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Food for Thought

Navigating concepts of social-ecological resilience in marine fisheries under climate change: shared challenges and recommendations from the northeast United States

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Abstract

Climate change is increasingly impacting marine fisheries worldwide. Concurrently, scientific interest has grown to understand how these systems can cope and adapt, with research shifting from examining vulnerability to assessing risks to focusing on determining and operationalizing resilience. As fisheries-climate-resilience researchers and practitioners navigating a sea of frameworks, toolkits, strategies, policy goals, and management desires, we take stock to ask: what does resilience mean to us? Drawing on our experiences in the northeast United States, we discuss the challenges and ambiguity we encounter in concepts of social-ecological resilience and explore implications for research and implementation. We bring together perspectives to discuss various approaches to resilience, highlighting shared and unique challenges we face. We outline three key considerations as we move forward in resilience research and practice: (1) the need for greater transparency and reflexivity among researchers regarding how they frame and approach resilience; (2) the value of increasing coordination and communication among fisheries groups working on these topics; and (3) the use of co-developed and co-produced resilience research and strategies. We urge for greater centring of communities in these discussions and to explicitly consider how resilience interacts with equity outcomes.

Keywords: adaptation; fishery; resilient; social-ecological system; vulnerability

Achieving climate resilient fisheries: what is the problem?

Climate change is a critical issue affecting fisheries globally, altering and shifting species availability and productivity, threatening fisher safety at sea, and impacting fishing communities dependent on these systems for food, livelihoods, culture, and wellbeing (Sumaila *et al.*, 2011; Pinsky and Fogarty, 2012; Weatherdon *et al.*, 2016; Pecl *et al.*, 2017; Savo *et al.*, 2017; Sainsbury *et al.*, 2018; IPCC, 2019; Ojea *et al.*, 2020). Increasing urgency for supporting fisheries in the face of these changes is mounting as impacts grow more extreme and newsworthy, such as the unprecedented marine heatwaves in the North Atlantic region throughout mid-2023 that threaten both marine life and associated coastal livelihoods (Copernicus, 2023; Kaminski, 2023).

This issue is of particular importance to fishing communities and the fisheries based in the United States (US) northeast region (fishing in the northwest Atlantic). Fisheries provide significant economic value to the region's coastal economy: in New England in 2019, fisheries landed 516.7 million pounds of finfish and shellfish, totalling $1.5 billion in landing revenues (NMFS, 2019). They also provide social and cultural contributions such as a sense of identity and occupational attachment, job satisfaction, and individual and community wellbeing (Smith and Clay, 2010; Jepson and Colburn, 2013; Pollnac *et al.*, 2015). Coastal and ocean waters along the northeast US are rapidly warming, with the Gulf of Maine warming faster than 95% of the world's oceans since the early 1980s (GMRI, 2023). Impacts of warming on marine ecosystems are already apparent in the region, posing challenges to fishing communities and fisheries management alike (Mills *et al.*, 2013; Pershing *et al.*, 2015; Colburn *et al.*, 2016; Hare *et al.*, 2016; Le Bris *et al.*, 2017; Rogers *et al.*, 2019; Pinsky *et al.*, 2020; Maltby *et al.*, 2023). In particular, range shifts of species, including summer flounder and black sea bass are crossing management jurisdictions, separating habitats from traditional fishing grounds, and provoking conflict over quota allocation (Dubik *et al.*, 2019; Rogers *et al.*, 2019; Palacios-Abrantes *et al.*, 2023). Fishers are also moving to fish further offshore, fishing from new ports, switching target fisheries, and, in some cases, leaving fishing altogether (Rogers *et al.*, 2019; Young *et al.*, 2019; Pinsky *et al.*, 2020;

Papaioannou *et al.*, 2021). Ocean acidification and sea level rise further threaten these systems and, alongside warming, are expected to have substantial cumulative effects in the upcoming decades (Colburn *et al.*, 2016).

