frontiers | Frontiers in Marine Science

TYPE Original Research
PUBLISHED 19 October 2022
DOI 10.3389/fmars.2022.1028280

Check for updates

OPEN ACCESS

EDITED BY
Oscar Sosa-Nishizaki,
Center for Scientific Research and Higher Education in Ensenada (CICESE), Mexico

REVIEWED BY
Oswaldo Huchim-Lara,
Universidad Marista de Mérida, Mexico
Lida Teneva,
Independent researcher, Sacramento, CA, United States

*CORRESPONDENCE
Farrah Powell
fpowell@sdsu.edu

SPECIALTY SECTION
This article was submitted to Marine Fisheries, Aquaculture and Living Resources, a section of the journal Frontiers in Marine Science

RECEIVED 25 August 2022
ACCEPTED 30 September 2022
PUBLISHED 19 October 2022

CITATION
Powell F, Levine A and Ordonez-Gauger L (2022) Fishermen's perceptions of constraints on adaptive capacity in the California market squid and California spiny lobster fisheries. *Front. Mar. Sci.* 9:1028280. doi: 10.3389/fmars.2022.1028280

COPYRIGHT
© 2022 Powell, Levine and Ordonez-Gauger. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.

Fishermen's perceptions of constraints on adaptive capacity in the California market squid and California spiny lobster fisheries

Farrah Powell[1,2]*, Arielle Levine[1] and Lucia Ordonez-Gauger[1]

[1]Department of Geography, San Diego State University, San Diego, CA, United States,
[2]Department of Geography, University of California, Santa Barbara, Santa Barbara, CA, United States

Planning for resiliency in the face of unprecedented environmental change requires understanding the factors that constrain fishermen's capacity to adapt. Scholars have highlighted numerous factors that may facilitate or constrain fishermen's adaptive capacity, but ultimately fishermen act based on their own perceptions of their ability to respond and adapt to change within their broader social, environmental, and governance context. Subjective assessments of adaptive capacity are limited, yet critical, given that in the face of stressors, people's actions are facilitated or constrained by their subjective perceptions of their capacity to take action. Using fishermen interviews and feedback sessions, we explored fishermen's perceptions of constraints on their ability to adapt to change in two fisheries in the California Current System: California spiny lobster and California market squid. Our comparative assessment revealed important similarities and differences with regard to the likelihood that fishermen would perceive a given factor as a constraint, as well as the extent to which different domains of adaptive capacity, including diversity and flexibility in livelihood options, knowledge, and access to physical and financial capital, influence fishermen's perceptions of constraints. Constraints relating to fishery governance, including permit access, fishery regulations, and broader concerns with fishery management were the most commonly perceived constraints in both fisheries. Individual-level constraints including mobility and knowledge of other fisheries and fishing locations were less frequently cited and significantly more likely to be perceived as constraints by spiny lobster fishermen than market squid fishermen. Our results highlight the importance of considering interactions between factors constraining different elements of adaptive capacity given that the broader governance context of fisheries can inhibit individual-level adaptive strategies. Overcoming barriers to adaptation necessitates planned and participatory governance processes that strengthen fishermen's individual agency and ability to take meaningful action in the face of change.

KEYWORDS

adaptive capacity, constraints, agency, fisheries governance, subjective assessments, environmental change

1 Introduction

Rapid and unprecedented environmental change is reshaping ocean ecosystems, dramatically affecting those dependent on natural resources, and raising concerns regarding how communities will respond and adapt (Marshall and Marshall, 2007; McClanahan and Cinner, 2011). The degree to which changes in climate affect human populations varies considerably across both places and individuals, depending on the local manifestations of a given stressor (i.e., exposure), the degree to which people depend on affected resources (i.e., sensitivity), and on their capacity to adapt to or take advantage of the changes they experience (i.e., adaptive capacity) (Adger, 2006; Gallopín, 2006; Cinner et al., 2018). Affected communities and individuals must respond to both climatic and non-climatic stressors, and understanding how they respond and their ability and willingness to adapt is essential for climate adaptation planning.

Scholarship on adaptive capacity seeks to better understand the conditions that enable individuals or communities to anticipate and respond to changes, to minimize and recover from the consequences of change, or take advantage of new opportunities (Grothmann and Patt, 2005; Gallopín, 2006). Some scholars identify key underlying determinants of adaptive capacity as the availability of and access to different forms of capital, such as natural, human, social, financial, and physical capital (Adger, 2003; Smit and Wandel, 2006; Hinkel, 2011). However, adaptive capacity is not solely determined by underlying access to capital (Mortreux and Barnett, 2017; Cinner et al., 2018; Green et al., 2021). It is also contingent on people's willingness and capability to convert resources into effective action, and thus adaptation efforts can be hindered in a multitude of ways (Coulthard, 2012; Islam et al., 2014a). Other less tangible domains of adaptive capacity, including governance and institutions, learning and knowledge, diversity and flexibility, and agency also play key roles in facilitating or hindering a social system's ability to adapt to climate change (Brown and Westaway, 2011; Bennett et al., 2014; Whitney et al., 2017; Cinner et al., 2018; Green et al., 2021). As such, conceptualizing adaptive capacity as constrained primarily by resources and capital can obscure value-laden personal and societal limits to adaptation and the ways in which different strategies are negotiated. In the face of stressors, people typically act upon their subjective internal perceptions rather than objective external measures (Grothmann and Patt, 2005; Smith and Clay, 2010). Thus, subjective assessments of adaptive capacity deal with perceptions of the adequacy of available resources and the factors that empower or constrain social systems or actors to adapt (Adger et al., 2009; Seara et al., 2016).

In the context of fisheries, fishermen have historically employed multiple strategies to cope with or adapt to variable conditions including: diversifying fishing portfolios and targeting multiple species (Anderson et al., 2017; Cline et al., 2017; Robinson et al., 2020), diversifying fishing grounds (Young et al., 2019), altering harvesting techniques (Sievanen, 2014; Cinner et al., 2015), or exiting a fishery and pursuing alternative employment (Coulthard, 2009). These strategies fall under the flexibility domain of adaptive capacity and reflect options for altering one's livelihood within fishing or outside the fishing sector entirely in response to stressors (Cinner et al., 2018; Oestreich et al., 2019). While the literature concerning adaptation in commercial fisheries has shown that these strategies can buffer against environmental uncertainty and income variability (Kasperski and Holland, 2013), their feasibility requires a holistic consideration of the costs and constraints to pursuing them, which will differ amongst individuals and communities (Islam et al., 2014a; Anderson et al., 2017; Ward et al., 2018; Beaudreau et al., 2019).

Limits and barriers to adaptation emerge as a result of specific characteristics of the individuals involved, the nature and scale of the fishery systems involved, and/or the larger regulatory context within which the systems operate (Moser and Ekstrom, 2010; Islam et al., 2014b). Prior to changing harvest locations, times, or targeting species, new information and knowledge may be needed. Fishermen are typically limited in where they can fish based on local ecological knowledge, vessel size or gear type, geographic distance, and costs (Rogers et al., 2019; Young et al., 2019; Papaioannou et al., 2021). The high financial capital necessary to augment physical capital (e.g., larger vessels or new gear), to purchase additional fishing permits (assuming they are available), or to travel to more distant fishing grounds may limit the viability of pursuing a given strategy (Stoll et al., 2017). In addition, fishermen's ability to diversify is constrained by their regulatory context, including restrictions on access to licenses and fishing rights, spatial management measures, jurisdictional boundaries, and at times, customary territoriality (Murray et al., 2010; Sievanen, 2014).

While effective adaptation to climate change requires that individuals have assets, flexibility, and knowledge, they must also have the ability to mobilize these elements of adaptive capacity, which relates to the agency domain of adaptive capacity (Cinner et al., 2018). Distorted beliefs regarding an individual's own ability to respond to and manage climate impacts, whether it relates to personal traits or to larger regulatory factors, can pose barriers to adaptation. Despite the importance agency plays in activating other domains of adaptive capacity (Cinner et al., 2018; Green et al., 2021), this domain is underutilized (Hicks et al., 2016). An improved understanding of fishermen's own perceptions of constraints on their capacity to adapt can assist in the development of policies that remove barriers to key adaptation options, promote resilience, and maintain livelihoods while simultaneously ensuring the sustainability of resources (Seara et al., 2016).

In this study, we directly engaged with fishermen to better understand their perceptions of constraints on their capacity to adapt to change in two diverse fisheries in the California Current System (CCS): California spiny lobster (*Panulirus interruptus*) and California market squid (*Doryteuthis opalescens*). The CCS is a highly productive upwelling system, producing and supporting numerous fisheries (Harvey et al., 2021). It is characterized by seasonal wind-driven upwelling and high biological productivity (García-Reyes and Largier, 2012). Climate change projections indicate a robust and unambiguous signal of future surface warming in the CCS (Pozo Buil et al., 2021), along with changes in the timing and intensity of upwelling, which critically affects the productivity and distribution of marine species from primary producers to top predators (Checkley and Barth, 2009; Iles et al., 2012; Xiu et al., 2018; Pozo Buil et al., 2021). Furthermore, although market squid and spiny lobster rank among the highest value commercial fisheries in the CCS (NMFS, 2018), studies addressing the adaptive capacity of these fisheries are limited. There are also notable differences in these fisheries in terms of scale of operations, seasonality, gear and vessels, regulations, and species' responses to climate variability, which can generate dramatically different adaptation responses and outcomes. We examine how perceptions of constraints on adaptive capacity vary across these two fisheries, as well as how characteristics of individual fishermen, particularly as they relate to assets, flexibility, and agency, influence the likelihood that they will perceive different factors to be constraints within each fishery. We situate our findings within the broader fishery and regulatory context in which fishermen operate and conclude with a discussion of how interactions between different domains of adaptive capacity can enhance or negate broader adaptive capacity within fisheries.

2 Materials and methods

We employed a comparative research approach in order to understand constraints on adaptive capacity in California spiny lobster and California market squid fisheries. Previous fisheries research has demonstrated the usefulness of the comparative approach for identifying similarities and differences between fishery systems (Gaichas et al., 2012; Dey et al., 2016; Murciano et al., 2021).

