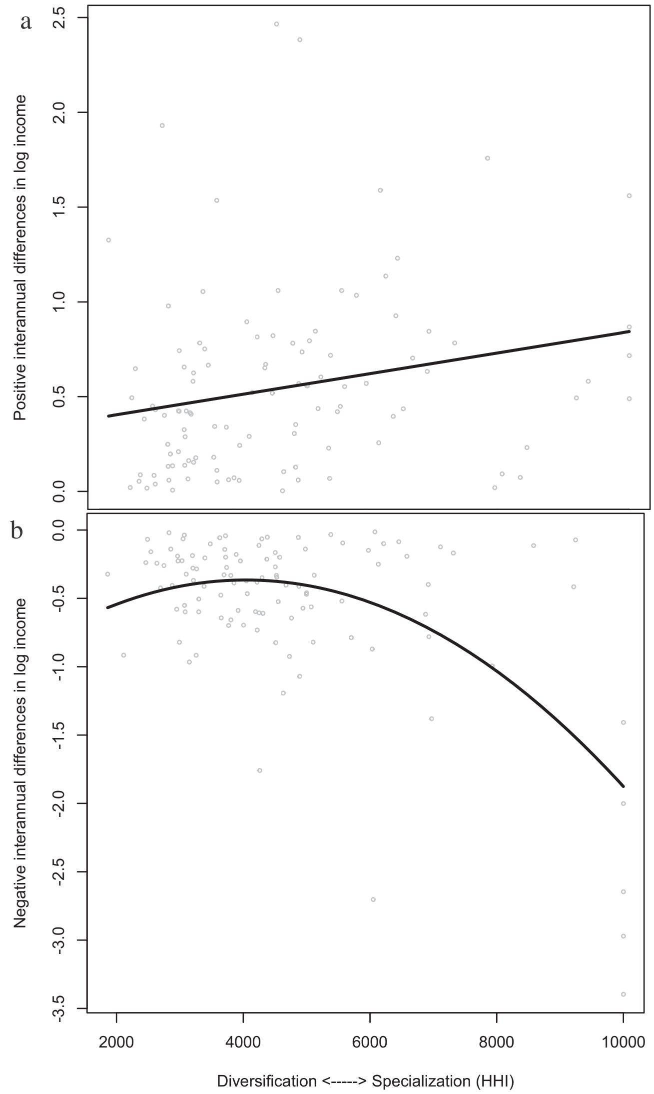

Fig. 3. (a) Income diversification (HHI) and positive interannual differences in cooperative income. Cooperative income $\Delta \sim 2.767e{-}01^{*} + 5.665e{-}05(\text{HHI})^{*} + \varepsilon$. (b) Income diversification (HHI) and negative interannual differences in cooperative income. Cooperative income $\Delta \sim -1.060^{**} + 3.441e{-}04(\text{HHI})^{**} + -4.256e{-}08(\text{HHI}^2)^{***} + \varepsilon$. Significance levels: $^{***}p$-value < 0.001, $^{**}p$-value < 0.01, $^{*}p$-value < 0.05.

diversification with respect to Puerto Adolfo Lopez Mateos (Fig. 1; Table 5, Model A). Year was also a significant factor, elucidating a trend toward more diversification over time (Table 5, Model A).

3.3. Environmental conditions and the relative importance of diversification

Controlling for variability in market and oceanographic conditions decreased the original model's residual variance and was selected as a better model using Aikake's Information Criteria (AIC, Table 5, Models A and B). ENSO was the most important oceanographic parameter, and has a significant inverse relationship with the diversification index (Table 5, Model B). In other words, warmer ocean temperatures are associated with diversification relative to specialization strategies. The coefficient of variation in finfish price was the most important market variability parameter, and its significant inverse relationship with the dependent variables suggests that increased local market volatility is associated with diversification (Table 5, Model B).

After introducing fishing cooperative as a random intercept to the most parsimonious model, the presence of a savings fund, external support, and reported strategies for dealing with hard years became less statistically linked to a cooperative's ability to diversify (Table 5, Model C). Additionally, region became less statistically important in the overall model after the intercept was allowed to vary by cooperative (Table 5, Model C). The AIC value was considerably lower in the random intercept model with respect to the previous model (Table 5, Models B and C), suggesting that there is residual variation in each cooperative that is not accounted for explicitly in the cooperative characteristics derived from this dataset. However, there are no substantive changes in results across the standard and random intercepts models; relationships between and among variables are similar and the overall trend remains the same (Table 5, Models B and C).