In recognition of the challenges already being faced and inevitable future uncertainties, momentum has grown among those in research, funding, management, and policy spaces to understand, support, and build climate resilience in fisheries systems (De Young *et al.*, 2012; Pinsky and Mantua, 2014; Bell *et al.*, 2020; Peck *et al.*, 2020; FAO, 2021; Tilley *et al.*, 2021; Woods *et al.*, 2021). The United Nations Ocean Decade has further elevated resilience as a research and policy priority, such as through the SUPREME (SUstainability, Predictability and REsilience of Marine Ecosystems) and FishSCORE 2030 (Fisheries Strategies for Changing Oceans and Resilient Ecosystems) programmes (https://oceandecade.org/decade-actions/). Other groups have assembled to progress action in this area, such as the global Science for Nature and People Partnership (SNAPP) working group for operationalizing climate resilience in marine fisheries management (https://snappartnership.net/teams/climate-resilient-fisheries/). While different projects vary in their approaches and research objectives (including but not limited to vulnerability, adaptation, adaptive capacity, and resilience), the overall aspirations of this growing body of work and wider initiatives have been to bolster resilience in fisheries and their associated communities along the coastline. However, despite best intentions, this rapid growth of focus on resilience has led to multiple interpretations of what climate resilience in fisheries means or looks like, with little consensus over how resilience can be understood or "built." The vague terms and goals therefore make it difficult to leverage climate resilience in practice.

As researchers working in this field within the northeast US, we are passionate about contributing to projects that enable fisheries to continue to provide economic, social, and cultural benefits in the face of growing ecological change and climate impacts. We are encouraged by the array of projects occurring in this space and the enthusiasm to develop collaborative solutions. Yet, given the growing momentum and "buzz" surrounding climate-resilient fisheries at large, we feel it necessary to take stock of how we as a community, both here in the northeast and more widely, are approaching resilience, what challenges we face, and how we can progress the field in ways that help to effectively operationalize resilience in fisheries.

Within this perspective piece, we hope to highlight: (1) varied ways of knowing and understanding resilience; (2) the shared challenges we face while reconciling the need for resilience to be both vague yet specific as a concept; and (3) key considerations for the future for those working in the climate-resilient fisheries space. As part of these considerations, we adapt Meerow and Newell's (2019) five W's for resilience—a framework within the resilience literature developed to provoke critical reflections and examinations of the concept in both work and practice—to the context of marine fisheries, giving more definition to the questions "of what," "for whom," "for when," "for where," and "why." We summarize these challenges, our approach, and our recommendations in Figure 1.

Positionality and approach

We are a group of social-ecological systems (SES) researchers studying resilience across a range of fisheries contexts in the northeast US. We frame our positionality in Box 1. Perspectives in this paper build on a series of conversations and discussions held through bi-monthly, virtual meetings from June 2022 to May 2023 via a recently developed research network (the Northeast Climate Resilient Fisheries Network). This network was created as a space to enable researchers in the region to share our research, discuss different approaches to and interpretations of resilience we observe in our institutions and among communities we work with, and reflect and grapple with shared challenges and questions arising from this work. The challenges and recommendations outlined in this paper reflect recurring topics and ideas among Network members across these multiple meetings, many of which are echoed in other current critiques in the wider resilience literature. These are not intended to be comprehensive, and we hope will serve to motivate readers rather than instruct. While these insights are grounded in our experiences working in the northeast US, we hope that the perspectives may be applicable beyond the region, especially as climate change continues to impact coastal systems and communities globally.

Box 1. Positionality statement

The authors of this paper are social-ecological researchers with experience in academia, government, and non-profit organizations. We represent a mix of career stages, with four of seven of us at the early-career stage. Our resilience-focused research has mostly been informed and developed through an academic lens of western, Eurocentric concepts of resilience, although we have undertaken projects in a range of fisheries contexts and communities around the world. However, the majority of our current work (at the time of writing) takes place in the northeast US, utilizing a range of disciplinary tools and approaches.

As individuals, we have been inclined to collaborate with a range of stakeholders on projects in different ways. Admittedly, in many cases, we have come to those collaborations with predefined ideas about what resilience may mean or look like. We often have understood or examined resilience through a normative lens, as something to be "built," "operationalized" or "supported" because climate change or other stressors threaten marine ecosystems and/or make fishers and fishing communities more "vulnerable." While narratives of building resilience are commonplace in the northeast US, we recognize this may be at odds with how particular stakeholder groups or communities see themselves, while other perspectives may not accurately capture why resilience matters to that community or context. In other fisheries worldwide, there are some communities resisting resilience narratives and for whom visions of transformations, viability, and prosperity are more favourable. Throughout our experiences, we have also often struggled with using or working with broad and "fuzzy" concepts of resilience, and been guilty of not fully interrogating its meaning in different contexts or circumstances.

