



Enhancing the adaptive capacity of fisheries to climate change: Bridging academic theory and management practice through practitioner interviews

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ABSTRACT

Climate change is dramatically altering the environmental context in which marine resources are harvested and managed. A growing field of academic literature has begun to explore the adaptive capacity of fishers and managers to respond to this change, but much of this field is abstract and theory-driven. Therefore, it is unclear whether this literature accurately reflects the adaptation priorities of fishery management practitioners, or whether there are gaps in the literature that these practitioners could fill with on-the-ground knowledge. Second, even if these principles of adaptive capacity are perfectly aligned with management practitioners' priorities, it is unclear to what extent these principles are actively considered in the decision making process, and if not, why. This study seeks to address these questions by confronting fisheries professionals with academic ideas around adaptive capacity through a series of semi-structured interviews with federal fishery managers and scientists whose work informs decision making in the United States regional fishery management system. The study then uses these interviews to identify three low-cost, high-impact action items that could make concepts from the academic literature more accessible and useful to these practitioners and expand the literature by incorporating practitioners' expertise. These action items are: 1) distinguish adaptive capacity from adaptive management, 2) use practitioner insights to contextualize the elements of adaptive capacity within the constraints and opportunities of governance systems, and 3) expand academic research to explicitly consider the capacity to adapt on appropriate timelines given the scale and pace of systemic change.

1. Introduction

Fisheries worldwide are facing unprecedented change linked to climate change [1,2], including overall changes in productivity [2], species distribution shifts [3], and increased frequency of severe storms, among other impacts [4]. The vulnerability of specific fisheries and communities to the impacts of climate change depends on their *exposure* (the specific stressors that a system faces), their *sensitivity* (the degree to which people depend on the natural resources threatened by those stressors), and finally, their *adaptive capacity* (people's ability to respond to or take advantage of those stressors to create transformative change) [5,6] (Fig. 1). The academic literature has produced proliferating definitions of adaptive capacity based on a variety of theoretical frameworks

[7]. Therefore, for the purposes of this analysis, adaptive capacity is defined here as broadly as possible as the ability of a system—including ecological, socioeconomic, and governance components of the system—to anticipate and respond to change, including environmental, social, and/or regulatory changes. This definition is adapted from the one used by the Intergovernmental Panel on Climate Change [8], but expands that definition to consider all types of change. Along with this definitional complexity, another challenge to considering adaptive capacity in the fishery management process is that, while a fishery's exposure and sensitivity can be evaluated using projected climate change and the nature of the community's reliance on seafood and marine industry-related livelihoods, adaptive capacity is more difficult to measure. This difficulty is due, in part, to this system characteristic's

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dependence on a wide variety of emergent, difficult-to-observe traits, including ecosystem variables, fishers' material and sociocognitive traits, and the governance structure that regulates a fishery [7].

Despite this complexity, adaptive capacity is increasingly being incorporated into climate change vulnerability assessments [9] and there is a growing academic literature on the aspects of complex social-ecological systems like fisheries that enable adaptive capacity in the face of change [6,10]. These include flexibility in governance systems, fishing communities, and ecosystems; assets like natural resources, infrastructure, fishing gear, human capital and wealth; organized social and ecological relationships at different scales that promote resilience, including effective leadership, ecological connectivity and social capital; opportunities for fishers and managers to learn and innovate; and people and institutions' freedom and agency to make and act on choices [6,10]. Some analyses also consider the socio-cognitive constructs of individuals and communities, such as risk tolerance and cognitive biases [11].

The concept of adaptive capacity tends to be abstract and theory-driven, and it is not clear to what extent it is useful or actionable for the people who make on-the-ground decisions that can influence a fishery's adaptive capacity. When researchers have tried to link adaptive capacity concepts to decision making, their advice has tended to be generic and heuristic rather than specific to the context of the types of decisions being made and the decision making process [12,13]. This is particularly true in marine capture fisheries, where there has been little formal attempt to identify and protect the components of the fishery system that allows for adaptation to climate change, or to make decisions to enhance the ability of the fishery to cope with climate change (with some exceptions, e.g. [14]). Also, even if these principles of adaptive capacity are perfectly aligned with managers' priorities, it is unclear to what extent the principles are actively considered in the decision making process, and if not, why. This is important because decisions that fail to consider the capacity to adapt to future change can inadvertently weaken the components of a fishery system that provide that capacity. For example, short-term economic goals and managers' actions to regulate fishing effort (e.g. limited access permits) may drive fishers to specialize on a few species. Yet, over the long run, fishers that target a wide portfolio of species tend to better cope with change and

have better economic outcomes [15–17]. Similarly, fishery policy decisions that ignore species, stock, or genetic diversity are generally easier and less costly in the short term than are decisions that do consider these factors. However, such decisions can erode the ability of ecological systems to adapt to environmental change [18,19]. These are only a few of the ways that management decisions that focus only on short-term consequences rather than potential influences on a fishery's adaptive capacity can put fishery social-ecological systems more at risk of reduced performance in the face of environmental change.

This study uses semi-structured interviews with key individuals involved in decision-making processes in the United States federal fishery management system to explore the overlap between theoretical concepts about adaptive capacity to change and these individuals' perceptions of what influences the ability of fisheries systems to adapt to change. A previous report based on this interview process highlighted a central tension in the U.S. governance system between the traits needed to enhance adaptive capacity in fisheries and the current structure of the fishery management process: the fact that fishers and managers cite an urgent need for flexibility in order to adapt, but management systems are built around rigid structures designed to promote fisheries sustainability [20]. This paper delves into more detail about specific matches and mismatches between academic ideas around adaptive capacity and their application to fisheries governance. Specifically, it asks 1) How do fishery management practitioners define adaptive capacity, and how do their definitions compare to the understanding of these concepts in the academic literature? And 2) What attributes of fisheries do practitioners see as being important to their adaptive capacity, and how do these attributes match or diverge from the domains of adaptive capacity identified in the literature? The study then uses this analysis to identify key mismatches between the academic literature and fishery professionals' perspectives on adapting to change, which we use to inform three future pathways through which researchers can reconcile this divide between theory and practice. These pathways are to 1) more explicitly distinguish adaptive capacity from the existing fisheries practice of adaptive management when communicating with fishery professionals, 2) use practitioners' practical insights to deepen the literature on the adaptive capacity of governance systems, and 3)