2.1 Study fisheries

The California spiny lobster fishery is a relatively small-scale fishery, with the majority of fishing activity occurring in the Southern California Bight, from Point Conception to the California-Mexico border, including some areas surrounding the offshore Channel Islands (CDFW, 2019) (Figure 1). The fishing season runs from early October to mid-March each year, although 80% of a season's catch is landed between October and mid-January (CDFW, 2016). There is considerable evidence that the spiny lobster fishery is enhanced during warm sea surface temperature (SST) conditions associated with El Niño events and the warm phase of the Pacific Decadal Oscillation (Koslow et al., 2012). Fishermen operate relatively small boats (mean size 30.5 feet) to deploy baited rectangular traps made of wire or plastic mesh and set on the bottom (CDFW, 2019). The spiny lobster stock has been managed using a number of regulations designed to protect the spawning potential of spiny lobster including restrictions on: size, season, access (number of permits), gear type, and total harvest (CDFW, 2016). Marine protected areas (MPAs) implemented under the Marine Life Protection Act in 2012, also prohibit take of lobster in certain locations to increase egg and larval production (Lenihan et al., 2021). The CDFW adopted the California Spiny Lobster Fishery Management Plan (FMP) in 2016, which put into place a cohesive management strategy to guide the future sustainable management of the recreational and commercial lobster fisheries, as required by the Marine Life Management Act (CDFW, 2016). The purpose of the FMP was to formalize a management strategy for spiny lobster that is responsive to environmental and socio-economic changes and establish a framework for informed decision-making to achieve a sustainable fishery integrating the entire ecosystem.

The California market squid fishery is a large-scale industrial fishery operating over a significantly larger geographic range. The fishery in California is comprised of northern (centered in Monterey Bay) and southern components (predominantly in the Channel Islands vicinity and coastal areas within the Southern California Bight), with the majority of landings historically occurring in the southern fishery (Figure 2). The northern fishery typically operates from April through November, while the southern fishery operates from October through March

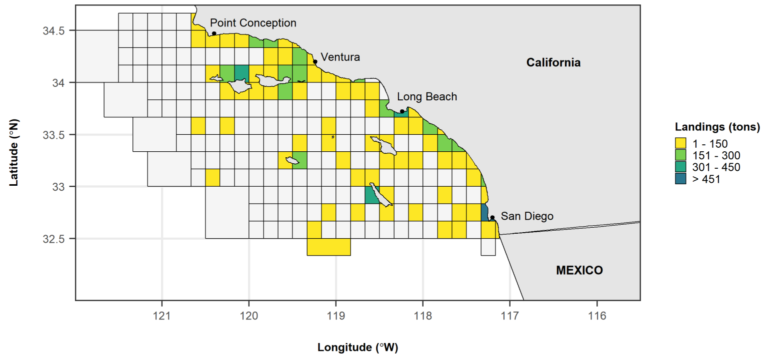

FIGURE 1
Map of total California commercial spiny lobster fishery landings (tons) by fishing block from 2000 to 2019 fishing seasons (CDFW Marine Landings Database System, MLDS). Fishing blocks with less than 15 entries were excluded.

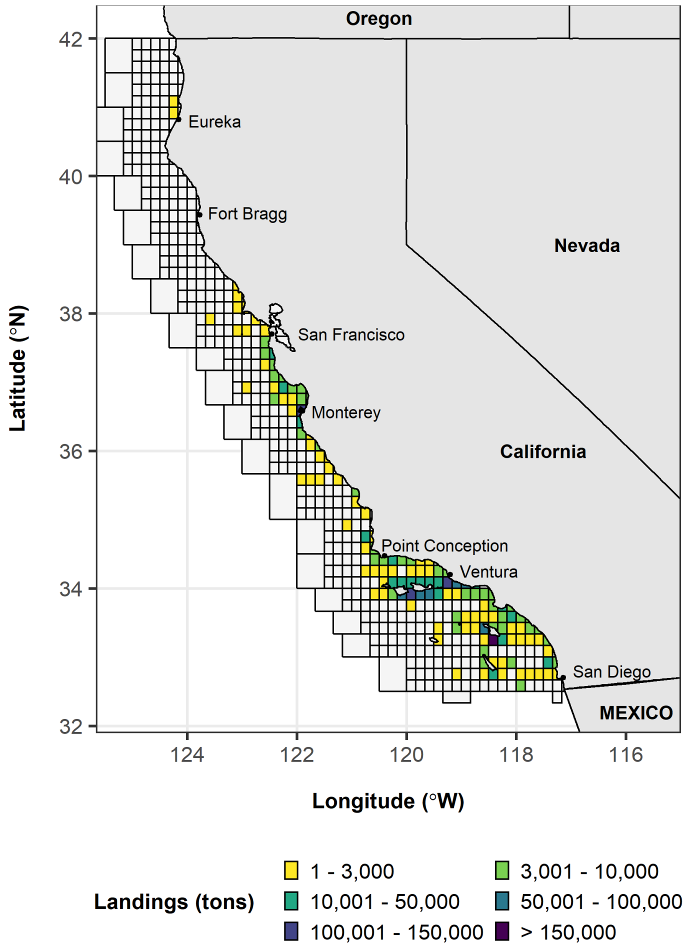

FIGURE 2
Map of total California commercial market squid fishery landings (tons) by fishing block from 1996 to 2018 fishing seasons (CDFW MLDS). Fishing blocks with less than 15 entries were excluded.

(CDFW, 2005). Recently, fishing activity has extended into northern California, Oregon, Washington, and Alaska as a result of warming ocean temperatures (Chambers, 2016; Columbia Basin Bulletin, 2018). Market squid fishermen operate large, high-capacity vessels (mean size 55 feet, mean capacity 64 tons) alongside lightboats that are used to attract the squid. Market squid is harvested primarily using roundhaul gear (e.g., purse seine, drum seine, and lampara nets) with a minor proportion of seasonal catch coming from brail/dip net gear (CDFW, 2005). In order to prevent excessive fishing effort (facilitated by newer, larger, and more efficient vessels) and allow for critical periods of uninterrupted spawning, the CDFW developed the Market Squid FMP in 2005, which consists of several static management measures including: a fixed seasonal catch limit of 118,000 tons, 2-day weekend closures, light and gear restrictions, a restricted access program, and monitoring programs (port sampling and logbooks) (CDFW, 2005). Market squid populations, and associated catch, fluctuate dramatically in response to variations in ocean conditions, declining drastically in unfavorable environments associated with El Niño events, characterized by warm SST and low productivity, and rebound rapidly during favorable conditions associated with La Niña events, characterized by cool SST and high productivity (Reiss et al., 2004; van Noord and Dorval, 2017; Powell et al., 2022).

2.2 Data collection

Semi-structured interviews were conducted with owners and operators of vessels participating in the commercial California market squid and California spiny lobster fisheries during the 2017-2019 fishing seasons (see Supplementary Material for relevant interview questions). Interview subjects were primarily identified at fishing docks and by snowball sampling, later supplemented with a contact list from the CDFW. Interviews for both fisheries consisted of closed-ended, open-ended, and multiple-choice questions. We used a series of yes/no questions to examine whether fishermen experienced a pre-defined list of constraints to adaptive capacity, including permit access, regulations, mobility, knowledge of other locations, and knowledge of other fisheries. They were also provided the opportunity to add additional constraints to this pre-defined list, and to elaborate and explain their responses for each identified constraint. The interviews also included a series of multiple-choice and open-ended questions concerning fishermen's access to assets or capital, as well as diversity and flexibility that might influence the likelihood of experiencing a given constraint. The interviews lasted approximately 60 minutes, and any personally identifiable information was removed from interviews prior to analysis.

Interviews with spiny lobster fishermen were conducted with the goal of surveying as many active fishermen as possible. Permit-holding fishermen were considered 'active' if the fisherman participated in the fishery (landed and reported catch) in at least one of the previous three fishing seasons (i.e., 2014–15, 2015–16, 2016–17) based on a list of permits and landings data obtained from CDFW. Interviews were conducted at major southern California fishing ports in San Diego, Orange County, Los Angeles, and Santa Barbara or by phone (based on fishermen's preference). A total of 88 lobster fishermen were interviewed, representing 59% of total active fishermen during the interview period.

Interviews were conducted with active market squid fishermen with the goal of surveying an owner or boat operator representing as many active squid vessel permits as possible. Vessel permits were considered 'active' if the vessel participated in the fishery (landed and reported catch) in at least one of the previous three fishing seasons (i.e., 2014–15, 2015–16, 2016–17) based on a list of permits and landings data obtained from CDFW. Interviews were conducted at Ventura Harbor, the primary landing port for squid, as well as non-port locations or by phone (if preferred or if fishermen were based outside of southern California). A total of 54 squid fishermen were interviewed, representing 48% of total active vessels (both squid and squid lightboat) during the interview period.

2.3 Data analysis

After reviewing and familiarizing ourselves with the interview data, open-ended responses were coded using an iterative, inductive approach (Maguire and Delahunt, 2017). We identified an initial list of themes pertaining to the nature and context of each constraint for each fishery individually. Initial codes were reviewed and refined for internal consistency and to reduce overlap across themes. After identification of themes, fishermen's responses to perceived constraints were analyzed using descriptive statistics (frequency, mean, and standard deviation). In order to determine whether the likelihood of experiencing a given constraint was associated with fishery-specific, demographic, or socio-economic characteristics, we used inferential statistics within the R environment (R Core Team, 2020). T-tests were selected under the assumption that both samples are random, independent, and come from normally distributed populations (confirmed using the Shapiro-Wilk test) with unknown but equal variance. If samples were not normally distributed, we used the Wilcoxon Rank Test. When dealing with categorical data, we used the two-proportion z-test to determine if the proportions of categories in two group variables significantly differed from each other.

2.4 Fishermen feedback sessions

As a supplement to the interviews, we engaged groups of knowledgeable fishery participants in a series of feedback sessions. Those who had participated in the survey were recruited based on an opt-in question at the end of the survey (asking fishermen if they wanted to participate), and some fishermen were recruited by word-of-mouth at the harbor for the market squid feedback session. Preliminary findings were presented during the feedback sessions to invite discussion, validate results, and address additional questions that emerged from our preliminary data analysis.

The market squid feedback session was held in November 2019 with 11 fishermen in Ventura, CA, the primary port for squid and where most fishermen are based during that time in the fishing season. Detailed notes were taken throughout the session. Due to the pandemic, spiny lobster fishermen feedback sessions were conducted *via* Zoom, and thus in much smaller groups. For these meetings, we attained verbal consent for audio recording of the meeting into written transcriptions. A total of eight spiny lobster fishermen participated in three different sessions held in April and May 2021. Participants included fishermen from San Diego, Newport, and Santa Barbara.