We developed this manuscript partly to help us confront and consider some of the issues and doubts we have experienced or encountered when undertaking resilience research, and intend to use this piece to guide our future work. In this sense, we hope that this paper can serve to prompt those using the resilience concept to think critically about how it is used in communities they are working with and whether it is appropriate in some cases (or what the limits might be). While we generate recommendations, we see these as much for ourselves as for other readers. As such, we hope to encourage similar conver-

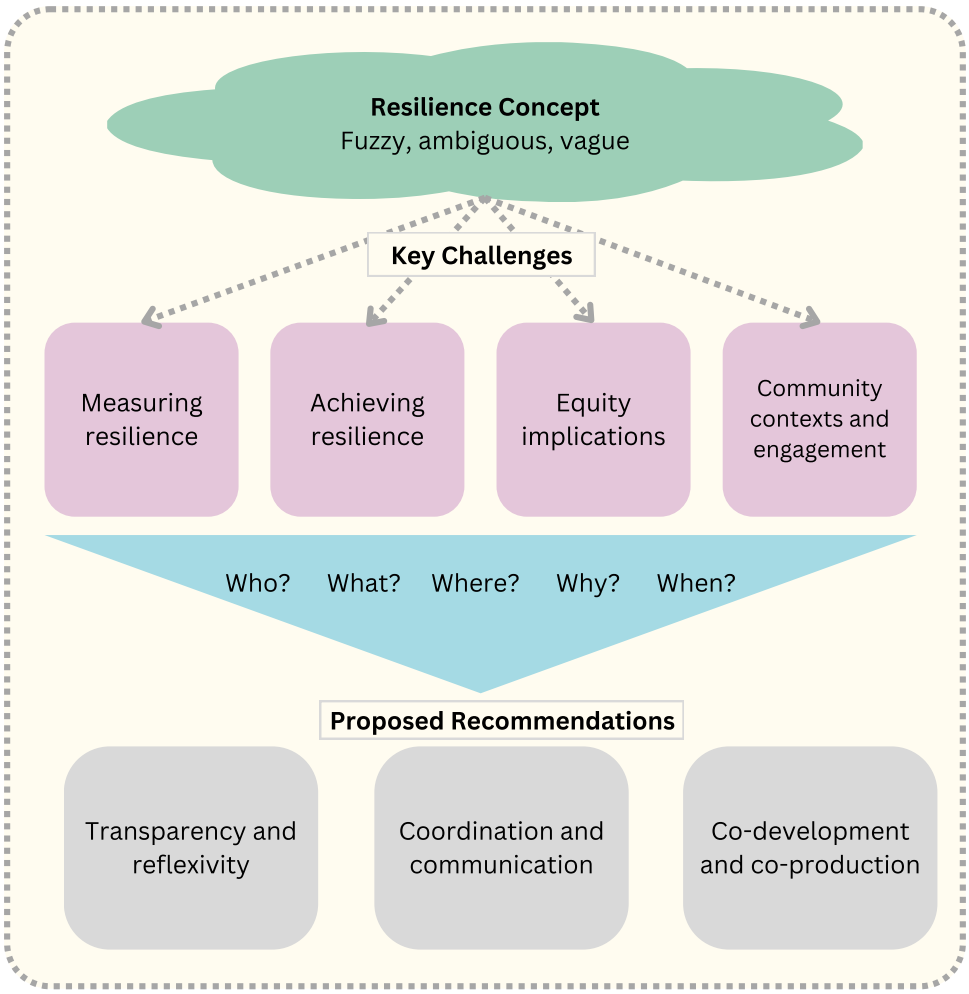

Figure 1. Conceptual figure depicting the key perspectives in this paper and their linkages: (1) the concept of resilience; (2) key challenges; (3) application of Meerow and Newell's five W's (2019); and (4) proposed recommendations related to resilience research and practice.

sations and reflections among researchers rather than prescribe directly to those working in other fisheries.