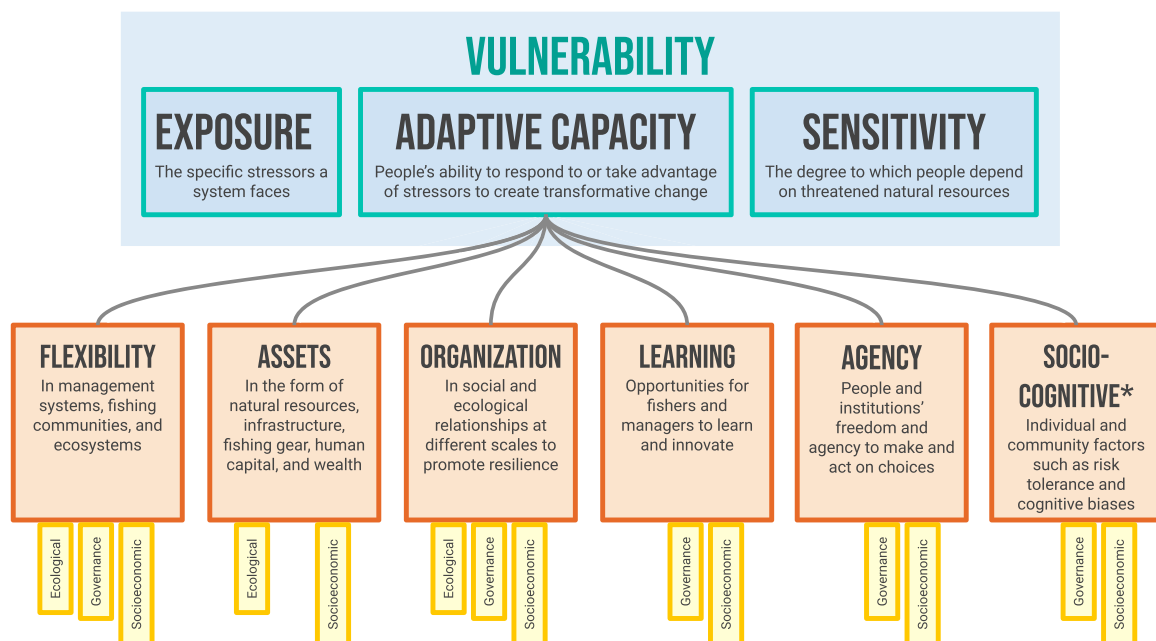


Fig. 1. Conceptual diagram showing hierarchical links between elements of vulnerability and adaptive capacity. Aspects of vulnerability commonly identified in the literature are outlined in blue, and domains of adaptive capacity in orange. The subsystems of fisheries social-ecological systems in which each domain can appear are outlined in yellow at the bottom. Note that some newer analyses include socio-cognitive constructs (indicated with an asterisk) as a domain of adaptive capacity, but this concept is less fully operationalized than the other five domains of adaptive capacity, so it is not a main focus of this paper.

expand the academic dialogue to explicitly consider the capacity to adapt on appropriate timelines given the scale and pace of systemic change.

2. Methods

The research team recruited and conducted in-depth interviews with twenty key informants involved in federal fishery management processes at a high level. These key informants represented all eight regions of the U.S. fishery management system, and included scientists and decision makers who had a high-level working knowledge of how and why decisions get made at the regional council level. These included individuals in leadership positions at seven of the eight regional fishery management councils (both council members and staff), one of the three interstate commissions, the six NOAA Fisheries Science Centers, and three of the five NOAA Fisheries regional offices. These various roles interact to define and implement management actions for federally managed U.S. fisheries. Specifically, members of the regional fishery management councils, made up of state-level fishery managers, fishing industry members, and other stakeholders, provide harvest limit recommendations to administrators at the NOAA Fisheries regional offices for species caught within the U.S. Exclusive Economic Zone. Scientists at the NOAA Fisheries Science Centers provide scientific information to inform these recommendations. Council staffers, who include scientists and administrators, support Council activities and decision making processes. Members of the interstate coastal commissions similarly manage species that are harvested in state waters (0-3 nautical miles from shore) across multiple states. Interviews were conducted with 2-4 respondents from each management region and included 1-7 respondents from each role (Table 1). Respondents were recruited for a 60-90 min interview, with actual interviews ranging from 60 to 160 min. Sampling frame definition, interview recruitment, and the interview script development process are described in detail elsewhere [20]. Throughout this paper, we use the terms “fishery professional” and “fishery management practitioner” interchangeably to refer to people in any of the roles outlined above. We use the terms “decision maker” and “manager” interchangeably to refer to people in roles with decision making power, including Council members, Commissioners, and NMFS regional office administrators. We use “respondents” to refer to participants in the study.

At the beginning of the interviews, respondents were briefly introduced to the academic concept of adaptive capacity and its relevance to fisheries through a standardized verbal script introducing the project (Appendix). This script described adaptive capacity as the ability of

systems to respond to change, but did not define it in concrete terms. Respondents were then asked to define adaptive capacity in their own words and to identify aspects of fisheries that are important to their ability to adapt, before being introduced verbally to the five domains of adaptive capacity identified by Cinner and colleagues: flexibility, assets, organization, learning, and agency [6]. Once exposed to these concepts, respondents were asked how the concepts aligned with their own understanding of adaptive capacity, then asked about each domain’s relevance to fishery adaptation in their own management region(s). They were then asked whether each of these domains were considered actively in decision making in the respondents’ region(s) and, if so, how, with reference to specific examples where possible (see Appendix for full interview script). Note that while some respondents distinguished between broader governance structures like the regional fishery management council system and day-to-day management activities, most respondents used the two terms interchangeably. Here, we use the term “governance” when referring to broad-scale legislative and structural frameworks and “management” when speaking about the current U.S. system for managing fisheries, regional organizations within that system, or those organizations’ activities. In all direct quotes, we preserve the language used by respondents themselves.