3 Results and discussion

Planning for resiliency in light of ongoing climate change requires understanding and addressing the factors that constrain fishermen's capacity to adapt. Our study focused on subjective assessments, or fishermen's own perceptions of constraints to their adaptive capacity. This focus has been noted for its importance, given that people act based on their own perceived capacity, regardless of what might be considered more objective measures of their adaptive capacity (Seara et al., 2016).

Given the geographic proximity of market squid and spiny lobster fisheries, both are exposed to similar climatic, regulatory, and socio-economic stressors. However, inherent differences between the fisheries, including the scale of operation, management policies, vessels, and gear, influence fishermen's perceptions of constraints to adaptation and thus adaptation outcomes. We found that fishermen participating in both the squid and lobster fisheries perceived regulatory and governance related constraints as influencing their capacity to adapt to future change, in particular: 1) limited access to additional fishery permits, 2) restrictive fishery regulations, and 3) broader concerns with fishery management processes (Figure 3). Factors related to individual fishermen's knowledge or ability to act, including 1) limited mobility or 2) knowledge of other locations and fisheries, were also seen as constraining adaptation in both fisheries, although to a lesser extent (Figure 3). Each of these factors was expressed in different

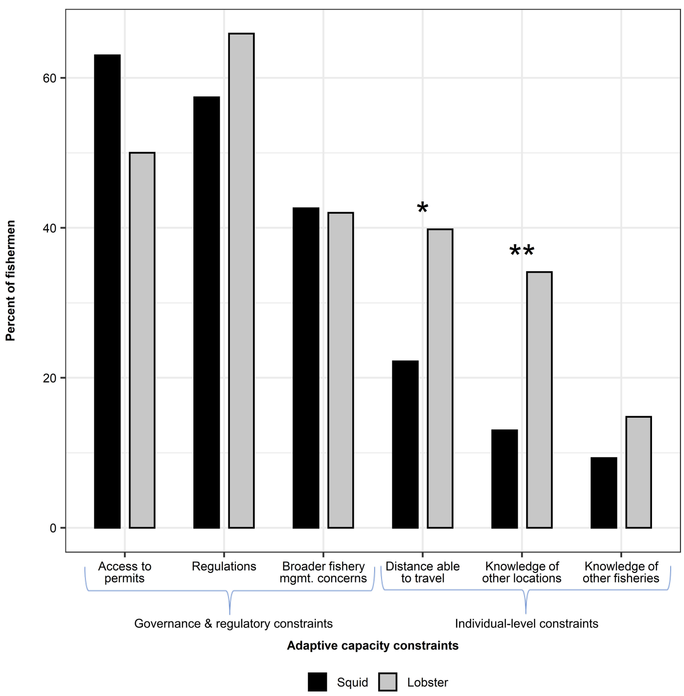

FIGURE 3
Percent of market squid fishermen (n = 54) and spiny lobster fishermen (n = 88) who stated that each factor constrained their capacity to adapt to future change. * Statistically significant difference between the proportion of fishermen in each fishery (z = 2.16, *p* = 0.015). ** Statistically significant difference between the proportion of fishermen in each fishery (z = 2.78, *p* = 0.003).

ways across the two fisheries, as well as amongst individuals within each fishery, highlighting the importance of comparative assessments of adaptive capacity both within and between fisheries.

While there were significant differences between the two fisheries in the proportion of fishermen who perceived mobility or knowledge of other locations to be constraints, the proportion of fishermen who cited regulatory and governance-related constraints was similar in each fishery. Furthermore, fishermen's access to individual assets (financial and physical capital), and their flexibility within and across fisheries, influenced their perceptions of constraints. In both fisheries, fishermen who had less financial capital and less diversity and flexibility in livelihood options were more likely to perceive certain factors as constraints (Table 1). For lobster fishermen, physical capital (smaller boat size) also increased the likelihood of fishermen perceiving a constraint (travel and distance), and for squid fishermen, learning/knowledge (in the form of years of fishing experience) was associated with greater likelihood of perceiving regulations as a constraint.

Although all of these factors have been cited as important for adaptive capacity in fisheries (Whitney et al., 2017; Cinner et al., 2018), our results demonstrate that the extent to which each of these influences fishermen's perceptions of constraints is fishery-dependent. Furthermore, our results suggest that the broader governance context may limit fishermen's agency and their ability to take advantage of assets such as large vessels, mobile gear, and knowledge of additional species and fishing grounds. If fishermen view regulatory and management structures and policies as inflexible and feel that they are unable to influence fishery governance processes, they may perceive themselves as limited in their ability to adapt, in spite of high 'objective' levels of adaptive capacity associated with individual access to capital, learning/knowledge, and flexibility.

TABLE 1 Results from significance tests (two-proportion z-test and Wilcoxon signed rank test) showing factors associated with perceived constraints in each fishery.

Constraint	Variable	Adaptive capacity domain	Fishery	Test statistic	p-value	Value associated w/ constraint
Inability to obtain or access permits	Access to/reliance on alternative income (non-fishing) (Y or N)	Diversity/flexibility	Market squid	z = 2.17	0.015 *	No
			Spiny lobster	z = 2.57	0.005 **	Yes
	Household income category (≤ $150,000 or > $150,000)	Financial capital	Market squid	z = 0.53	0.297	
			Spiny lobster	z = 1.99	0.023 *	≤ $150,000
	Additional fishing permits held (Y or N)	Diversity/flexibility	Market squid	z = 2.05	0.02 *	No
			Spiny lobster	z = 2.01	0.022 *	No
Strict regulations	Years fishing (in respective fishery)	Learning/knowledge	Market squid	W = 186	0.001 ***	Longer duration
			Spiny lobster	W = 970	0.189	
	Household income category (≤ $150,000 or > $150,000)	Financial capital	Market squid	z = 1.38	0.084	
			Spiny lobster	z = 2.42	0.008 **	≤ $150,000
	Type of permit held (light boat/brail or vessel/seine)	Financial capital	Market squid	z = 2.01	0.022 *	Light boat/brail
Distance able to travel	Household income category (≤ $150,000 or > $150,000)	Financial capital	Spiny lobster	z = 2.08	0.019 *	≤ $150,000
	Vessel size (≤ 30 ft or > 30 ft)	Physical capital	Spiny lobster	z = 2.99	0.001 ***	≤ 30 ft
Knowledge of other locations	Household income category (≤ $150,000 or > $150,000)	Financial capital	Spiny lobster	z = 2.63	0.004 **	≤ $150,000
	Resource dependence (≤ 60% or > 60% of total annual income)	Diversity/flexibility	Spiny lobster	z = 3.54	0.0002 ***	> 60% of total annual income
	Vessel size (≤ 30 ft or > 30 ft)	Financial & physical capital	Spiny lobster	z = 2.81	0.002 **	≤ 30 ft

Significance tests were only conducted if at least 30% of fishermen in each fishery cited a given constraint. * p value < 0.05, ** p value < 0.01, *** p value < 0.001.

3.1 Institutional influences on adaptive capacity (governance and regulations)

3.1.1 Ability to access or obtain permits

In order to sustainably manage fisheries and halt or prevent stock declines, fisheries in the U.S. and internationally have been subject to increasingly restrictive regulatory measures including: limited access or catch share programs, fishery closures, quota reductions, and MPAs (Murawski et al., 2000; Roberts et al., 2005; Costello et al., 2008; Mora et al., 2008; O'Keefe et al., 2014). While this regulatory context has been critical to preventing overfishing and rebuilding U.S. fish stocks (NOAA Fisheries, 2021), it also constrains fishermen's actions and access to fisheries in which they participate, as well as complimentary fisheries in which they may wish to participate. We found that 63% of squid fishermen and 50% of lobster fishermen cited the ability to obtain permits for other fisheries as a factor that limited their ability to adapt to future change (Figure 3). There was consensus among fishermen in both fisheries that the high cost and limited availability of permits reduce the number of different fisheries that they can potentially access (Figure 4). Indeed, given the large number of limited entry fisheries and high cost of entry for most fisheries on the U.S. West Coast, permit-related constraints have been documented to affect nearly all fishermen and fisheries operating within this region (Holland and Kasperski, 2016; Richerson and Holland, 2017; Frawley et al., 2021).

Diversity and flexibility in livelihood options and access to financial capital influenced whether fishermen perceived their ability to obtain or access additional permits as a constraint (Table 1). The high cost of entry disproportionately impacts fishermen in lower income brackets given that obtaining access to fishing rights and associated permits requires high financial capital. This corresponds with our finding that lobster fishermen in lower income brackets (annual household income below $150,000) were significantly more likely to perceive access to additional permits as a constraint than those in higher income brackets (annual household income $150,000 or more) (Table 1). Moreover, we found that both squid and lobster fishermen were more likely to perceive access to permits as a constraint if they did not already hold additional permits due to their limited availability, regardless of whether they could afford the expense (Table 1). Access to permits in limited entry or quota-regulated fisheries is also likely to limit newer entrants to fishing as an occupation, given that permits and quota are typically initially allocated based on historical participation and catch (Bertheussen et al., 2021). Although access to non-fishing sources of income was correlated with whether or not fishermen perceived access to additional permits as a constraint, the direction of the relationship differed between fisheries. While squid fishermen who relied on alternative sources of income (as opposed to those solely dependent on fishing for income) were significantly less likely to perceive their ability to obtain or access additional permits as constraining their adaptive capacity, the opposite was the case for lobster fishermen (Table 1). This suggests greater complexity in these relationships possibly related to the level of dependence on alternative income sources or potentially other factors we did not test for.