4. Discussion

4.1. Diversification and income stability

Here I document a statistical link between diversification and income stability in SSF, corroborating similar recent research in

Table 3
Income diversification (HHI) and positive inter-annual differences in cooperative income – multivariate model controlling for oceanographic (ENSO) and market (CV Finfish Price) conditions. Significance levels: $^{***}p$-value < 0.001, $^{**}p$-value < 0.01, $^{*}p$-value < 0.05.

	Model estimates
Intercept	−8.392e−02
HHI	6.963e−05**
ENSO	−1.287e−02
CV Finfish Price	0.2242***

Table 4
Income diversification (HHI) and negative inter-annual differences in cooperative income – multivariate model controlling for oceanographic (ENSO) and market (CV Shrimp Price) conditions. Significance levels: $^{***}p$-value < 0.001, $^{**}p$-value < 0.01, $^{*}p$-value < 0.05.

	Model estimates
Intercept	−0.3535
HHI	3.273e−04**
HHI^2	−3.957e−08***
ENSO	−0.2816**
CV Shrimp Price	−1.774***

Table 5
Model coefficients demonstrating, A: Cooperative level characteristics related to income diversification; B: Cooperative level characteristics and environmental conditions related to income diversification; C: Similar to Model B but adding fishing cooperative as a random effect (allowing intercept to vary by fishing cooperative). Significance levels: $^{***}p$-value < 0.001, $^{**}p$-value < 0.01, $^{*}p$-value < 0.05.

	Model A	Model B	Model C
Intercept	8229.37***	8807.41***	8764.344***
Cooperative Gear Ownership Index	–	–	–
External Support	2992.43**	2849.39**	3254.601
Savings Fund	−717.78**	−708.82**	−714.829
Concession	–	–	–
Authorized Rights Index	−4768.65***	−4703.81***	−4924.770**
Permits/Socio	–	–	–
Internal Rules	−2583.31***	−2485.08***	−2731.534*
Enforcement	–	–	–
Reported Strategies	1337.96*	1317.76*	1381.798
Gulfo de Ulloa Region	−1404.11***	−1420.41***	−1324.716
San Carlos Region	−856.48**	−838.19*	−826.311
Year	−210.66***	−585.19**	−566.459**
ENSO	NA	−392.98*	−396.445**
CV Finfish Price	NA	−230.74***	−233.856***
AIC	2984	2970	2816

west coast United States fisheries (Kasperski and Holland, 2013), and demonstrating the importance of maintaining human response diversity for collective groups of fishers facing change. However, my research takes this theory a step further through my explicit examination of the *type of variation* in income (positive or negative changes) instead of just examining the coefficient of variation. My research shows that while diversification generally stabilizes income and likely acts as an important risk aversion or coping strategy, during favorable conditions specialization can generate greater positive changes in income. This is important because income stabilization could be interpreted as a favorable outcome unless income is stabilized at very low levels, or the fishery is in a poverty trap (Cinner, 2011; Cinner et al., 2009). In other words, while diversification could be important for risk mitigation and for coping with disasters, specialization may be important for poverty reduction and wealth accumulation. Thus, a resilient SSF (from an economic perspective) would have the elasticity to move between both diversification and specialization strategies as conditions change. Facilitating flexibility to move across these fishing strategies may be a critical target for governance.

4.2. Institutional factors mediating access to environmental resources

Different components of environmental access are important for facilitating fishing cooperatives' flexibility to employ different fishing strategies. Similar to the development literature's theory on environmental access (Leach et al., 1999), my statistical models suggest that resources, rights, and legitimate effective command are all important for a cooperative's ability to diversify and subsequently minimize inter-annual changes in income. Specifically, the presence of a savings fund, a greater suite of legally authorized rights, and internal rules developed by cooperative members, were all important characteristics of cooperatives with relatively greater diversification. Surprisingly, the possession of a concession did not come out as an important predictor of the ability to diversify, despite the fact that the uni-variate relationship between concession and diversification is significant (Fig. 4). However, cooperatives with concessions, or exclusive access to particular species groups in designated geographic areas, are generally characterized by enforcement incentives and capacity, strong internal rules, and deeper savings funds in particular (McCay et al., 2014; Micheli et al., 2012), the latter two of which were statistically important in explaining model variance.