Interviews were conducted over video conference, video recorded, and transcribed. The interview transcripts were analyzed using NVivo qualitative coding software (Release 1.7.1). First, respondents’ definitions of adaptive capacity were compared to concepts in the academic research to identify commonalities and differences. Next, interview responses relating to the aspects of fisheries that influence adaptive capacity were analyzed. A hybrid inductive/deductive approach [21] was adopted in which some domains of adaptive capacity were coded *a priori* from the literature (assets, flexibility, organization, learning, agency [6]) and additional domains were allowed to emerge inductively during the analysis process. The interview text that was coded to each domain was then compared to the aspects of that domain defined in a recent synthesis [10] in order to determine whether and how respondents’ understanding of these domains overlapped with or diverged from academic ideas. Domains of adaptive capacity that were introduced by respondents themselves in early stages of the interview, before they were exposed to the domains from the literature, were coded as “unprompted” and were assumed to be highly salient and/or top of mind for respondents. This study was designated as Exempt by the University of Washington Institutional Review Board.

3. Results

3.1. Defining adaptive capacity

Respondents’ definitions of adaptive capacity generally aligned with the academic literature in describing adaptive capacity as the ability of the ecological, socioeconomic, and/or governance components of a fishery to respond to a variety of types of change (Fig. 2). A subset of respondents ($n = 3$) defined adaptive capacity generically as the ability of a system overall to respond to change writ large, without specifying particular stressors or particular aspects of the system that were responding to those stressors (Fig. 2, bottom light orange bar). One typical expression of this was a description of adaptive capacity as “the ability to adapt to different shocks and stressors that hit the system” (NOAA Southeast region scientist). However, it was far more common for respondents to drill down into the specific subsystems within fisheries that they saw as most important to this ability to adapt. Most commonly ($n = 9$), this was the U.S. *management* system’s ability to cope with a variety of changes (environmental, socioeconomic, and/or regulatory), rather than the ability of *fishers* or *ecosystems* to adapt: “I would define it as the capacity of the management system to adapt to changing conditions in any number of things, in the resource, the environment, or the human component of a fishery” (NMFS Southeast region manager). A few respondents ($n = 4$) went further in this narrow focus on

Table 1

Matrix of interview respondents by region and management role. Each x represents one respondent. Note that some respondents possessed expertise about multiple management regions because of the regional structure of the NOAA science centers and NMFS regional offices, represented here using merged cells.

	Council member	Commission member	Council staff	NOAA Science Center	NMFS Regional Office
Western Pacific			x	x	x
North Pacific	x			x	
Pacific			x	xx	
Gulf of Mexico	x		x	x	x
Caribbean			x		
South Atlantic	x	x	x		
Mid-Atlantic			xx	x	x
New England					

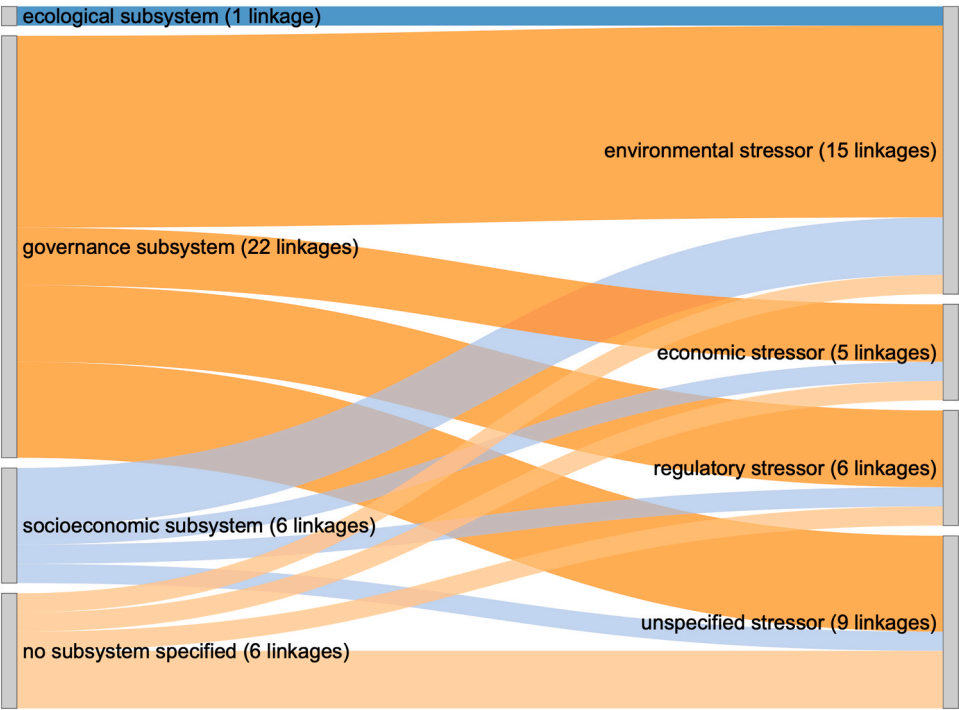


Fig. 2. Sankey diagram of the fishery subsystems (left) and types of stressor (right) that respondents included in their definitions of adaptive capacity. The width of the link between each subsystem on the left and stressor on the right indicates the number of respondents who included this linkage in their definition of adaptive capacity. The total number of links associated with each stressor and subsystem category is listed in parentheses next to the text label for that stressor/subsystem. Note that the overall links sum to more than the number of respondents in the study, because several respondents identified links between multiple subsystems and/or stressors in their definitions.