3.1.2 Regulatory constraints

Fishermen from both the squid (57%) and lobster (66%) fisheries cited fishery regulations as constraining their capacity to adapt to future change (Figure 3). However, the specific regulations that were cited as constraining adaptive capacity varied by fishery (Figure 5). For squid fishermen, closures and quota reductions in other fisheries were a frequently cited

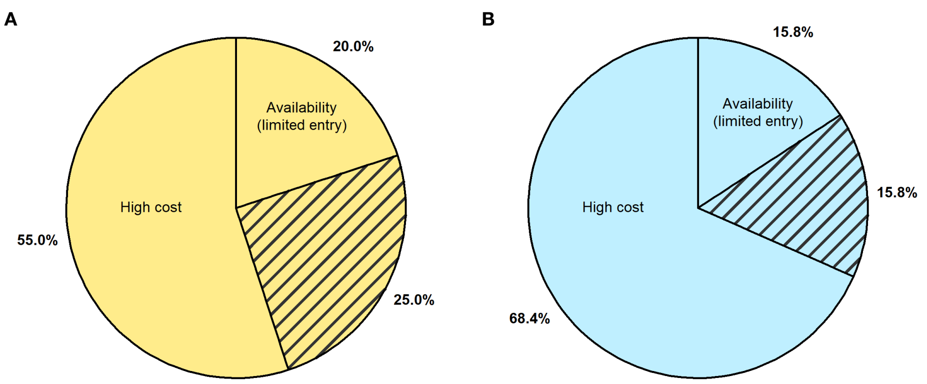

FIGURE 4
Themes from open-ended responses from fishermen who chose to elaborate on the ability to access or obtain permits as a constraint to adaptive capacity. **(A)** indicates the percent of responses from market squid fishermen who chose to elaborate (n=20) and **(B)** indicates the percent of responses from spiny lobster fishermen who chose to elaborate (n=19). Each theme is labeled in the pie chart and hashing indicates overlap between two adjacent themes.

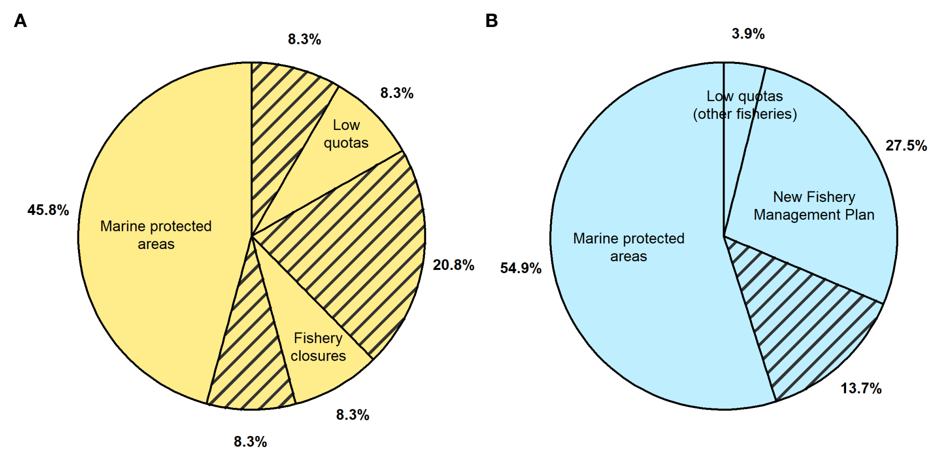

FIGURE 5
Themes from open-ended responses from fishermen who chose to elaborate on regulatory-based constraints to adaptive capacity. **(A)** indicates the percent of responses from market squid fishermen who chose to elaborate (n=24) and **(B)** indicates the percent of responses from spiny lobster fishermen who chose to elaborate (n=51). Each theme is labeled in the pie chart and hashing indicates overlap between two adjacent themes.

regulatory constraint (Figure 5A). While access to multiple permits is often cited as increasing fishermen's flexibility, and thus overall ability to adapt to environmental change (Aguilera et al., 2015; Cinner et al., 2018; Young et al., 2019), closures or quota reductions in alternative fisheries may negate the benefit of holding additional permits. Squid fishermen historically have shifted effort among coastal pelagic finfish species (i.e., Pacific sardine, Pacific and jack mackerel, and northern anchovy) in response to fluctuations in resource availability or demand associated with climate, market, and regulatory changes (Pomeroy et al., 2002; Aguilera et al., 2015). Coastal pelagic finfish permits are the most frequently held additional permit for market squid fishermen (Powell et al., 2022) due to their overlapping ranges, and overlapping requirements for gear, vessels, and personnel (Pomeroy et al., 2002). Despite the interconnectedness of these fisheries and the flexibility it historically afforded fishermen, recent closures of the sardine fishery, an overall decrease in market value, and quota reductions now undercut the advantages of having this permit, meaning the most complementary and commonly held additional permit no longer increases flexibility (Powell et al., 2022).

One fisherman who commented on the implications of recent fishery closures stated, "It's dangerous to have all your eggs in one basket. We've always had another fishery to move to, and sardine helped us stay afloat. Now there's nothing else you can do." These closures and quota reductions not only reduce fishermen's flexibility to shift target species, but they have also led to much higher effort and competition within the squid fishery, evidenced by one fisherman who stated, "I was involved in many fisheries, but it's all gone to hell. I can't make any money. Salmon's not very good, sardine's closed … we're getting squeezed and having to spend more time in squid." Although only a few lobster fishermen cited low quotas in other fisheries as a constraint to their adaptive capacity (Figure 5B), one fisherman specifically commented on the loss of opportunity and flexibility in the face of larger regulatory constraints, stating, "It used to be that rock cod was a fill-in fishery for slow lobster seasons, but the quota is now so low you may as well toss the permit. Someone with the knowledge, boat, and gear for another fishery often can't even use it because of issues like this with quota being lowered and lowered."

Over half of squid fishermen and the majority of lobster fishermen who elaborated on regulatory constraints specifically cited MPAs as constraining their capacity to adapt to future change (Figure 5). Fishermen perceived MPAs to reduce their adaptive capacity by restricting their access to fishing locations, and in many cases displacing them from traditional harvesting grounds (Charles and Wilson, 2009; Moreno-Sánchez et al., 2013). Displacement associated with MPAs has been documented to lead to overcrowding and social tension, increased travel costs to new fishing grounds, and increased time spent 'learning' new fishing areas (Murray et al., 2010; Bennett and Dearden, 2014; Guenther et al., 2015). Furthermore, nearly all of the respondents who elaborated on MPAs as a constraint expressed their dissatisfaction with the implementation process as well as the chosen locations for the protected areas. As one lobster fisherman stated, "I am not okay with the way managers did it and the way areas were chosen. They took some of the best fishing away from us, and they didn't do it fairly. They changed meeting dates and nobody was able to show up. They got people that don't even fish to represent people from the islands." Another fisherman said, "MPAs are killing us. The best and most productive areas were taken away. MPAs took all the reefs and left us sand. Everything that closed hurt us or was our habitat."

Lobster fishermen who elaborated on regulatory constraints as limiting their capacity to adapt to future change also cited the new Fishery Management Plan (FMP) (Figure 5B). Nearly all of these fishermen expressed their dissatisfaction with the new trap limit (300 per season) and the allowance of permit stacking. Whether or not fishermen saw the new trap limit as a constraint varied based on their scale of operation. Larger-scale operators felt disproportionately impacted by the new, lower trap limit, stating that it is too restrictive for larger vessels that have greater trap capacity. Some of these fishermen commented on the loss of opportunity associated with the lower limit, stating, "The new trap limit inhibits ambition and money you can make, [reducing] production potential for good, established fishermen. We should have the right to work harder if we want to, to get more reward." Conversely, smaller-scale operators, who generally fish less than 300 traps per season, felt that the allotment was unnecessarily high and will lead to an unsustainable number of traps in the water. Furthermore, fishermen felt that permit stacking only favors the wealthier individuals and will lead to excessive trap neglect, evidenced by one fisherman's comment: "I am not okay with stacking. It's becoming an arms race. It lets the rich get richer. It's classist and unfair, and it's not even realistic to service that many traps."

Within each fishery, different types of factors including access to financial capital and fishery-specific knowledge influenced whether fishermen perceived certain management measures as constraining their capacity to adapt to future change (Table 1). For squid fishermen, we found that those holding brail permits (as opposed to those holding vessel/seine permits) were more likely to perceive within-fishery regulations such as quota as a constraint (Table 1), likely due to differences in vessel capacity and the timing of harvesting associated with each type of permit (Hennessey, 2013). We also found that those who had more years of participation in the commercial fishery (i.e., greater experience and knowledge) were more likely to feel constrained by fishery regulations (Table 1). Given that fisheries in California have undergone substantial and increasingly restrictive regulatory changes over the last several decades, fishermen who have participated in the fishery for longer have experienced dramatic changes in the regulatory context, whereas newer entrants may accept the current regulatory regime as the status quo.

For lobster fishermen, those in lower income brackets (with lower financial capital) were more likely to perceive fishery-specific regulations as a constraint than those in higher income brackets (Table 1). Given that MPAs were a frequently cited regulatory constraint, this relationship could be related (in part) to financial costs associated with MPAs such as increased travel expenses or loss of income (typically short-term) from restricted access (Davis et al., 2019), both of which disproportionately impact individuals with lower financial capital. The permit stacking allowance in the new FMP was another frequently cited regulatory constraint that benefits only fishermen who can afford multiple permits. Thus, those in lower income brackets would not have access to the same opportunity and may be more likely to perceive this as a constraint.

3.1.3 Broader concerns with fishery governance

Both market squid and spiny lobster fishermen were given the option to list additional constraints that limited their adaptive capacity and were not represented by the pre-defined constraint categories provided during the interviews. Forty-three percent of squid fishermen and 42% of lobster fishermen cited additional constraints, all of which were related to broader concerns with fishery governance (Figure 3). The majority of fishermen in each fishery specifically mentioned mistrust in management entities and limited fishermen representation and input in decision-making as constraints (Figure 6). Mistrust in authorities also stemmed from fishermen's perceptions of a lack of science-based management as well as a perception of insufficient fishing regulations. One squid fisherman stated, "We want net depth restrictions please. Ban cable purse and require rib line. Managers don't listen to us. We need changes to save the resource or we're going to lose it." Another squid fisherman who commented on his general mistrust in management and lack of input in decision-making said, "I inherently don't trust CDFW. They get way too carried away with everything. MPAs, all these regulations, they're just shoved down our throats. If we manage to get a say, it's once they've already made the big decisions so our opinion doesn't really matter." For lobster fishermen, concerns with fishery management included both the commercial and recreational sectors of the fishery (Figure 6B). Lobster fishermen expressed similar sentiments regarding mistrust and exclusion from decision-making, with one stating, "I really get the feeling that our input as fishermen isn't valued by managers or scientists. At the hearings, your voice isn't heard. I would like to see a higher value placed on fishermen's intrinsic knowledge. Management needs to talk to fishermen one-on-one, work directly with us, not just top-down process of acknowledgement."