The authorized rights index, provided a measurement of authorized species groups, gear types, and fishing zones, and was the most statistically powerful cooperative characteristic explaining the ability to diversify. In other words, having a greater suite of rights, issued by fishing permit, is important for cooperatives' relative ability to access the environment and diversify. Fishers in Mexico tend to have slightly larger fishing portfolios than legally authorized, because multiple mechanisms exist for landing illegal catch. However, I found that a cooperative's *de facto* fishing portfolio with respect to a legally authorized portfolio had a weaker relationship with the relative ability to

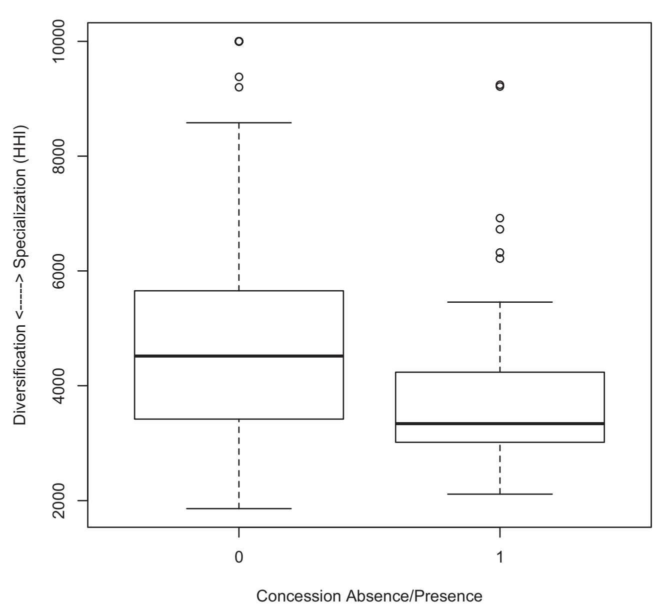

Fig. 4. Concession rights and income diversification. Income diversification (HHI) ~ 4896.6*** − 935.1(Concession)** + ε. Significance levels: $^{***}p$-value < 0.001, $^{**}p$-value < 0.01, $^{*}p$-value < 0.05.

diversify. This may be attributed to the fact that, although not impossible, it is more difficult to market species groups without corresponding rights. The importance of legally authorized rights for a cooperative's relative ability to diversify has important implications for the region. Fisheries permitting mechanisms in Mexico tend to be characterized by a lack of transparency, inefficient bureaucracies, and favoritism, thus there is an uneven distribution of fisheries rights, and a tendency for fisheries rights to accumulate under wealthier and more powerful individuals (Basurto et al., 2012; Cinti et al., 2010, 2009). Thus, if livelihood security is considered an important governance objective for Mexico, my research suggests the need to increase cooperatives' access to the environment through the redistribution of fishing rights in a more equitable manner.

In terms of a cooperative's relative ability to specialize when certain market, environmental, or other conditions are favorable for the extraction of a particular species, my research suggests that the ability to mobilize support from external agencies is important for fishing cooperatives in the region. Most commonly, state and federal governments provide support via financing mechanisms for motors, boats, fishing gear, and fuel. In some cases (i.e. cooperatives possessing concessions), the government aids in augmenting local enforcement capacity. External agencies can also provide support in terms of opening marketing channels and facilitating market integration across scales. The importance of greater communication and collaboration between fishers and external agencies in Mexican small-scale fisheries is a common theme in other regional studies (Finkbeiner and Basurto, 2015). In particular, Cudney-Bueno and Basurto (2009) found that a lack of cross-scale communication and support between Gulf of California fishers and the federal fisheries enforcement agency, led to the demise of a fisher organization's attempt at self-governance and sustainable resource extraction. Achieving better cross-scale linkages is difficult in the context of rural Mexican fisheries, as federal agencies have limited funding and personnel to provide adequate support. However, there is a diversity and abundance of stakeholder bodies with a common interest in facilitating healthy and resilient coastal communities and related ecosystems, along the Baja Peninsula in particular. A surge in civil society organizations in recent years with a shift in focus from environmental conservation to participatory sustainable management, has the potential to facilitate communication and coordination across fishers and various levels of governance (Espinosa-Romero et al., 2014; Schneller and Baum, 2010).