Various ways of approaching and conceptualizing resilience create ambiguity

Resilience is broadly about how complex systems respond to change or disturbance, but it carries different—and sometimes contradictory—definitions and connotations across disciplines (widely reviewed in, e.g. Alexander, 2013; Davidson *et al.*, 2013; Brown, 2015; Folke, 2016; Moser *et al.*, 2019). It is unsurprising to find diverse and disorganized approaches to resilience in fisheries because they are multifaceted SES that hold different meanings and values for different actors—they may be thought of as ecosystems, food systems, livelihoods, and components of coastal communities, to name a few (Ostrom, 1990; Allison and Ellis, 2001; Restrepo-Gómez *et al.*, 2022; Tigchelaar *et al.*, 2022). Thus, fisheries researchers and practitioners necessarily come together from diverse fields, bringing with them their different conceptualizations of resilience. This diversity adds richness but can also create confusion and even conflict when actors are not aware of how their resilience concepts mesh (or do not) with others.

For example, practitioners in disaster reduction might conceptualize resilience as risk reduction or resistance to change, while ecologists and social scientists might emphasize absorption of or adaptation to change (Folke, 2016; Reyers *et al.*, 2018). The ecological framing of resilience tends to be descriptive (that is, positive) rather than normative, where, for example, a degraded but stable algal-dominated and defaunated coral reef would be highly resilient (Côté and Darling, 2010; Cannon *et al.*, 2021). Conversely, social and social-ecological framings, which emphasize the ability of human communities to continue to develop in the face of change, uncertainty, and surprise (Folke, 2016), are in many contexts explicitly normative, where resilience is considered desirable (Béné *et al.*, 2014; Thorén and Olsson, 2018). The social-ecological resilience field has increasingly come to encompass, and even emphasize, capacities for transformation in the face of novel regimes under climate change, as well as the need to break out of persistent maladaptive dynamics (e.g. social-ecological traps) to achieve desirable outcomes (Cinner, 2011; Kates *et al.*, 2012; Folke, 2016; Reyers *et al.*, 2018). However, the inclusion of transformation in resilience concepts is not universal and may vary by field and ecosystem context (Glaser *et al.*, 2018; Peterson St-Laurent *et al.*, 2021). Meanwhile, popular usage of resilience in non-academic settings tends to draw from psychology and health perspectives that emphasize individual grit or

perseverance in the face of adversity (e.g. Zimmerman, 2020; Ferrazzi *et al.*, 2021) (incidentally, traits stereotypically associated with fishers). Given these different conceptual lineages, academic framings of resilience can often be distinct from how grant funders, resource managers, or fishing industry participants view resilience.

Finally, regardless of how resilience is defined, researchers and practitioners may variously interpret resilience as a *property* of a system (by identifying attributes, traits, or characteristics), a *process* (by describing actions and interventions to build resilience), an *outcome* (by characterizing a system's state at a given time following a disturbance), or a *combination* of these (Moser *et al.*, 2019). This can lead to disagreement or ambiguity in what resilience "success" looks like, much less how and when to measure or evaluate it.

Where resilience researchers do tend to agree is that it is critical to define resilience "of what" (the bounds of the system, e.g. individual fisher vs. fishing community vs. coastal region), "to what" (the stressors or disturbances, e.g. general vs. specific, pulse vs. press), and "for whom" (how benefits or outcomes are distributed among actors in the system) (Carpenter *et al.*, 2001; Meerow and Newell, 2019). This is because each of these incurs trade-offs, and how they are delineated would impact conclusions about resilience or the design of resilience interventions. Supporting ecological resilience may run counter to social resilience goals (Adger, 2000), or what confers resilience at a community scale could harm marginalized individuals. "General" resilience to any disturbance or uncertainty has been shown to have trade-offs against "specific" resilience to particular threats (Carpenter *et al.*, 2012). Furthermore, questions remain about the characteristics that confer resilience to press stressors, like gradual warming, vs. pulse stressors, like hurricanes (Cantarello *et al.*, 2017). Additionally, mapping and defining complex systems in order to bound them may be challenging and time-consuming, beyond the scope of management, project funding, or timelines. And more importantly, these delineations are fraught and potentially controversial: inherently political, value-laden choices that may conflict with individuals and communities' goals for well-being (Folke, 2016; Harris *et al.*, 2017; Chaigneau *et al.*, 2021). Defining a system broadly or vaguely may be appealing because it appears more inclusive and could promote buy-in among diverse stakeholders. However, zooming out and defining resilience at a higher level can mask heterogeneity, trade-offs, and inequality among actors and outcomes.