Both squid and lobster fishermen who perceived management of their respective fishery as a constraint to their ability to adapt also mentioned the lack of enforcement of existing fishing regulations, including spatial and temporal management measures, gear restrictions, permitting issues, and size limits (specifically poaching of undersized lobster). Weak or inconsistent enforcement of local rules can exacerbate mistrust, diminish perceived legitimacy in local rules and policy-makers, and perpetuate non-compliance, all of which constrain fishermen's adaptive capacity (Islam et al., 2014b; Rohe et al., 2017). For many lobster fishermen, their concerns about poaching and the loss of access to fishing areas were exacerbated by perceptions that rules are unequally enforced

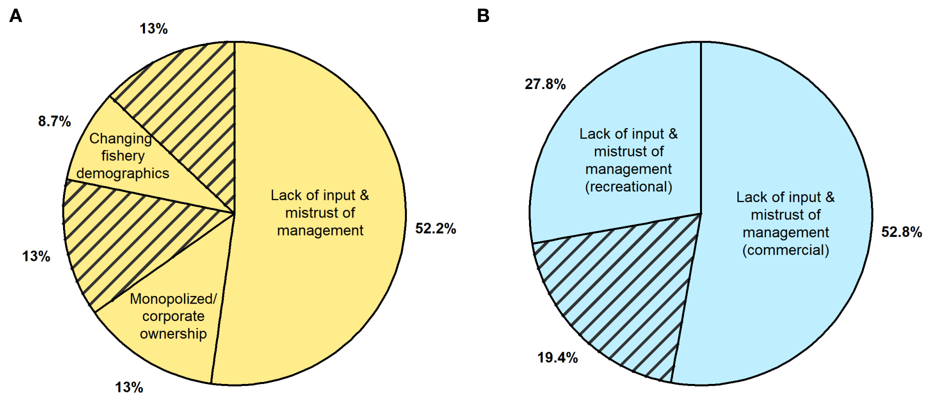

FIGURE 6
Themes from open-ended responses from fishermen who chose to elaborate on broader concerns with fishery governance and its effects on adaptive capacity. **(A)** indicates the percent of responses from market squid fishermen who chose to elaborate (n=23) and **(B)** indicates the percent of responses from spiny lobster fishermen who chose to elaborate (n=37). Each theme is labeled in the pie chart and hashing indicates overlap between two adjacent themes.

between the recreational and commercial fisheries. Nearly all lobster fishermen who discussed their concerns with management of the recreational fishery commented on the perceived widespread poaching due to weak enforcement and regulation, particularly in MPAs and lobster nurseries or in reference to size or bag limits, which directly impacts the commercial fishery *via* removal of the breeding stock. For example, one fisherman who commented on the management of the recreational fishery said, "It is so poorly managed. They kill more than we do. Hoop netters are going wild, catching 8lb lobsters in the bay and catching tons of undocumented ones … everybody sees and knows. Why is nothing being done? Enforcement is not paying attention." Another lobster fisherman who discussed the perceived lack of enforcement said, "Our biggest problem is Fish & Game's [CDFW's] lack of manpower to enforce their regulations. All of the veteran guys are very frustrated with the lack of enforcement and low fines and penalties for taking of shorts. We need stronger penalties to incentivize compliance."

Many squid fishermen who elaborated on broader concerns with fishery management discussed the influx of out-of-state fishery participants (primarily from Alaska) as well as the increasing corporate ownership of vessels and subsequent monopolization of the industry (Figure 6A). One squid fisherman who commented on the more aggressive fishing style of the recent out-of-state entrants and subsequent increased competition for fishery resources stated, "Our fishery changed last year with all the new Alaska guys entering the fishery. These are heavy weather fishermen, fishing any weather, any time, and it's pushing us to fish in more dangerous conditions. The fishery is so aggressive now. They want every squid." In regards to increasing corporate ownership of the fleet, fishermen were concerned about the impact of this trend on profit to operators, particularly when a single corporation controlled both fishing permits and processors. As one fisherman stated, "Traditional Italian families buy up all the boats and permits. Employees end up with no say on the price and we can't go on strike. No competitive action is available in reaction to price collusion. Having permit holders and processors as one is a monopoly. Processors should never own boats." Several lightboat captains also discussed the implications of corporate ownership of vessels in regards to their inability to unionize and strike.

3.2 Individual-level constraints on adaptive capacity: Mobility and knowledge

Both squid (22%) and lobster (40%) fishermen cited the distance they are able to travel for fishing as limiting their capacity to adapt, although the proportion of lobster fishermen who listed this as a constraint was significantly greater than that of squid fishermen (Figure 3). Of the market squid fishermen who elaborated on this constraint, the majority cited the limited infrastructure for offloading, processing, and cold freezer storage in northern ports where the fishery has recently expanded as constraining factors (Figure 7A). It is important to note that at the time of the interviews, squid fishermen were limited by the distance they were able to travel due to a lack of offloading infrastructure in the most northern range of the fishery. Due to the high perishability of squid once it is caught, specialized offloading, processing, and cold freezer storage facilities are needed within an 8 to 10 hour travel range from the place it is caught. However, with the more recent increasing use of mobile pumps and proposed investment into new industrial scale

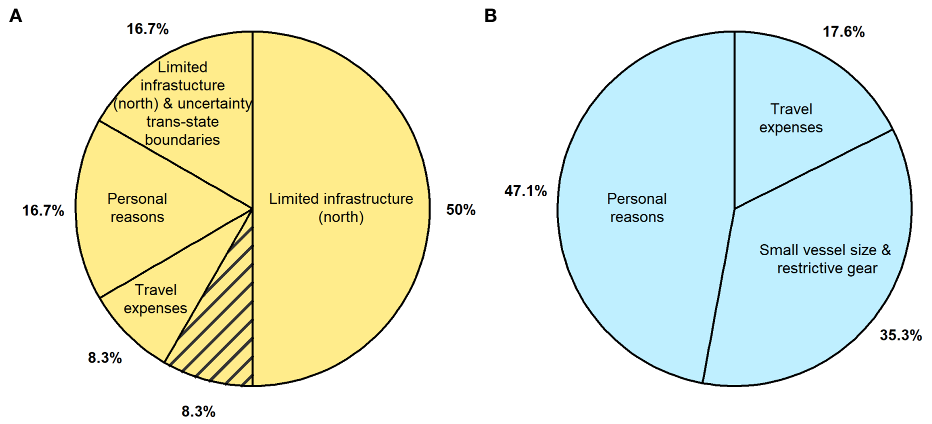

FIGURE 7
Themes from open-ended responses from fishermen who chose to elaborate on travel/mobility-related constraints to adaptive capacity. **(A)** indicates the percent of responses from market squid fishermen who chose to elaborate (n=11) and **(B)** indicates the percent of responses from spiny lobster fishermen who chose to elaborate (n=17). Each theme is labeled in the pie chart and hashing indicates overlap between two adjacent themes. Note that half of fishermen cited limited infrastructure in northern regions alone and an additional 16.7% cited that along with uncertainty in trans-state fishery boundaries (e.g., Oregon, Washington, Alaska).

infrastructure (Bates & Hildebrand, 2018), insufficient infrastructure is now less likely to pose a significant constraint to mobility in the squid fishery. Other squid fishermen who elaborated on this constraint mentioned: personal reasons such as age, family, or place attachment, travel expenses such as fuel and trucking, and uncertainty regarding trans-jurisdictional fishery boundaries as constraints to mobility. Of the spiny lobster fishermen who elaborated on this constraint, about half of respondents cited personal reasons such as age, health, family, place attachment, while others cited small vessel size and restrictive gear and travel expenses as constraints to the distance they are able to travel for fishing (Figure 7B).

Both squid (13%) and lobster (34%) fishermen also cited knowledge of other locations as limiting their capacity to adapt, although the proportion of lobster fishermen who listed this as a constraint was significantly greater than that of squid fishermen (Figure 3). Of the fishermen who elaborated on their limited knowledge of other locations as a constraint, all market squid fishermen and the majority of spiny lobster fishermen discussed the importance of local ecological knowledge for fishing and the difficult and time-consuming learning curve associated with obtaining this knowledge (Figure 8). Lobster fishermen who elaborated on this constraint also referenced the territorial nature of the fishery as a related constraint, referring to social etiquette, shaming, and conflict if they moved into the established zones of other fishermen.

Differences in the nature and scale of the two fisheries may explain the notable differences in the proportion of fishermen in each fishery who perceived the distance they are able to travel for fishing and knowledge of other locations as constraints. Squid fishermen operate large industrial-scale vessels capable of extensive travel, whereas lobster fishermen operate much smaller vessels with limited ranges. In addition, the spiny lobster fishery operates with fixed gear, and space is "marked" or occupied, reducing the likelihood that another fisherman will fish that space (Wilson et al., 2013; Guenther et al., 2015). As a result, lobster trap fisheries are notoriously territorial and fishermen typically have limited knowledge of locations outside their specific territories. Furthermore, lobster fishermen do not anticipate net benefits from increasing their range or shifting fishing grounds large distances due to unsuitable habitat and environmental conditions beyond the current range of the fishery in the California Bight. For squid fishermen, however, high mobility is a requirement due to dramatic species range shifts associated with cyclical ENSO-related climate variability (Powell et al., 2022). Recently observed temperature-driven northward shifts in market squid distribution (Chasco et al., 2022) also indicate that fishermen will need to continue to expand their fishing grounds and travel farther up the coast to continue to participate in the squid fishery in the future. Squid fishermen's ability and past experiences travelling substantial distances to harvest squid all contribute to observed differences in individual-level constraints between the two fisheries.

Responses to change are based not only on the nature of a fishery itself, but also on what individuals and communities participating in the fishery value, their history, and their attachment to particular places (Hidalgo and Hernández, 2001; Devine-Wright, 2013). As evidenced from both interviews and follow-up sessions, harvesting lobster requires specialized local ecological knowledge of bottom benthic habitat as well as trap placement, which increases investment in learning and attachment to fishing in a particular place. Lobster fishermen

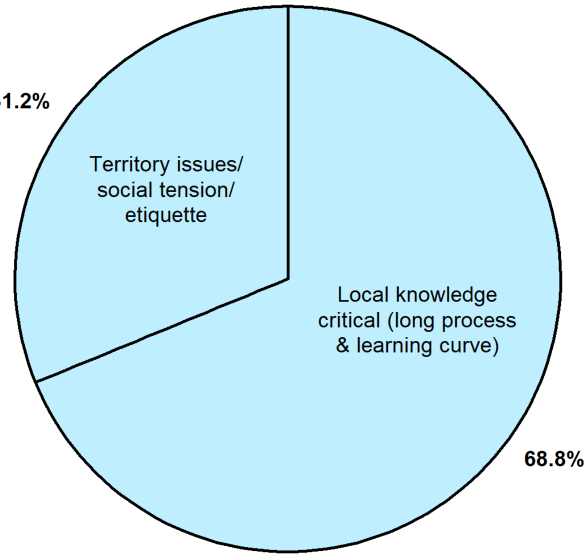

FIGURE 8
Themes from open-ended responses from spiny lobster fishermen who chose to elaborate on locational knowledge-related constraints to adaptive capacity (n=16). Responses by market squid fishermen (n = 5) are not displayed as a pie chart given that 100% of fishermen who elaborated cited the importance of local ecological knowledge.

frequently change where they set traps based on storms and weather, local conditions, and seasonal patterns, and acquisition of this specialized local knowledge in variable environments requires a significant investment of time (Wilson et al., 2013). The long-term investment associated with acquisition of local ecological knowledge, coupled with the territorial nature of the fishery, make it more challenging for fishermen to fish for lobster in new locations.