Cooperatives with a higher proportion of members who reported having a strategy to confront hard times were more likely to specialize when conditions were favorable. This result seems counterintuitive since coping strategies have been linked to diversification not specialization. For example, the most frequently cited strategies for confronting difficult years identified by cooperative members were changing gear type or species groups, moving to another livelihood outside of the fisheries sector, and switching fishing zones, respectively. All of these strategies correspond with fishers' ability to diversify. However, interpreted within the context of a cooperative's "legitimate effective command" to mobilize resources and rights, a fishing cooperative that has command over how and when they access the environment, should be able to mobilize these different resources and rights during both lean and productive times, moving between diversification and specialization strategies. Importantly, command is a difficult concept to measure because it is intricately linked to opportunities available to humans (i.e. resources and rights); thus, it needs to be interpreted within this context. Regardless, the idea of command from the development literature is consistent with human agency, or the capacity for individuals and groups to decide and act independently. Human agency has recently been identified as an important component of social resilience (Berkes and Ross, 2013), and scholars are calling for the need to better integrate human agency into resilience studies (Davidson, 2010). Although this research barely scratches the surface of the underlying mechanisms linking human agency to resilient SSF, it nonetheless suggests that fishing cooperatives with autonomy to mobilize resources and rights will have a greater capacity to adapt to change.

4.3. Environmental conditions and the relative importance of diversification

My findings provide additional evidence that the proportion of generalist versus specialist fishers may fluctuate over time in response to changes in environmental conditions (Smith and McKelvey, 1986). Periods characterized by cooler oceanographic temperatures and market stability corresponded with an increase in specialization across cooperatives. In contrast, warmer oceanographic temperatures and increased market volatility, indicative of increased system uncertainty and variability, corresponded with greater cooperative diversification, again providing evidence that diversification is a risk aversion strategy. In recent years, variability and uncertainty in coastal communities have increased due to a confluence of factors including the recent economic crisis, increased conflict in Mexico associated with the narcotic trade, a subsequent halt in tourism, changing oceanographic conditions such as seasonal reductions in dissolved oxygen and pH (Micheli et al., 2012), and frequent and intense hurricane events, suggesting the relevance and importance of this research. Supplemental interview data from this study demonstrate a common perception among fishers that variability and uncertainty are indeed affecting their livelihoods. Specifically, 88% of interview respondents reported that market changes or fluctuations in price affect their livelihood. Interview responses most commonly emphasized a sense of powerlessness against buyers and middlemen, in addition to drastic seasonal changes in fish prices associated with product volume flooding the market. Likewise, 96% of interview respondents reported that environmental and biophysical changes affected their livelihood, citing strong winds and inter-annual changes in water temperature as critical factors in inhibiting their ability to make an income.

Given globalization and climate change processes currently underway, if diversification is an important risk aversion strategy during periods of increased uncertainty and variability, there should be a significant increase in diversification over the time period of the study (1998–2007). And in fact, these data provide evidence that this is the case, demonstrating a significant trend toward greater diversification over the study period (Fig. 5). As it takes time for a cooperative to accrue permits and resources since its inception, the trend toward diversification could be indicative of the process toward creating a more diverse portfolio. In any case, its emergent nature suggests that diversification is becoming a desirable or perhaps necessary strategy for these cooperatives. If given the choice to diversify across many different species or specialize in just one, 86% of fishers interviewed reported they would rather diversify. When asked why, most fishers talked about livelihood and income security given seasonal and inter-annual changes in production, in addition to complying with seasonal closures, and adjusting for constant changes in price. Interestingly, some fishers responded that this fishing strategy is the best from an environmental sustainability perspective – that the ability to switch across species reduces pressure on overexploited species, allowing them to recover. Diversification as a fishing strategy, therefore, may be important for ecological sustainability in addition to livelihood sustainability.