Challenges with resilience

Given the proliferation of approaches to characterizing resilience, an important trade-off emerges between the advantages of the term being vague and adaptable enough to suit different needs and perspectives vs. the desire for it to be specific in order to be suitably measured, operationalized, and "achieved" (e.g. Moser *et al.*, 2019; Soubry and Sherren, 2022). Further, present climate change impacts on fisheries and resulting management challenges in the northeast US have created a sense of urgency, with the desire and expectation to operationalize resilience possibly outpacing researchers', practitioners', and managers' abilities to understand what this could look like for different contexts.

On the one hand, the vagueness of resilience is useful; there does not need to be one universal definition or solution to how we operationalize it. Its adaptability enables more diverse, context-specific studies and interventions that are best suited to community needs and realities. Others have also highlighted that the broadness of resilience enables it to serve as a "boundary object" that can spark conversation and engagement surrounding resilience topics among different stakeholders and inspire action (Moser *et al.*, 2019). Purposefully using resilience in this broad sense can also facilitate wider conversations with communities regarding the futures they want to see for their fisheries and ways for getting there.

On the other hand, the ambiguity of resilience poses challenges to research and implementation. Through our experiences as fisheries resilience researchers, we identify four general issues emerging from this vagueness: how to measure resilience, "achieving" resilience, equity implications, and the role of community context and engagement. These challenges do not negate the very real values of a vague resilience framing noted above, but rather highlight key areas for consideration in future research and practice.

Measuring resilience

The first challenge is that vague definitions of resilience inevitably invite a multitude of methodologies for measuring it. This in itself is not a problem, although navigating the resilience space can be daunting given the weighty academic debates that surround it. For early-career researchers in particular, choosing the "right" definition or concept may be intimidating and time-consuming, even when ultimately there is no one correct approach. The core issue, however, is that certain methodologies may conclude that a system (or component of the system) is resilient, while others may come to different conclusions. In this instance, how do we know which is right or wrong?

Additionally, resilience or "achievement" of resilience is hard to measure, depending on indirect metrics or indicators. These indirect measures can become ambiguous, reductive, or, at worst, contradictory when multiple different perspectives of resilience exist (Quinlan *et al.*, 2016). Method diversity can also hamper comparisons of the resiliency of different fisheries or project outcomes due to misaligned metrics or opposing resulting information (e.g. large quantitative data describes systems very differently to qualitative information highlighting nuanced contexts). This can lead to challenges regarding the standardization of resilience measures to compare or contrast against different contexts and case studies. Further complicating the evidence base for researchers and decision-makers are shifting baselines, the lack of counterfactuals, the diversity of disciplinary perspectives involved, and the variability in study scales. Together, these potential contradictions in measurement pose obstacles for evaluating success against management and policy resilience goals.

"Achieving" resilience

Resilience research tends to be applied and action-focused, with aspirations towards operationalization and supporting policies that "build" or "achieve" resilience. However, the ambiguity of and diversity in defining and measuring resilience can hinder specific, measurable, and actionable policy targets. This creates confusion about the goals of, pathways to, and evaluation of resilience (Moser *et al.*, 2019; Soubry and Sherren, 2022). Several questions about this process arise, including: is resilience achievable, or is it an ongoing process? Is it something that you can measure before a disturbance (e.g.

traits), or do you wait until after the system has been disturbed (e.g. outcome/process)? What does "success" look like for achieving a policy target given multiple potential viewpoints and evaluation criteria? We do not have all the answers to these questions, but they offer important considerations for management and policy development.