Financial capital, physical capital, and individual-level constraints on adaptive capacity are inter-related (Young et al., 2019), which was corroborated by the associations we found between smaller vessel size, lower income, and a higher likelihood that lobster fishermen perceived the distance they are able to travel for fishing as well as their knowledge of other locations as constraints to adaptive capacity (Table 1). Although high mobility has been shown to buffer fishing communities from the effects of environmental change (Sievanen, 2014; Young et al., 2019; Fisher et al., 2021), in order to expand or move into new fishing grounds, fishermen may need larger, longer-range fishing vessels, which requires access to financial and physical capital. In addition, there are typically higher fuel costs to power larger vessels and to travel farther, compounding the challenges faced by fishermen with limited financial resources. Even if fishermen have sufficient financial capital and/or large fishing vessels, they could still be limited in their ability to diversify fishing grounds and travel beyond their current range if they did not possess the local ecological knowledge necessary to fish successfully in new locations. Furthermore, we found that lobster fishermen with high resource dependence (> 60% of annual income) were more likely to perceive limited knowledge of other locations as a constraint (Table 1). Actors who participate in more than one fishery interact with different parts of the marine environment and have multiple perspectives that can enhance broader knowledge about the system and other fishing locations (Stoll, 2017; Frawley et al., 2019). In this case, high dependency on a single fishery resource may lead to increased specialization, limited knowledge of other species and/or locations, and thus, lower capacity to diversify and adapt (Daw et al., 2012; Blythe et al., 2014).

Knowledge of other fisheries was the least commonly cited constraint in both fisheries. Nine percent of squid fishermen and 15% of lobster fishermen stated that they were limited by their knowledge of other fisheries (Figure 3). Although neither group of fishermen chose to elaborate specifically on this constraint, several fishermen indicated that they would switch fisheries but given their limited knowledge of other fisheries, it is not a viable option. Ultimately, even if fishermen were knowledgeable about other fisheries, limited access to permits and/or fishery closures constrain their ability to switch fisheries.

4 Conclusion

Attention to the interactions between factors constraining different elements of adaptive capacity is critical for effective adaptation planning and for ensuring continued resiliency in the face of future change. Our results demonstrate that some characteristics that have been shown to enhance adaptive capacity may be constrained by pressures inhibiting other aspects of adaptive capacity. In the squid and lobster fisheries, we found that governance and regulatory constraints are viewed as the most significant factors constraining fishermen's adaptive capacity. Although individual-level constraints including mobility and knowledge are relevant, they were viewed as less important in the face of a highly constraining regulatory environment. Even if fishermen have assets, flexibility, and knowledge, effective adaptation requires that they have the power and ability to mobilize these domains of adaptive capacity to actively shape their future (Brown and Westaway, 2011; Coulthard, 2012; Cinner et al., 2018).

Certain factors including fishermen's engagement and representation in decision-making, trust in management and institutions, and perceptions of risk all influence fishermen's perceptions of their own agency and thus which adaptation strategies they can or will pursue (Cinner et al., 2015; Frawley et al., 2019b). Studies have shown that fishermen who do not participate in decision-making generally have limited agency to influence resource governance and are least able to respond and adapt to negative changes (Cinner et al., 2015; Mortreux and Barnett, 2017; McClenachan et al., 2019). Furthermore, resource users feel less prepared to handle future challenges when perceived levels of trust are low, and they have little incentive to adapt unless they believe that their input is valued and their adaptive actions can produce desired outcomes (Bandura, 2000; Dressel et al., 2020). Given that low levels of trust in management, as well as limited input in decision-making, were commonly cited constraints amongst fishermen in both fisheries, it is likely that many fishermen have low perceptions of their own agency in the face of governance and regulatory constraints, creating a substantial barrier to adaptation.

Overcoming the complex and multifaceted barriers to adaptation necessitates planned and participatory adaptation strategies. Given that governance and institutional dimensions of adaptive capacity, the dimensions over which fishermen have the least control, are perceived as inhibiting their capacity to adapt, this highlights an opportunity for enhanced resilience through participatory governance processes to strengthen fishermen's individual agency and ability to meaningfully act in the face of change (Stoll et al., 2017). Although many studies highlight how fishery management is ignoring, or cannot accommodate, climate change (Pershing et al., 2015), it is evident that fishery management decisions are actively structuring where and how communities can adapt (Suatoni, 2020; MAFMC and ASMFC, 2021). As such, attention to adaptive capacity in management decision-making and acknowledgement of the multiple ways regulatory policies can enhance or constrain adaptation is increasingly important with ongoing climate change.

Data availability statement

The datasets presented in this article are not readily available to protect the confidentiality of those interviewed. Requests to access the datasets should be directed to FP, fpowellhb@gmail.com.

Ethics statement

The studies involving human participants were reviewed and approved by San Diego State University Institutional Review Board (# 2459098). The patients/participants provided their verbal informed consent to participate in this study.

Author contributions

FP and AL contributed to the study conception and design. Data collection was performed by all authors. FP prepared and organized the data, and conducted data analysis. FP wrote the first draft of the manuscript. FP and AL contributed to manuscript revisions. All authors read and approved the submitted version.

Funding

This work was supported by the National Science Foundation (Coastal SEES Collaborative Research grant no. 1600149) and the San Diego State University Graduate Research Fellowship Program.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2022.1028280/full#supplementary-material

References

Adger, W. N. (2003). Social capital, collective action, and adaptation to climate change. *Econ. Geogr.* 79, 387–404. doi: 10.1111/j.1944-8287.2003.tb00220.x

Adger, W. N. (2006). Vulnerability. *Glob. Environ. Change* 16, 268–281. doi: 10.1016/j.gloenvcha.2006.02.006

Adger, W. N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D. R., et al. (2009). Are there social limits to adaptation to climate change? *Clim. Change* 93, 335–354. doi: 10.1007/s10584-008-9520-z

Aguilera, S. E., Cole, J., Finkbeiner, E. M., Cornu, E. L., Ban, N. C., Carr, M. H., et al. (2015). Managing small-scale commercial fisheries for adaptive capacity: Insights from dynamic social-ecological drivers of change in Monterey bay. *PloS One* 10, e0118992. doi: 10.1371/journal.pone.0118992

Anderson, S. C., Ward, E. J., Shelton, A. O., Adkison, M. D., Beaudreau, A. H., Brenner, R. E., et al. (2017). Benefits and risks of diversification for individual fishers. *Proc. Natl. Acad. Sci. U.S.A.* 114, 10797–10802. doi: 10.1073/pnas.1702506114

Bandura, A. (2000). Exercise of human agency through collective efficacy. *Curr. Dir. psychol. Sci.* 9, 75–78. doi: 10.1111/1467-8721.00064

Bates, K., and Hildebrand, L. (2018). *Proposal for a small-scale trial squid fishery north of point arena, California: Offered as an amendment/addition to the California fishery management plan*. Available at: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=156321&inline.

Beaudreau, A. H., Ward, E. J., Brenner, R. E., Shelton, A. O., Watson, J. T., Womack, J. C., et al. (2019). Thirty years of change and the future of alaskan fisheries: Shifts in fishing participation and diversification in response to environmental, regulatory and economic pressures. *Fish. Fish.* 20, 601–619. doi: 10.1111/faf.12364

Bennett, N. J., and Dearden, P. (2014). Why local people do not support conservation: Community perceptions of marine protected area livelihood impacts, governance and management in Thailand. *Mar. Policy* 44, 107–116. doi: 10.1016/j.marpol.2013.08.017

Bennett, N., Dearden, P., Murray, G., and Kadfak, A. (2014). The capacity to adapt?: communities in a changing climate, environment, and economy on the northern Andaman coast of Thailand. *Ecol. AND Soc.* 19, 5. doi: 10.5751/ES-06315-190205

Bertheussen, B. A., Dreyer, B. M., Hermansen, Ø., and Isaksen, J. R. (2021). Institutional and financial entry barriers in a fishery. *Mar. Policy* 123, 104303. doi: 10.1016/j.marpol.2020.104303

Blythe, J. L., Murray, G., and Flaherty, M. (2014). Strengthening threatened communities through adaptation: insights from coastal Mozambique. *Ecol. Soc.* 19, 6. doi: 10.5751/ES-06408-190206

Brown, K., and Westaway, E. (2011). Agency, capacity, and resilience to environmental change: Lessons from human development, well-being, and disasters. *Annu. Rev. Environ. Resour.* 36, 321–342. doi: 10.1146/annurev-environ-052610-092905

CDFW (2005) *Market squid fishery management plan*. Available at: https://www.wildlife.ca.gov/Conservation/Marine/MSFMP.

CDFW (2016) *California Spiny lobster fishery management plan*. Available at: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=121938&inline (Accessed February 3, 2022).

CDFW (2019) *California Spiny lobster, panulirus interruptus, enhanced status report. CDFW*. Available at: https://marinespecies.wildlife.ca.gov/california-spiny-lobster/true/ (Accessed January 20, 2022).

Chambers, S. (2016)Californias squid show up in Oregon where 6 vessels are fishing, meeting on regs set for June. In: *SeafoodNews.com*. Available at: https://www.seafoodnews.com/Story/1018390/Californias-Squid-Show-up-in-Oregon-where-6-Vessels-are-Fishing-Meeting-on-Regs-Set-for-June (Accessed April 10, 2021).