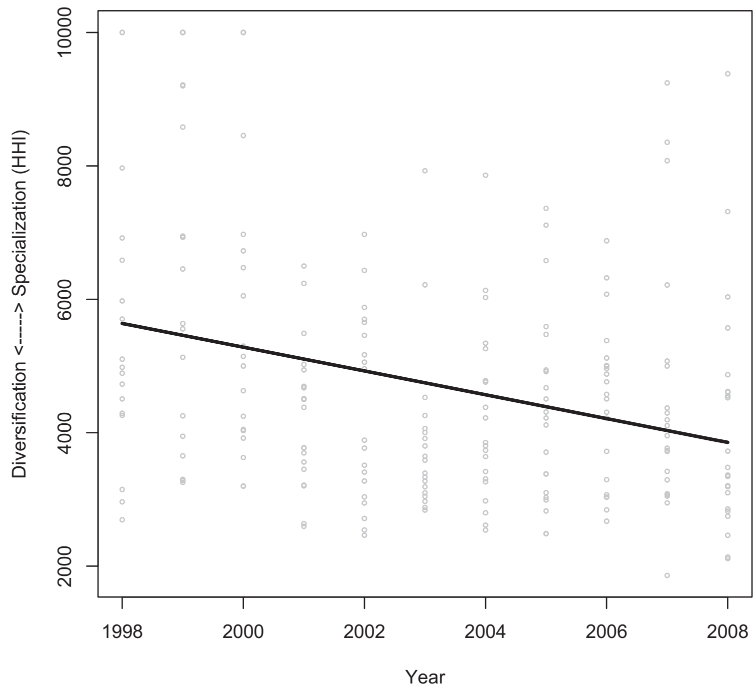

Fig. 5. Temporal trend in income diversification over the dataset time period. Income diversification (HHI) $\sim$ 5639*** − 178(Year)*** + ε. Significance levels: $^{***}p$-value $<$ 0.001, $^{**}p$-value $<$ 0.01, $^{*}p$-value $<$ 0.05.

4.4. Caveats

There are a number of important caveats to address in the context of interpreting these results. First, resilience is a difficult concept to operationalize in empirical research given the multi-dimensional and multi-scale qualities. Using one indicator as a proxy for resilience is not appropriate given its scalar, economic, and social dimensions (Adger, 2000). In this study, I measured the ability of common-property institutions to cope with stresses and shocks, using income stability as a proxy, and then by examining the underlying institutional mechanisms driving these patterns. Thus, given available data, this study interpreted and measured social resilience from an economic and institutional perspective, and subsequently these results must be interpreted within this context alone.

Second, in understanding how institutional configurations can promote or erode social resilience to environmental change, the concept of scale is critical, as processes that control resilience can manifest differently at varying scales (Adger, 2006; Adger et al., 2004). For example, Cinner and Bodin (2010) found that with increasing socio-economic development, resilience was compromised at the household level as livelihoods became increasingly specialized, but at the community level economies remained diversified. In other words, the capacity for a household to adapt to change is constrained or enabled by conditions at the community level or at other scales (Smit and Wandel, 2006). Thus, when studying resilience of social–ecological systems, it is imperative to measure individual and collective levels of resilience (Adger, 2000). As I only measured certain aspects of social resilience at the aggregate, cooperative-level in this study, future research should assess the distribution of these rights and resources within cooperatives, affecting individual fishers. This is especially important for this study region in particular, as fishing cooperative resources and rights are not always equitably distributed among members within cooperatives.

Third, I only assessed diversification within the context of the fishery, and did not account for livelihood diversification of cooperative members in this analysis. In this region, and across many SSF, livelihood diversification represents an important strategy for sustaining income. Because this analysis occurred at the level of the fishing cooperative, this precluded the consideration of diverse livelihoods among fishers. The importance of livelihood diversification for adaptive capacity of individual fishers will need to be addressed in future research.