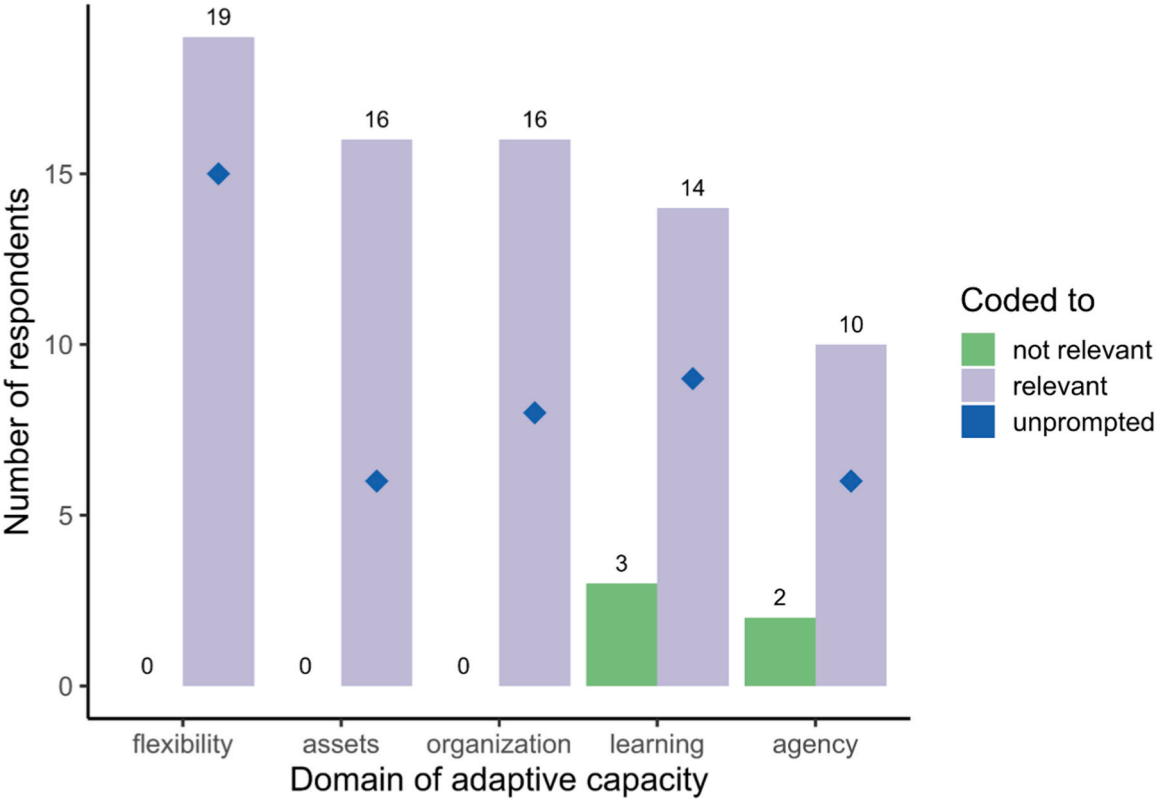


Fig. 3. Number of interview respondents out of 20 who described each domain of adaptive capacity as relevant (purple) and not relevant (green) to their management region. The number of respondents who brought up a domain unprompted before the interviewer introduced it is indicated with a blue diamond overlaid on the 'relevant' column. Note that the 'relevant' and 'not relevant' columns for each domain sometimes sum to less than twenty, since not all respondents chose to address the relevance of all domains.

management and conflated adaptive capacity with adaptive management, defining it, for instance, as "a management paradigm where you learn as you go along" (NOAA Pacific region scientist), a common interpretation of adaptive management [22].

There were no clear trends in how respondents defined adaptive capacity based on the region or role that they represented. Most respondents ($n = 16$) expressed at least a superficial prior familiarity with the concept of adaptive capacity, with the exception of the Gulf of Mexico and the South Atlantic, where some respondents said they were unfamiliar with the term "adaptive capacity" before their exposure to this research process: "We've never had a discussion about, adaptive capacity, what is it? Has anybody heard of that? And I was even talking to a few colleagues around here, it was like, 'Hey, you familiar with this?' They're like, 'No, what's that?'" (South Atlantic council member). Instead, as this council member said, "We're finding ourselves adapting without thinking about what it is we're doing... We don't think about the academics of it. We just do what we need to do to get things done" (South Atlantic council member).

3.2. Domains of adaptive capacity

Respondents saw all five *a priori* domains of adaptive capacity (flexibility, assets, organization, learning, and agency) as relevant to their regions (Fig. 3). Flexibility was most often cited as relevant ($n = 19$ respondents, out of a total of 20 interviews) and came up frequently ($n = 15$) without prompting, suggesting that it is top of mind for respondents. Agency was least frequently cited as being relevant ($n = 10$) and tied with assets as being least likely to come up unprompted ($n = 6$). Across domains, but especially with regard to flexibility, assets, and organization, interviews revealed a mismatch between academic theory and respondents' priorities. Specifically, respondents barely addressed ecological and socioeconomic aspects of these concepts, two areas that synthesis efforts have explored in detail [10], but they explored the governance and management aspects of them in far greater detail than tends to be true in the literature. Specific instances of this mismatch are explored for each of the five domains of adaptive capacity below. Note that the adaptive capacity domain of socio-cognitive constructs [11] was not introduced in interviews because it is not included in recent synthesis efforts and therefore less fully operationalized than the other domains [10,13]. Concepts that can fall under the broad category of socio-cognitive constructs, such as a resilience mindset, emerged only rarely in interviews, so they are discussed only briefly here as they relate to other domains.

3.2.1. Flexibility

Although respondents found the concept of flexibility highly relevant and it emerged unprompted near the beginning of 15 of the 20 interviews, respondents rarely ($n = 3$) mentioned the aspects of ecological flexibility that are prominent in the literature, such as environmental niche breadth, fish mobility and dispersal, and phenotypic variation [10,13,23]. Instead, respondents tended to give detailed responses about flexibility needs within the governance system. These included the flexibility to adapt data collection processes, the flexibility to adjust management timelines, and the flexibility to adjust scientific assumptions. These flexibility needs are explored more fully in a previous study based on this dataset [20]. However, more than any other system attribute, we note that attitudes toward flexibility were context-dependent and polarized. Respondents in multiple regions independently cited cases where fishers themselves drove more restrictive access regimes in order to protect their economic interests in a given fishery and prevent competition from new people entering that arena, even in cases where managers wanted to provide more flexibility. The resistance to reallocation of state-by-state quotas for black sea bass and summer flounder on the East Coast is one example of this. Similarly, respondents in some regions, like the Pacific and North Pacific, valued the rigor of the U.S. federal fisheries management system and the clarity

of its legal mandates, while respondents elsewhere (Western Pacific, South Atlantic) expressed frustration with the restrictions it placed on their ability to provide regulatory flexibility to fishers.