Charles, A., and Wilson, L. (2009). Human dimensions of marine protected areas. *ICES J. Mar. Sci.* 66, 6–15. doi: 10.1093/icesjms/fsn182

Chasco, B. E., Hunsicker, M. E., Jacobson, K. C., Welch, O. T., Morgan, C. A., Muhling, B. A., et al. (2022). Evidence of temperature-driven shifts in market squid doryteuthis opalescens densities and distribution in the California current ecosystem. *Mar. Coast. Fish.* 14, e10190. doi: 10.1002/mcf2.10190

Checkley, D. M., and Barth, J. A. (2009). Patterns and processes in the California Current System. *Prog Oceanogr* 83, 49–64. doi: 10.1016/j.pocean.2009.07.028

Cinner, J. E., Adger, W. N., Allison, E. H., Barnes, M. L., Brown, K., Cohen, P. J., et al. (2018). Building adaptive capacity to climate change in tropical coastal communities. *Nat. Clim. Change* 8, 117–123. doi: 10.1038/s41558-017-0065-x

Cinner, J. E., Huchery, C., Hicks, C. C., Daw, T. M., Marshall, N., Wamukota, A., et al. (2015). Changes in adaptive capacity of Kenyan fishing communities. *Nat. Clim. Change* 5, 872–876. doi: 10.1038/nclimate2690

Cline, T. J., Schindler, D. E., and Hilborn, R. (2017). Fisheries portfolio diversification and turnover buffer alaskan fishing communities from abrupt resource and market changes. *Nat. Commun.* 8, 14042. doi: 10.1038/ncomms14042

Columbia Basin Bulletin. (2018), El Nino, 'Warm blob' expected to supercharge storms, redistribute marine species. In: *Chinook Observer*. Available at: https://www.chinookobserver.com/news/local/el-nino-warm-blob-expected-to-supercharge-storms-redistribute-marine/article_14f3ac3f-4632-5229-98ce-9c9161a3b870.html (Accessed April 10, 2021).

Costello, C., Gaines, S. D., and Lynham, J. (2008). Can Catch Shares Prevent Fisheries Collapse? *Science* 321, 1678–1681. doi: 10.1126/science.1159478

Coulthard, S. (2009). "Adaptation and conflict within fisheries: insights for living with climate change," in *Adapting to climate change*. Eds. W. N. Adger, I. Lorenzoni and K. L. OBrien (Cambridge: Cambridge University Press), 255–268. doi: 10.1017/CBO9780511596667.017

Coulthard, S. (2012). Can we be both resilient and well, and what choices do people have? incorporating agency into the resilience debate from a fisheries perspective. *Ecol. Soc.* 17, art4. doi: 10.5751/ES-04483-170104

Davis, K. J., Vianna, G. M. S., Meeuwig, J. J., Meekan, M. G., and Pannell, D. J. (2019). Estimating the economic benefits and costs of highly-protected marine protected areas. *Ecosphere* 10, e02879. doi: 10.1002/ecs2.2879

Daw, T. M., Cinner, J. E., McClanahan, T. R., Brown, K., Stead, S. M., Graham, N. A. J., et al. (2012). To fish or not to fish: Factors at multiple scales affecting artisanal fishers' readiness to exit a declining fishery. *PloS One* 7, 1–10. doi: 10.1371/journal.pone.0031460

Devine-Wright, P. (2013). Think global, act local? the relevance of place attachments and place identities in a climate changed world. *Glob. Environ. Change* 23, 61–69. doi: 10.1016/j.gloenvcha.2012.08.003

Dey, M. M., Gosh, K., Valmonte-Santos, R., Rosegrant, M. W., and Chen, O. L. (2016). Economic impact of climate change and climate change adaptation strategies for fisheries sector in Fiji. *Mar. Policy* 67, 164–170. doi: 10.1016/j.marpol.2015.12.023

Dressel, S., Johansson, M., Ericsson, G., and Sandström, C. (2020). Perceived adaptive capacity within a multi-level governance setting: The role of bonding, bridging, and linking social capital. *Environ. Sci. Policy* 104, 88–97. doi: 10.1016/j.envsci.2019.11.011

Fisher, M. C., Moore, S. K., Jardine, S. L., Watson, J. R., and Samhouri, J. F. (2021). Climate shock effects and mediation in fisheries. *Proc. Natl. Acad. Sci. U.S.A.* 118, e2014379117. doi: 10.1073/pnas.2014379117

Frawley, T. H., Crowder, L. B., and Broad, K. (2019). Heterogeneous perceptions of social-ecological change among small-scale fishermen in the central gulf of California: Implications for adaptive response. *Front. Mar. Sci.* 6. doi: 10.3389/fmars.2019.00078

Frawley, T., Finkbeiner, E., and Crowder, L. (2019b). Environmental and institutional degradation in the globalized economy: lessons from small-scale fisheries in the gulf of California. *Ecol. Soc.* 24, 7. doi: 10.5751/ES-10693-240107

Frawley, T. H., Muhling, B. A., Brodie, S., Fisher, M. C., Tommasi, D., Le Fol, G., et al. (2021). Changes to the structure and function of an albacore fishery reveal shifting social-ecological realities for pacific Northwest fishermen. *Fish. Fish.* 22, 280–297. doi: 10.1111/faf.12519

Gaichas, S. K., Bundy, A., Miller, T. J., Moksness, E., and Stergiou, K. I. (2012). What drives marine fisheries production? *Mar. Ecol. Prog. Ser.* 459, 159–163. doi: 10.3354/meps09841

Gallopín, G. C. (2006). Linkages between vulnerability, resilience, and adaptive capacity. *Global Environ. Change* 16, 293–303. doi: 10.1016/j.gloenvcha.2006.02.004

García-Reyes, M., and Largier, ,. J. L. (2012). Seasonality of coastal upwelling off central and northern California: New insights, including temporal and spatial variability. *J. Geophys. Res. Oceans* 117, C03028. doi: 10.1029/2011JC007629

Green, K. M., Selgrath, J. C., Frawley, T. H., Oestreich, W. K., Mansfield, E. J., Urteaga, J., et al. (2021). How adaptive capacity shapes the adapt, react, cope response to climate impacts: insights from small-scale fisheries. *Clim. Change* 164, 15. doi: 10.1007/s10584-021-02965-w

Grothmann, T., and Patt, A. (2005). Adaptive capacity and human cognition: The process of individual adaptation to climate change. *Glob. Environ. Change* 15, 199–213. doi: 10.1016/j.gloenvcha.2005.01.002

Guenther, C., López-Carr, D., and Lenihan, ,. H. S. (2015). Differences in lobster fishing effort before and after MPA establishment. *Appl. Geogr.* 59, 78–87. doi: 10.1016/j.apgeog.2014.12.016

Harvey, C., Garfield, N., Williams, G., and Tolimieri, N. (2021). *Ecosystem status report of the California current for 2020-21: A summary of ecosystem indicators compiled by the California current integrated ecosystem assessment team (CCIEA)* (Washington, DC: US Department of Commerce). doi: 10.25923/x4ge-hn11

Hennessey, V. (2013) Illegalities stoke squid fishing war. *Monterey herald*. Available at: https://www.montereyherald.com/general-news/20130429/illegalities-stoke-squid-fishing-war (Accessed March 17, 2022).

Hicks, C. C., Levine, A., Agrawal, A., Basurto, X., Breslow, S. J., Carothers, C., et al. (2016). Engage key social concepts for sustainability. *Science* 352, 38–40. doi: 10.1126/science.aad4977

Hidalgo, M. C., and Hernández, B. (2001). Place attachment: conceptual and empirical quetions. *J. Environ. Psychol.* 21, 273–281. doi: 10.1006/jevp.2001.0221

Hinkel, J. (2011). "Indicators of vulnerability and adaptive capacity": Towards a clarification of the science–policy interface. *Glob. Environ. Change* 21, 198–208. doi: 10.1016/j.gloenvcha.2010.08.002

Holland, D. S., and Kasperski, S. (2016). The impact of access restrictions on fishery income diversification of US West coast fishermen. *Coast. Manage.* 44, 452–463. doi: 10.1080/08920753.2016.1208883

Iles, A. C., Gouhier, T. C., Menge, B. A., Stewart, J. S., Haupt, A. J., and Lynch, ,. M. C. (2012). Climate-driven trends and ecological implications of event-scale upwelling in the California current system. *Glob. Chang. Biol.* 18, 783–796. doi: 10.1111/j.1365-2486.2011.02567.x

Islam, M., Sallu, S., Hubacek, K., and Paavola, J. (2014a). Limits and barriers to adaptation to climate variability and change in Bangladeshi coastal fishing communities. *Mar. Policy* 43, 208–216. doi: 10.1016/j.marpol.2013.06.007

Islam, M., Sallu, S., Hubacek, K., and Paavola, J. (2014b). Vulnerability of fishery-based livelihoods to the impacts of climate variability and change: insights from coastal Bangladesh. *Reg. Environ. Change* 14, 281–294. doi: 10.1007/s10113-013-0487-6

Kasperski, S., and Holland, D. S. (2013). Income diversification and risk for fishermen. *Proc. Natl. Acad. Sci. U.S.A.* 110, 2076–2081. doi: 10.1073/pnas.1212278110

Koslow, J. A., Rogers-Bennett, L., and Neilson, D. J. (2012). A time series of California spiny lobster (Panulirus interruptus) phyllosoma from 1951 to 2008 links abundance to warm oceanographic conditions in southern California. *CalCOFI Rep.* 53, 132–139.

Lenihan, H. S., Gallagher, J. P., Peters, J. R., Stier, A. C., Hofmeister, J. K. K., and Reed, D. C. (2021). Evidence that spillover from marine protected areas benefits the spiny lobster (Panulirus interruptus) fishery in southern California. *Sci. Rep.* 11, 2663. doi: 10.1038/s41598-021-82371-5

MAFMC and ASMFC (2021) *MAFMC and ASMFC approve changes to commercial and recreational allocations of summer flounder, scup, and black Sea bass*. Available at: http://www.asmfc.org/uploads/file/61bb8086pr31SFSBSB-AllocationAmendment.pdf (Accessed April 18, 2022).

Maguire, M., and Delahunt, B. (2017). Doing a thematic analysis: A practical, step-by-step guide for learning and teaching scholars. *AISHE-J* 9, 3351–33514. Available at: https://ojs.aishe.org/index.php/aishe-j/article/view/335.