This lack of specificity in the ways resilience can be understood within management and policy contexts may cause tensions with stakeholders or result in less buy-in (Soubry and Sherren, 2022). Indeed, unless stakeholder groups gain positive and tangible benefits from resilience-based management, reduced trust and legitimacy in decision-making may occur, further hindering progress (Soubry and Sherren, 2022). Effective management that works towards resilient resources and systems stems from enhancing the saliency, credibility, and legitimacy of the information each group brings while reinforcing communication, translation, and management across groups (Cash *et al.*, 2003). Issues of reduced trust and legitimacy are already commonplace amongst stakeholders engaging in fisheries management processes broadly, but especially in the northeast US, where there is a long history of fisheries management controversy and varied trust in the management process (Hartley and Robertson, 2006; Mulvaney and Druschke, 2017; Scyphers *et al.*, 2019). Additionally, resilience-building strategies and interventions have the potential to have long-lasting consequences for fishing communities' livelihoods and wellbeing, meaning that due consideration to how we frame resilience in research, management, and policy is critical (Chaigneau *et al.*, 2021).

Further, even if standard definitions or approaches to measuring and achieving resilience existed, current fisheries management systems are not well designed to deal with the complexity of the information produced. In the northeast US, fisheries management has traditionally been developed from and for biology and ecology, which contrasts SES framings that emphasize system complexity, adaptiveness, and social dynamics at multiple scales (St. Martin *et al.*, 2007; Folke, 2016; Reyers *et al.*, 2018). Fisheries resilience research is increasingly utilizing social science approaches and incorporating different knowledge forms, the outcomes of which are hard to integrate into current management systems that rely on quantitative data and methodologies (Williams *et al.*, 2020; Steins *et al.*, 2022). This ultimately hinders progress towards achieving resilience outcomes, despite some developments in this area (e.g. NOAA social indicators project, https://www.st.nmfs.noaa.gov/data-and-tools/social-indicators/; New England and Mid-Atlantic Fishery Management Councils research priorities that include human dimensions, NEFMC, 2021; MAFMC, 2022; and NOAA Fisheries northeast Fisheries Science Center's State of the Ecosystem reports, NEFSC, 2023).

Equity implications

Climate change impacts communities unequally, which can exacerbate existing and historical injustices and vulnerabilities (Marino and Ribot, 2012; Blasiak *et al.*, 2017; Bennett *et al.*, 2023; Gill *et al.*, 2023). Interventions designed to manage climate impacts and build resilience also have equity implications regarding the distribution of who benefits and loses from particular strategies (Matin *et al.*, 2018; Bryndum-Buchholz *et al.*, 2021; Gill *et al.*, 2023). While questions are being raised about how resilience interventions in fisheries provide fair and equitable outcomes (e.g. Kleisner *et al.*, 2021; NMFS, 2022), less attention has been paid to the equity implications of the decisions—and the transparency of those decisions—regarding how resilience is framed and defined in the first place. Yet, such decisions hinge on the different contexts, priorities, interests, scales, and sectors of those involved in the decision-making (Harris *et al.*, 2017; Meerow and Newell, 2019; Moser *et al.*, 2019; Soubry and Sherren, 2022). This ultimately can lead to subjectivity in choices made, power-laden decisions, and value judgements regarding what and whom to include, such as the types of dynamics, relationships, processes, and actors in the research or management questions, framing, and interventions (Harris *et al.*, 2017; Meerow and Newell, 2019; Moser *et al.*, 2019).

Trade-offs therefore must be made, thus privileging and/or prioritizing certain actors or perspectives in these decisions over others (Moser *et al.*, 2019). This is particularly important given that much of fisheries science and management is rooted in western, male-centric, colonial ways of thinking and knowing, leading to approaches and decisions that can be inappropriate, unjust, and harmful for already marginalized communities (Silver *et al.*, 2022). Many of the resilience concepts used in research and practice are similarly derived from white, colonial, and Eurocentric viewpoints with existing resilience frameworks also developed from male perspectives due to a lack of gendered and intersectional studies examining fisheries systems, climate, and resilience (Djoudi *et al.*, 2016; Amo-Agyemang, 2021; Axelrod *et al.*, 2022; Plastina, 2022; Szaboova *et al.*, 2022). Failing to critique these framings and consider or mitigate their potential consequences can result in goals and interventions that not only risk increasing vulnerability and marginalization for particular groups, but also lead to problems regarding stakeholder buy-in, cooperation among groups, issues of compliance and conflict, and low social capital (Harris *et al.*, 2017; Meerow and Newell, 2019; Moser *et al.*, 2019; Kleisner *et al.*, 2021; Soubry and Sherren, 2022). However, some management bodies in the US have made recent progress in considering issues of equity and environmental justice (e.g. NOAA Fisheries' draft Equity and Environmental Justice Strategy; NMFS, 2022; http://www.fisherycouncils.org/ccc-meetings/may-2022), providing more formal frameworks for addressing certain inequities in fisheries.