3.2.2. Organization

In interviews, the majority of respondents ($n = 16$) said that having effective organizational structures was relevant to their regions, and about half ($n = 11$) said that this aspect of adaptive capacity was currently being considered in management, at least implicitly. When describing the role of organization in the adaptive capacity of their region, respondents tended to focus heavily on the structure and organization of management bodies ($n = 12$) rather than ecosystem structure ($n = 1$) or self-organization by fishermen ($n = 4$). For instance, respondents across regions consistently brought up the participatory nature of the U.S. fishery management system ($n = 9$), often in the context of acknowledging tradeoffs between enabling stakeholders' participation in transparent processes and the ability to make timely decisions. In contrast, only three respondents mentioned ecosystem connectivity, an aspect of ecological structure and organization, and they did so in the context of challenges related to the fact that marine ecosystems often overlap multiple jurisdictional boundaries of management bodies. One exception to the above generalization was that the broad concept of social capital was frequently raised during interviews with respondents in New England, the Mid-Atlantic, and the South Atlantic. In particular, respondents in these regions cited the East Coast's many political entities and diverse stakeholders as an impediment to organizing effectively: "We're a lot of different states with a lot of different personalities. Florida is very different from Alabama and Texas...the cultural differences prevent effective organizational structures, because you're dealing with very heterogeneous groups" (NOAA Southeast region scientist).

Respondents also identified a number of organizational attributes of governance systems that did not appear explicitly in the literature but that influence those systems' ability to adapt to change. One of these that came up in almost every interview in some form ($n = 19$) was the role of legal mandates in enabling or allowing organizations to adapt to change. This sometimes emerged as a positive theme, as when a few high-level administrators cited the "beauty" or the "genius" of the Magnuson-Stevens Act's transparent, participatory, and rigorous structure in enabling them to manage fisheries sustainably. A large number of other respondents ($n = 12$), usually council members and staffers, described the rigidity of the Magnuson-Stevens Act's mandates or the conflicting requirements of other regulations (e.g., Endangered Species Act, National Environmental Policy Act, Regulatory Flexibility Act) as impediments to adapting to new conditions or offering flexibility to fishers. They often framed this barrier implicitly as a gap in agency, in that management entities with all the attributes of effective organizational structure are still subject to competing legal mandates that can deny them agency to make needed changes.

3.2.3. Learning

More than any other system attribute, respondents rarely thought of learning as a key component of adaptive capacity on its own; instead, they brought it up in dialogue with concepts of agency, assets, flexibility, and organization. For instance, several respondents ($n = 5$) linked fishers' learning capacity to their possession of a resilience mindset (flexibility) and their willingness to accept climate change (socio-cognitive constructs) [11]: "Even when we have evidence to try to say things are different now, it can be hard to get constituents to accept that things are different and to really learn from a new situation" (South Atlantic council staffer). Conversely, regions where fishers had the agency to work effectively through the management process saw more effective incorporation of diverse knowledge sources into management decisions. In the Northeast, for instance, "all the information we were getting early on about the change in the oceans was coming from the fishermen" (Mid-Atlantic council staffer), and in Alaska, one respondent

said, “I’ve seen fishermen work through the management process to try and make sure we’re out there collecting more scientific data” (North Pacific NOAA scientist).

Learning and organization structures were seen as especially tightly linked. A number of respondents ($n = 4$) cited examples in which polycentric governance structures, in which multiple connected regional decision-making centers have autonomy to act within an overarching regulatory framework [24], enabled them to innovate, learn, and adopt new management strategies. For instance, several respondents identified cross-jurisdictional groups like the Northeast Regional Coordinating Committee and Council Coordinating Committee as crucial facilitators of their ability to learn from other regions: “We’re not shy about stealing ideas from other Councils and improving on them” (Mid-Atlantic council staffer). One manager drew on his experience in international management to develop a new approach to quota allocations on the East Coast:

Through my interaction with the New England Council, I was fortunate to have participated in the Transboundary Resources Assessment Committee [TRAC]. That is the committee that is set up to manage jointly with Canada the Georges Bank stocks, namely cod, haddock, and yellowtail, and so they have a system there that uses science to kind of divvy up the allocations of these three species. And so I kind of took that model and then tried to adapt it to fluke, scup, and black sea bass in the Mid-Atlantic. (Atlantic States Marine Fisheries Commission member)

Conversely, though, respondents also identified ways that organizations could hamper innovation if they possessed strong institutional inertia, lacked long-term institutional memory, or had siloed data collection and analysis processes. For instance, the TRAC-inspired reallocation plan for black sea bass, which was described as “brilliant” by another manager (NMFS Greater Atlantic Region manager), was not implemented because of strong economic and political incentives for decision makers to maintain southern stakeholders’ access to quota of northward-moving species, which resulted in inertia at the Council level. As the same manager put it, “the Mid-Atlantic Council has no reason to make it easier for a fisherman from Massachusetts to fish for and land black sea bass, because Massachusetts is not represented on the Mid-Atlantic Council, and so they don’t have a vote... there is an inherent disconnect there.”

3.2.4. Assets

Respondents mostly identified assets as being relevant to adaptive capacity in their regions ($n = 16$) but not actively considered in decision making. Respondents focused on monetary resources and wealth in their responses ($n = 9$), especially the ability of fishers to pay for new limited-access permits to increase their fishing flexibility. Many ($n = 8$) also cited processing and dock infrastructure and fishing gear as important assets for fishers and fishing communities. A number of respondents ($n = 9$) cited diverse fisheries (in the sense of having many potential fishing targets and the gear, vessels, expertise, and market availability to switch between them) as an important asset and source of flexibility. Only a handful ($n = 3$) identified abundant fish populations as an asset, and none mentioned the related ecological characteristics of robust age structure or intraspecific genetic diversity.