Finally, while this study considered how access to the environment is linked to certain aspects of social resilience, it did not consider how these same processes link back to the ecosystem. Furthermore, the ecological impact of diversification remains elusive and the literature divided (Cinner, 2014). In one sense, resource dependency (specialization) is thought to incentivize resource stewardship, so accordingly, fishers who diversify may place less importance on the future of one particular resource given ease of switching (Gelcich et al., 2007; Ostrom, 1990; Smith and McKelvey, 1986). In contrast, others suggest that policies pushing toward fishery specialization can increase dependency on fishing, or on a particular fishery, making it harder for fishers to turn to non-fishing economic activities, or to other fisheries, during periods of resource scarcity. This may further undermine the viability of fish stocks (Allison and Ellis, 2001; Berkes, 2003; Hilborn et al., 2001), and erode resilience of the social–ecological system (Chapin et al., 2010; Mahon et al., 2008; McClanahan et al., 2008a,b). Understanding the ecological effects of diversification in SSF deserves further attention.

5. Conclusions

The main goal of this research was to contribute to the growing body of literature that investigates how to govern SSF from a resilience perspective. In other words, how can governance enable SSF to adapt to change over time in an environment characterized by uncertainty and variability? In particular, this research investigated the importance and underlying mechanisms of governing to enhance human response diversity in a changing environment, with three main objectives. First, I wanted to understand if diversification was important for fishing cooperatives to maintain stability in their economic activity over time. I found that while diversification was important for risk mitigation and stabilizing income, the ability of cooperatives to specialize during favorable conditions may be important for poverty reduction and wealth accumulation. Thus, the flexibility to move across fishing strategies given changing environmental conditions is important for the adaptive capacity of small-scale fishing cooperatives. Next, I wanted to understand what institutional factors enable fishers to access the marine environment and mobilize these different fishing strategies. I found that elements of resources possessed by fishing cooperatives, rights conferred to cooperatives, and command over these resources and rights were important for mobilizing diversification and specialization strategies. My last research objective was to investigate the environmental conditions under which diversification becomes a dominant strategy. I found that diversification is an important strategy during increased environmental and market uncertainty and volatility. I also found that fishing cooperatives in northwest Mexico are diversifying more over time, perhaps in response to accelerated rates and intensity of change this region is facing. In sum, human response diversity and access to the environment is important for these small-scale fishing cooperatives to adapt to change over time.

The implications of this research for Mexican and global SSF are important. Fishing rights in Mexico are difficult to obtain as the solicitation process is arduous, requires economic, social, and political capital, and often lacks transparency. As a result, many small-scale fishers in Mexico continue to fish without rights, while select cooperatives and individuals in positions of power may have access to numerous fishing rights that are often unused. Fishers without rights, or with limited rights, tend to be the most marginalized from policy-processes and have a difficult time accessing the marine environment. A first step in the direction of governing for resilience, would involve legal recognition of the fishing labor force, and a redistribution of permits among fishing cooperatives and permit holders for more equitable access to the environment.

Resources, such as fishing gear, financial capital, and external support provide important buffers during lean times, and can also provide opportunities for fishers. For example, cooperatives with savings funds have secure access to financial capital during emergencies and crises, and can better take advantage of opportunities that arise (buying a larger boat authorized for tourism, or building a processing plant to add value to their fishery). Important resources facilitating resilience in small-scale fisheries can also include capacity building support from non-governmental organizations, foundations, and fishers themselves to exchange ideas and skills for adapting to change.

Last, increased command or agency across small-scale fishers can be achieved by empowerment processes from the ground-up and top-down. Specifically, more needs to be done in Mexico and around the world, to integrate fishers into policy arenas, where their voices are heard, opinions considered, and ideas integrated into policy. The more fishers are involved in formal and informal governance (i.e. monitoring, enforcement, rule-making, conflict resolution), the more they are able to act independently with greater agency. Therefore, granting autonomy to fisher organizations (like cooperatives) and creating stronger mechanisms integrating fishers into policy arenas will be important for achieving resilient small-scale fisheries in the face of change.

These lessons have implications beyond fisheries; this knowledge is applicable to resource-extraction economies in general, particularly for regions disproportionately affected by climate change and other global processes. Just as the investor knows to diversify an investment portfolio in a market characterized by risk and uncertainty, in the face of a changing world, all humans should be able to access a diversity of responses for overcoming challenges and achieving resilience.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.gloenvcha.2015.03.009.

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