In addition to decisions surrounding resilience "of what," "to what," and "for whom," Meerow and Newell (2019) argue that choices and trade-offs also have to be made regarding resilience "for when" (i.e short-term shocks or long-term stresses), resilience "for where" (i.e. considerations of spatial scale and cross-scale effects), and finally, "why" resilience (i.e. what are the motivations and reasons for wanting to achieve resilience?). Their framework, developed through interrogation of current social scientists' and human geographers' critiques of the resilience concept in urban systems and more broadly, provides a tangible guide to enable researchers to critically reflect on the use of resilience in their own projects, initiatives, and programmes. We apply these questions into a marine fisheries context (Table 1) to illustrate the breadth of assumptions and choices being made when conceptualizing resilience, but which may not always necessarily be considered explicitly. As researchers, we have our own inherent biases, values, and disciplinary perspectives, and for many in this field, colonial viewpoints which may, whether unintentionally or not, lead to inequities (Silver *et al.*, 2022). Through adapting Meerow and Newell's questions, we hope to prompt

Table 1. Adapted from Meerow and Newell's 5 W's for urban systems (2019), we outline pertinent considerations of resilience for who, to what, for when, where, and why within fisheries contexts.

Question	General considerations (Meerow and Newell, 2019)	Example fisheries-specific considerations
Who	- Who determines what is desirable for a fishery system? - Whose resilience is prioritized? - Who is included (and excluded) from the fishery system?	- Are researchers, industry, coastal communities, practitioners, managers, or policymakers determining desirability? Importantly, how are they determining this? - Whose resilience is prioritized or centred: e.g. commercial fishers, recreational fishers, subsistence fishers, indigenous fishers, broader coastal community members, processors and dealers, seafood distributors, retailers, and food services? - Is heterogeneity within groups accounted for? - What fisheries or communities are being considered and why? Why not others? - Are resilience framings being based on the wants/needs of older generations or younger ones? - Are women or other historically marginalized groups included?
What	- What perturbations and changes should the fishery system be resilient to? - What networks and sectors are included in the fishery system? - Is the focus on generic or specific resilience?	- Climate impacts on fisheries can include warming, sea level rise, changing storminess/extreme events, ocean acidification, shifting species distributions, altered productivity, and phenology, among others. - Broader pertinent changes to fisheries include offshore wind developments, aquaculture, coastal gentrification, declining industry entrants, fishing pressure, regulatory changes, market demands and trade, and economic trends. - How is the fishery being defined—does it include the harvesting sector and/or the seafood supply chain and/or wider coastal community members? What scale is being considered—e.g. individuals, household, community, whole system? - Is the focus on a single or mix of species or broader ecosystem changes? - Is resilience being applied to the fishery or a larger SES that the fishery system is part?
When	- Is the focus on rapid-onset disturbances or slow-onset changes? - Is the focus on short-term resilience or long-term resilience? - Is the focus on the resilience of present or future generations? - Is resilience conceptualized as a process that can be measured pre-disturbance, or as an outcome, where resilience cannot be determined until after a disturbance? - Is resilience meant to be a "reactive" or "proactive" approach?	- Are the climate impacts considered (for example) long-term warming or marine heatwaves, coastal flooding events or sea-level rise, extreme storm events or general stormier conditions? - Are time scales daily, seasonal, annual, decadal or multi-decadal, or a mixture? Do they centre on an individual's life course or multi-generational time frames? - Is the resilience of those currently engaged in fishing being considered or are future generations and types of fishery participants also being considered?
Where	- Where are the spatial boundaries of the fishery system? - Is the resilience of some areas prioritized over others? - Does building resilience in some areas affect resilience elsewhere?	- Are local or global-scale dynamics being considered (e.g. local seafood networks vs. global supply chains)? - Does the fishery system include shore-based coastal communities, ports, or broader "portshed" perspectives? - Does the fishery include those working in state waters and/or federal waters? - Is the whole species or stock being considered, or just the part relevant to a particular area? - What are possible implications of building resilience in one fishery or sector given the interconnected nature of fisheries systems? - What are the characteristics and scale(s) of the ecosystem affected by fishery decisions?
Why	- What is the goal of building fishery resilience? - What are the underlying motivations for building fishery resilience? - Is the focus on process or outcome?	- Is building resilience meeting ecological, social, and/or economic goals? Which, if any, are being prioritized? - How is resilience "success" defined? For example, ensuring maximum sustainable yield or enabling healthy stock populations to rebound? Maintaining stable harvest or revenue? Sustained participation in the fishery? Or ensuring livelihoods and cultural benefits? - Is focus on property, process, or outcome, or a combination?