Marshall, N., and Marshall, P. (2007). Conceptualizing and operationalizing social resilience within commercial fisheries in northern Australia. *Ecol. Soc* 12, 1. doi: 10.5751/ES-01940-120101

McClanahan, T. R., and Cinner, J. (2011). *Adapting to a changing environment: Confronting the consequences of climate change* (New York: Oxford University Press).

McClenachan, L., Scyphers, S., and Grabowski, J. H. (2019). Views from the dock: Warming waters, adaptation, and the future of maine's lobster fishery. *Ambio* 49, 144–155. doi: 10.1007/s13280-019-01156-3

Mora, C., Myers, R. A., Coll, M., Libralato, S., Pitcher, T. J., Sumaila, R. U., et al. (2008). Management Effectiveness of the World's Marine Fisheries. *PLoS Biol* 7, e1000131. doi: 10.1371/journal.pbio.1000131

Moreno-Sánchez, R., del, P., and Maldonado, J. H. (2013). Adaptive capacity of fishing communities at marine protected areas: A case study from the Colombian pacific. *Ambio* 42, 985–996. doi: 10.1007/s13280-013-0454-y

Mortreux, C., and Barnett, J. (2017). Adaptive capacity: exploring the research frontier. *WIREs Clim. Change* 8, e467. doi: 10.1002/wcc.467

Moser, S. C., and Ekstrom, J. A. (2010). A framework to diagnose barriers to climate change adaptation. *Proc. Natl. Acad. Sci. U.S.A.* 107, 22026–22031. doi: 10.1073/pnas.1007887107

Murawski, S. A., Brown, R., Lai, H.-L., Rago, P. J., and Hendrickson, L. (2000). Large-Scale closed areas as a fishery-management tool in temperate marine systems: the georges bank experience. *Bull. Mar. Sci.* 66, 775–798.

Murciano, M. G., Liu, Y., Ünal, V., and Sánchez LIzaso, J. L. (2021). Comparative analysis of the social vulnerability assessment to climate change applied to fisheries from Spain and Turkey. *Sci. Rep.* 11, 13949. doi: 10.1038/s41598-021-93165-0

Murray, G., Johnson, T., McCay, B., Danko, M., Martin, K. S., and Takahashi, S. (2010). Cumulative effects, creeping enclosure, and the marine commons of new Jersey. *Int. J. Commons.* 4, 367–389. doi: 10.18352/ijc.148

NMFS (2018) *Fisheries economics of the united states 2016* (US Department of Commerce, NOAA). Available at: https://www.fisheries.noaa.gov/resource/document/fisheries-economics-united-states-report-2016 (Accessed March 18, 2020).

NOAA Fisheries (2021) *Status of U.S. fisheries 2020* (US Department of Commerce, NOAA, NMFS). Available at: https://media.fisheries.noaa.gov/2021-05/2020%20Status%20of%20Stocks%20RtC_5-18-21_FINAL.pdf?null (Accessed May 23, 2022).

Oestreich, W. K., Frawley, T. H., Mansfield, E. J., Green, K. M., Green, S. J., Naggea, J., et al. (2019). "The impact of environmental change on small-scale fishing communities: moving beyond adaptive capacity to community response," in *Predicting future oceans* (Amsterdam: Elsevier), 271–282. doi: 10.1016/B978-0-12-817945-1.00027-7

O'Keefe, C. E., Cadrin, S. X., and Stokesbury, K. D. E. (2014). Evaluating effectiveness of time/area closures, quotas/caps, and fleet communications to reduce fisheries bycatch. *ICES J. Mar. Sci.* 71, 1286–1297. doi: 10.1093/icesjms/fst063

Papaioannou, E. A., Selden, R. L., Olson, J., McCay, B. J., Pinsky, M. L., and St. Martin, K. (2021). Not all those who wander are lost – responses of fishers' communities to shifts in the distribution and abundance of fish. *Front. Mar. Sci.* 8. doi: 10.3389/fmars.2021.669094

Pershing, A. J., Alexander, M. A., Hernandez, C. M., Kerr, L. A., Le Bris, A., Mills, K. E., et al. (2015). Slow adaptation in the face of rapid warming leads to collapse of the gulf of Maine cod fishery. *Science* 350, 809–812. doi: 10.1126/science.aac9819

Pomeroy, C., Hunter, M. S., and Los Huertos, M. (2002)Socio-economic profile of the California wetfish industry. In: *California's "Wetfish" industry: Its importance past, present and future* (Santa Barbara: CA: California Seafood Council). Available at: https://caseagrant.ucsd.edu/sites/default/files/67570_0.pdf (Accessed February 16, 2020).

Powell, F., Levine, A., and Ordonez-Gauger, L. (2022). Climate adaptation in the market squid fishery: fishermen responses to past variability associated with El niño southern oscillation cycles inform our understanding of adaptive capacity in the face of future climate change. *Climatic Change* 173, 1. doi: 10.1007/s10584-022-03394-z

Pozo Buil, M., Jacox, M. G., Fiechter, J., Alexander, M. A., Bograd, S. J., Curchitser, E. N., et al. (2021). A Dynamically Downscaled Ensemble of Future Projections for the California Current System. *Front. Mar. Sci.* 8. doi: 10.3389/fmars.2021.612874

R Core Team (2020) *R core team, (2020)* (European Environment Agency). Available at: https://www.eea.europa.eu/data-and-maps/indicators/oxygen-consuming-substances-in-rivers/r-development-core-team-2006 (Accessed November 17, 2021).

Reiss, C. S., Maxwell, M. R., Hunter, J. R., and Henry, A. (2004). Investigating environmental effects on population dynamics of loligo opalescens in the southern California bight. *CalCOFI Rep.* 45, 87–97.

Richerson, K., and Holland, D. S. (2017). Quantifying and predicting responses to a US West coast salmon fishery closure. *ICES J. Mar. Sci.* 74, 2364–2378. doi: 10.1093/icesjms/fsx093

Roberts, C. M., Hawkins, J. P., and Gell, F. R. (2005). The role of marine reserves in achieving sustainable fisheries. *Philos. Trans. R Soc. Lond B Biol. Sci.* 360, 123–132. doi: 10.1098/rstb.2004.1578

Robinson, J. P. W., Robinson, J., Gerry, C., Govinden, R., Freshwater, C., and Graham, N. A. J. (2020) Diversification insulates fisher catch and revenue in heavily exploited tropical fisheries. *Sci. Adv.* 6, eaaz0587. doi: 10.1126/sciadv.aaz0587

Rogers, L. A., Griffin, R., Young, T., Fuller, E., St. Martin, K., and Pinsky, M. L. (2019). Shifting habitats expose fishing communities to risk under climate change. *Nat. Clim. Change* 9, 512–516. doi: 10.1038/s41558-019-0503-z

Rohe, J. R., Aswani, S., Schlüter, A., and Ferse, S. C. A. (2017). Multiple drivers of local (Non-) compliance in community-based marine resource management: Case studies from the south pacific. *Front. Mar. Sci.* 4. doi: 10.3389/fmars.2017.00172

SeafoodNews (2020). Oregon Sees record market squid landings. In: *SeafoodNews*. Available at: https://www.seafoodnews.com/Story/1169147/Oregon-Sees-Record-Market-Squid-Landings (Accessed May 4, 2022).

Seara, T., Clay, P. M., and Colburn, L. L. (2016). Perceived adaptive capacity and natural disasters: A fisheries case study. *Glob. Environ. Chang.* 38, 49–57. doi: 10.1016/j.gloenvcha.2016.01.006

Sievanen, L. (2014). How do small-scale fishers adapt to environmental variability? lessons from Baja California, sur, Mexico. *Marit. Stud.* 13, 9. doi: 10.1186/s40152-014-0009-2

Smith, C., and Clay, P. (2010). Measuring subjective and objective well-being: Analyses from five marine commercial fisheries. *Hum. Organ.* 69, 158–168. doi: 10.17730/humo.69.2.b83x6t44878u4782

Smit, B., and Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Glob. Environ. Chang.* 16, 282–292. doi: 10.1016/j.gloenvcha.2006.03.008

Stoll, J. S. (2017). Fishing for leadership: The role diversification plays in facilitating change agents. *J. Environ. Manage.* 199, 74–82. doi: 10.1016/j.jenvman.2017.05.011

Stoll, J. S., Fuller, E., and Crona, B. I. (2017). Uneven adaptive capacity among fishers in a sea of change. *PloS One* 12. doi: 10.1371/journal.pone.0178266

Suatoni, L. (2020). *On the move: How fisheries policy can address shifting fish stocks - fact sheet* (New York: NRDC). Available at: https://www.nrdc.org/sites/default/files/fisheries-policy-shifting-fish-stocks-fs.pdf.

The Research Group, LLC (2021) *Fishing industry economic activity trends in the Newport, Oregon area, update 2019* (Corvallis, Oregon: Midwater Trawlers Cooperative and Lincoln Board of Commissioners). Available at: https://www.co.lincoln.or.us/sites/default/files/fileattachments/board_of_commissioners/page/15271/fishing_industry_economic_activity_trends_in_the_newport_or_area_-_technical_report_-_june_2021.pdf (Accessed May 4, 2022).

van Noord, J. E., and Dorval, E. (2017). Oceanographic influences on the distribution and relative abundance of market squid paralarvae (Doryteuthis opalescens) off the southern and central California coast. *Mar. Ecol.* 38, e12433. doi: 10.1111/maec.12433

Ward, E. J., Anderson, S. C., Shelton, A. O., Brenner, R. E., Adkison, M. D., Beaudreau, A. H., et al. (2018). Effects of increased specialization on revenue of alaskan salmon fishers over four decades. *J. Appl. Ecol.* 55, 1082–1091. doi: 10.1111/1365-2664.13058

Whitney, C., Bennett, N., Ban, N., Allison, E., Armitage, D., Blythe, J., et al. (2017). Adaptive capacity: from assessment to action in coastal social-ecological systems. *Ecol. Soc.* 22, 22. doi: 10.5751/ES-09325-220222

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

Xiu, P., Chai, F., Curchitser, E. N., and Castruccio, F. S. (2018). Future changes in coastal upwelling ecosystems with global warming: The case of the California Current System. *Sci Rep* 8, 2866. doi: 10.1038/s41598-018-21247-7

Young, T., Fuller, E. C., Provost, M. M., Coleman, K. E., St. Martin, K., McCay, B. J., et al. (2019). Adaptation strategies of coastal fishing communities as species shift poleward. *ICES J. Mar. Sci.* 76, 93–103. doi: 10.1093/icesjms/fsy140