Many respondents specifically described scientific advice and data collection as assets, in particular in the context of lacking the funding they needed to collect the data and develop the scientific advice necessary to facilitate learning for proactive adaptation. Maintaining high-quality monitoring programs and cutting-edge science to support decision making is not usually thought of as an asset in the way that infrastructure or boats are, but many respondents made this comparison. They also cited a related concern that formalizing the inclusion of adaptive capacity into decision making would essentially create a new, unfunded mandate within the U.S. federal fishery management system: a requirement to add more data- and time-intensive tasks into the

management process without the assets needed to do those tasks effectively. One respondent compared that situation to the current status of other data-intensive initiatives, like the adoption of ecosystem-based management, within the U.S. system:

We still have our responsibilities to manage [single] species, we’re doing what we’ve been doing, but now they’re saying, “Hey, now we need you to consider climate change.” And so, okay, fine. That requires more data...Data costs money...Then you start contemplating something like ecosystem-based management and the data streams that have to feed into any type of ecosystem-based management model, in terms of habitat data, everything. That is a giant data-sucking endeavor. If you don’t have additional money for it, you just have to spread your existing assets. (South Atlantic council member)

This respondent and four others worried that any formal mandate to consider adaptive capacity would add another drain on those assets because of the amount of data and longer decision-making timelines it would require.

3.2.5. Agency

Respondents generally saw the Magnuson-Stevens Act as laying effective groundwork for fishers’ agency within the current U.S. management system:

When they came up with [the Magnuson-Stevens Act] in the 70 s and when they’ve updated it ever since, I think these principles [of adaptive capacity] are sort of front of mind, and I think the Magnuson-Stevens Act and the paradigm that it develops is really beautiful in that respect. It has deliberately created agency, right? As an example, the federal government inviting in the states and the tribes and the industries and environmental groups and anybody else who’s interested into the management process in really meaningful ways. (NOAA Northwest Center scientist)

Some respondents complicated this idea by noting that stakeholders vary in their ability to take advantage of these opportunities for participation:

I would say that those [stakeholders] that have been in the process a long time have the agency, and they know they have the agency, and they’re using it to their benefit. I’d say those that are new to the process, because of climate—so in particular I’m speaking of the Indigenous communities—I’d say, they don’t think they can do something about it and are learning how to play into the process. (NOAA Alaska Center scientist)

However, respondents identified unavoidable tensions between the U.S. management system’s participatory nature that facilitates stakeholders’ agency and the need for increased flexibility in response to change: “The Council process is a very publicly inclusive process...just the process itself, the steps you have to take, public scoping, public hearings, there’s a lot of back and forth...To just get an amendment through can take years” (South Atlantic council member). However, this did not mean that respondents recommended scrapping stakeholder participation in favor of expediting timelines and enhancing their own agency as leaders within the management system:

Should I [as a manager] wield all the power and just sit in my office up here and be able to get a science report in the door and read it and make a decision and tell somebody to go write this new reg? I don’t think that would be great. We could be quick. We could be much more responsive, and make decisions and respond to information much quicker. But those decisions, there’d be no transparency in the decision making process...There would be much less engagement by the people that are affected, and the people who have to live with the results of the decision, there would be much less engagement by a variety of experts who might have different opinions and different

interpretations of the data and what's needed to adapt. (NMFS Greater Atlantic region manager)

3.3. "Slow is not going to help you": adaptive capacity and timing

Finally, interviews revealed an underlying theme that does not appear to be commonly highlighted in academic explorations of adaptive capacity: the issue of being able to adapt governance systems and day-to-day management operations on an appropriate timescale for the pace and scope of change. This theme emerged in three contexts. First, respondents identified that the pace of climate change-related stressors has increased in recent years [25], creating new urgency in the struggle to adapt: "Slow is good when climate is changing in the background. Make sure you get it right, make sure you're not missing anything. But that doesn't help you with a heatwave. Slow is not going to help you" (North Pacific NOAA scientist). This new sense of urgency resonated across regions, emerging in such diverse areas as Alaska and the South Atlantic:

I've been here, been working in this field for 40 years or whatever, and things have changed, but it's been kind of slower change. It's just the rate, the rate of change has really ramped up in the past 10 years. And that's where you start realizing, "Oh boy, we got to do something." (South Atlantic council member)

Second, in the face of this new urgency, respondents identified time lags in a variety of arenas, including data collection, scientific processes, policy making, and fishers' adaptive capacity, that all threatened the ability of fisheries as a whole to adapt to long-term change. The timelines required for new data to be incorporated into management decisions are just one instance of this: "Our really important species often only get assessed every five to seven years....So you can see that, between the time lag and then a data update, from assessment to assessment, you just get a completely different picture" (NOAA Southeast region scientist). As one example, one Atlantic States Marine Fisheries Commission member cited the southern New England lobster fishery as a "cautionary tale" in which managers were able to implement adaptive strategies to control fishing pressure, but too late to prevent recruitment failure in the stock. Because of American lobster's complex life history, "there's like a seven year gap for things that are going on in the population to come into the actual fishery. That's way out of the range of most management cycles and management thinking" (ASMFC member).

Although the examples above focus on the need to be quicker in response to change, some respondents also expressed concern that overly nimble and abrupt management changes risked chasing adaptive responses to short-term fluctuations that don't represent the long-term future. As one North Pacific council member said:

If you're really nimble you can end up running around a huge amount chasing each and every unusual event that pops up, and trying to respond, and making things up on the fly, and expending a lot of energy. Everybody will be satisfied, it looks like you're trying to do something. And it probably feels right, because it's really hard to see those changes and not feel like you're able to respond. But...it might actually be somewhat counterproductive. And maybe our process, maybe the slow, grinding, glacial aspects of our process, might paradoxically be the more appropriate timing. (North Pacific council member)

Practitioners in the Western Pacific and South Atlantic raised similar concerns about responding too quickly to short-term trends in the data that might not represent long-term deviations from the norm: "If there's a knee jerk reaction to a perceived change in one year [we] may do something that looks good this year, but maybe that's a temporary thing. Maybe patterns return more toward normal two years down the road, and how does that thing shift back?" (South Atlantic council staffer).

4. Discussion

In general, the academic concept of adaptive capacity to change was broadly salient to interview respondents, with the exception of two respondents in the Southeast who were unfamiliar with the concept. Overall, study respondents' understanding of adaptive capacity overlapped broadly with academic ideas, with respondents considering all five main components of adaptive capacity as relevant and important to their regions. In addition, interviews revealed some important mismatches between the two. Specifically, respondents generally defined adaptive capacity narrowly. They rarely identified it as an attribute of all three components within fisheries (ecological, socioeconomic, and governance) and/or rarely considered adaptation to multiple types of change at once (e.g., intersecting stressors of climate change and changing market conditions). Some of them also conflated adaptive capacity with adaptive management, a more established idea in fisheries science [22]. While all the domains of adaptive capacity from recent synthesis efforts [6,10] were relevant to respondents, respondents added useful complexity to these theoretical domains, mostly by providing concrete examples of aspects of these domains within the governance system. Finally, they emphasized a specific temporal dimension to adaptive capacity that is not generally highlighted in academic discussions but can be crucial to fishery social-ecological systems' ability to adapt. Overall, this research emphasizes the broad salience of the adaptive capacity literature to on-the-ground practitioners, while the areas of mismatch they identify point toward productive pathways for making this literature more accessible and useful to marine fishery managers, and toward places where these professionals can help provide conceptual advances in defining theory in this field. These mismatches are translated into three action items below.

4.1. Action 1: build a shared definition of adaptive capacity

First, to increase uptake of ideas around adaptive capacity, researchers should consider ways to differentiate it from the concept of adaptive management, which is more established within the field of fishery science and which many fishery professionals will have prior experience researching or implementing [22]. Although only a subset (20 %) of respondents conflated the two concepts, the respondents for this study were purposively selected as individuals in leadership positions with high-level expertise in climate-ready fisheries management and science. Because even leaders in the field experienced this confusion, clarifying what is meant by "adaptive capacity" will be crucial when communicating with the profession as a whole. One way to do this could be simply to define the two terms whenever discussing adaptive capacity in the context of fisheries and to state explicitly that the ideas are related but distinct. More broadly, this finding suggests the need for more deliberate and evidence-based scientific communication strategies to effectively share these critical topics to practitioners, including clear communication goals; political, cultural and ethical sensitivity; and collaboration [26].

4.2. Action 2: practitioner insights to gain a more nuanced understanding of adaptive traits

This work revealed two clear mismatches between academic ideas about the traits needed for adaptive capacity and how fishery professionals conceptualized these traits. First, while the academic literature strongly emphasizes ecological flexibility (e.g. adult mobility, larval dispersal, habitat diversity), ecosystem connectivity, abundant natural resources, and biodiverse communities as traits that influence ecosystems' ability to adapt [10], respondents rarely spoke about these ecological traits as an aspect of their decision making. Because respondents' expertise and day-to-day decision making exist within the context of the fisheries management system, this gap in respondents' priorities does not necessarily mean that these traits are irrelevant or

unimportant. This mismatch could simply be the result of the open-ended interview structure used here, in which respondents were not prompted with specific adaptive traits and may have been more likely to bring up the adaptive traits and strategies they considered in their decision making on a day-to-day basis. Alternatively, respondents could have been fully cognizant of these ecological traits but opted not to raise them in the context of the interviews because they are less easily managed using the tools available to fishery managers such as effort and catch controls. However, it could also mean that the extensive literature on ecological and evolutionary adaptation to climate change [e.g. 18, 19] is not reaching the on-the-ground fishery practitioners whose actions can influence ecosystems' adaptive traits most strongly. Because the root causes of this mismatch are not clear, it would be premature to recommend a specific action item to address it. However, we intend to follow up this open-ended interview study with a more systematic closed-form survey approach that will provide more data to distinguish between these alternative hypotheses and help clarify the source of this mismatch.

In contrast to their lack of focus on *ecological* adaptive capacity, respondents went into far more detail about *governance* adaptive capacity than tends to exist in the academic literature, and their insight can help us add more detail to this literature. This is important because the adaptive capacity literature is especially abstract and high-level when it comes to the adaptive traits of fishery governance structures and management processes, making it difficult to operationalize these ideas in a concrete, practical way. The detail and nuance that respondents brought to their discussions of adaptive traits within governance systems can help make these abstract concepts more concrete and meaningful, as well as identify places where theory falls short. For instance, the presence of assets is not generally considered an adaptive trait of governance systems [10], but respondents made a compelling case that management organizations are constrained in their ability to adapt if they lack the paired assets of robust scientific data and skilled scientific personnel to interpret those data (Section 3.2.4). Similarly, interviews suggest that agency is important in governance systems beyond just the presence of strong individual leaders; specifically, organizations' overall agency depends on the type and number of legal mandates that empower or constrain them.

4.3. Action 3: make temporal factors explicit

Finally, interviews revealed an underlying question that shaped the way respondents perceived their regions' ability to adapt to change: on what timescale are governance systems able to adapt, and does that timescale match the pace and scale of change? As many respondents emphasized, the U.S. fishery management system is already adaptive and has the elements of adaptive capacity embedded in it. However, the system is most able to adapt at a slow, deliberate pace, and that pace is lagging behind the rate of environmental change. This question of timing is not necessarily a domain of adaptive capacity *per se*, but can be thought of as an essential consideration for all domains of adaptive capacity. This key insight from the interviews has implications for both scientists and decision makers. As scientists conduct research relevant to fisheries adaptation to change, they should incorporate a temporal lens and should be clear in communicating the appropriate timescales of proposed interventions. For management practitioners, respondents cautioned against rushing to respond to every type of change, given that some short-term adaptive coping mechanisms may be maladaptive in the long run. An alternative approach could be to set long-term goals in response to observed and anticipated changes and work towards those goals incrementally.

4.4. Study limitations

While this study's in-depth qualitative interviews provided nuanced insight regarding how those involved in fishery management processes

understand key concepts of adaptive capacity, the purposive sampling technique used here limits the ability to identify differences between management regions or different priorities for respondents based on their role in fisheries management. Instead, this study focuses on exploring consistent themes, identifying gaps in the current academic literature, and generating hypotheses for future quantitative work.

5. Conclusions

This study adds to the growing literature on the ability of fisheries to adapt to change, a literature that is becoming increasingly important as global climatic change accelerates [25]. It adds a novel dimension to this literature by systematically eliciting the perspectives of fishery professionals whose expertise spans a broad range of marine systems across multiple management regions in U.S. fisheries. The resulting analysis reveals a broad concordance between practitioners and the literature: respondents generally defined adaptive capacity in ways consistent with the literature and generally considered all five broad elements of adaptive capacity (flexibility, assets, organization, learning, and agency; [6,10]) to be relevant to their regions. At a more granular level, it identifies a number of mismatches between this current theory and how on-the-ground fishery practitioners think about the specifics of what they need in order to adapt to change. The manuscript then suggests three shifts in how researchers frame and present new advances in the adaptive capacity literature in order to help bridge this gap between theory and practice. They are 1) distinguishing between adaptive capacity and adaptive management when communicating with practitioners, 2) using practitioner insights to deepen the field's investigation of the adaptive capacity of governance systems, and 3) adding an explicitly temporal component to studies of adaptive capacity to change, especially when proposing specific interventions. Finally, this study suggests intriguing trends in responses based on management region, which can be explored further with more quantitatively robust methods like surveys. A follow-up survey of a broader sample of fishery professionals throughout the U.S. is currently in development to explore some of these trends further.

CRedit authorship contribution statement

Abigail S. Golden: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation. **Arielle Levine:** Writing – review & editing, Validation, Supervision, Software, Resources, Project administration, Methodology, Funding acquisition, Conceptualization. **Marissa L. Baskett:** Writing – review & editing, Validation, Methodology, Funding acquisition, Conceptualization. **Dan Holland:** Writing – review & editing, Validation, Methodology. **Katherine E. Mills:** Writing – review & editing, Validation, Methodology, Funding acquisition, Conceptualization. **Jacqueline Vogel:** Writing – review & editing, Visualization, Validation. **Tim Essington:** Writing – review & editing, Validation, Supervision, Software, Resources, Project administration, Methodology, Funding acquisition, Conceptualization.

Declaration of Competing Interest

The authors state that they have no competing interests to declare.

Data availability

The data that has been used is confidential.

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Appendix

1. First, I want to confirm your position at [X] in region [Y]. Have you worked in a management context in any other positions? Other regions? How long have you been working in management?

Next, I want to introduce the project briefly and make sure we're on the same page:

Fisheries are facing unprecedented change. In order to continue providing social and economic benefits and remain sustainable into the future, they need to be able to adapt to this change. We call this ability to respond to change *adaptive capacity*. There is a growing academic literature on the aspects of fisheries that can foster adaptive capacity, including ecological, socioeconomic, and governance factors. However, this academic research has struggled to provide concrete guidance to managers about how to promote the adaptive capacity of fisheries. The purpose of this project is to evaluate 1) the degree to which federal fishery managers in the U.S. are considering adaptive capacity when making decisions, 2) examples of decisions that promote adaptive capacity, and 3) what factors might prevent adaptive capacity from being considered in decision-making. In this interview, we want to explore what this concept of adaptive capacity to change means to you, and how and whether it factors into policy and regulatory decisions in your region's fisheries.

2. Briefly, how would you define adaptive capacity in fisheries systems? In your opinion, what makes a fishery system more or less able to adapt to change?

In the literature, some key principles of adaptive capacity include:

- Flexibility (for instance, access to alternative livelihoods or plasticity in fishes' behavior)
- Diversity (for instance, diversity of species or the ability to switch between gear types)
- Assets, such as money or natural resources
- Organization structures that promote effective action
- Agency, which means the ability to make decisions and respond to disruptions
- Learning, including the ability to learn from past experiences and innovate

How do these principles from the literature align with the way you think about adaptive capacity? Are there any key overlaps or differences?

3. How/to what extent do you think these principles we've discussed together are relevant or not relevant to your region?

4. To what extent do you think these key principles of adaptive capacity are considered when making decisions about fishery policy in the region in which you work?

5. Can you provide any examples of management decisions that have affected the adaptive capacity of your region's fisheries? If there are no examples in your region, can you think of examples from other regions?

-Please describe.

-Walk me through the process of making that decision. Was adaptive capacity actively considered in the decision making process? If so, how?

-What elements of that decision do you see as supporting or inhibiting (or influencing) adaptive capacity?

[Repeat for all examples.]

-Specifically, can you think of any examples of management that have harmed or reduced adaptive capacity in your region's fisheries?

6. Are there any reasons why adaptive capacity might not be considered in decision making in your region? Please describe these

reasons.

7. Based on the literature and input from our advisory panel, we have a few specific hypotheses about why managers in the U.S. might not be incorporating adaptive capacity into decision making. They include but are not limited to:

1. Disagreement with fundamental tenets of the concept
2. Belief that it will not benefit a particular management context
3. Insufficient information to support the inclusion of adaptive capacity in decision-making
4. Competing priorities in the decision-making process that make it politically challenging to navigate trade-offs associated with adaptive capacity
5. Jurisdictional boundaries and lack of coordination across boundaries, e.g. for stocks with shifting ranges
6. Lack of a policy mandate to do so
7. The costs of managing to improve adaptive capacity are perceived as outweighing the benefits, e.g. because of cumbersome decision-making processes
8. Lack of ability to manage on a long enough time horizon
9. Lack of resources and time
10. Lack of acceptance that external forces (e.g. climate change) are a driving factor in resource status
11. Stakeholders' focus on protecting current interests
12. Lack of trust between stakeholders and management, for instance that flexibility given to stakeholders won't be misused or that reductions in quota made by managers won't be permanent
13. Length of timelines for decision-making (long timelines make it difficult to respond adaptively; conversely, management decisions are frequently focused on the 3–5 year range instead of decadal scales required for long-term adaptation)
14. Potential for fishermen and managers to adopt a last-chance mentality as stocks decline
15. Mismatch between the long-term goals of fishery management in the U.S. (i.e. granting property rights) and the strategies required for adaptive capacity (i.e. flexibility)

Do you have any other potential explanations to add to this list?

To what extent do you think these are (or are not) applicable to your region? Have you encountered any of these specifically?

Provide examples if applicable.

8. Can you think of any potential ways to incorporate adaptive capacity despite [barrier X]?

[Repeat as needed, for each barrier that was mentioned.]

9. In your opinion, are the issues we've talked about in this interview specific to your region, or are they issues at the national level?

10. Is there anything else you think we should know relating to adaptive capacity and fisheries decision-making in your region?

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