others to reflect on the many choices they are making when engaging in resilience research and offer more structured ways to explore and outline the inevitable trade-offs that are made (Table 1).

Ultimately, the decisions we make at all stages of resilience research, management, and policy have equity consequences, and failing to consider and/or address them risks perpetuating the conditions that lead to vulnerability and inequity in the first place. Moving forward, we encourage researchers and practitioners to not only consider the historical, current, and future vulnerabilities and inequalities among groups being engaged, but also reflect upon and interrogate the resilience lenses we bring to our research and practices and their implications.

Community contexts and engagement

More broadly, the ways we measure, operationalize, and achieve resilience ultimately depend on engaging communities. This can lead to impacts and/or harm depending on how we approach resilience and, critically, how we engage across community boundaries.

While building resilience is a commendable goal, it is an increasingly normative one, which may be at odds with communities that already view themselves as resilient (Soubry and Sherren, 2022). In many fisheries, research is revealing that some fishers see themselves as able to cope and adapt to climate change and may put less perceived risk on climate change compared to other future threats (Johnson *et al.*, 2014; Maltby *et al.*, 2021; Nelson *et al.*, 2023; Runnebaum *et al.*, 2023). Understanding the context dependency of resilience—how definitions can vary with stakeholders and communities—is necessary to avoid top-down rigidity, superiority during engagement, and inappropriate strategies that may lead to further harm or inequities. Failure to incorporate community perspectives of resilience may also perpetuate political and economic interests that aim to retain the "status quo" rather than allow for transformative change and account for community needs (Soubry and Sherren, 2022). Sensitivity to community perspectives of their own resilience is also important for developing appropriate metrics and methodologies. It is increasingly common to use "checklists" and assessments to see whether communities conform or not to predefined notions of what constitutes resilience. This may lead to assessments indicating communities are not resilient when those being "measured" may already feel resilient or have different visions of what components contribute to resilience. Alternatively, communities may be disheartened or turned off by an assessment that they "fail," resulting in less buy-in. In light of this, how are we to proceed as researchers? While co-developing meanings of resilience can help to account for local contexts and understandings, these issues may still remain, and the trade-offs outlined above can still give rise to marginalization or disenfranchisement.

Engaging with communities to build their resilience can often, intentionally or not, lead to framings and narratives putting undue burden on individual and community actions to achieve resilience. This is despite evidence showing that within fisheries systems, many barriers and limits to individual and/or community adaptation and resilience ultimately stem from management and institutional realms (Monirul Islam *et al.*, 2014; Ojea *et al.*, 2017; Holsman *et al.*, 2019; Beckensteiner *et al.*, 2023; Maltby *et al.*, 2023). Working with communities to only focus on their own actions and individual resilience can therefore hold individuals responsible for the state or institutions' failures to provide them with what they need. These failures include processes and decisions by those very institutions and governance systems that often have historically racialized or burdened the most marginalized and disenfranchised (e.g. see commentary by Okafor-Yarwood, 2022, on fisherwomen's resiliency in West Africa). Working to operationalize resilience without acknowledging and/or addressing the root causes of vulnerabilities and inequities moves the focus away from the processes that necessitate resilience in the first place and thus increases the likelihood of ineffective strategies and unjust outcomes (Gill *et al.*, 2023). Attention to balancing between individual and community action vs. broader management and institutional actions is therefore needed in both framing and operationalization of resilience. Valuing and incorporating multiple types of knowledge (e.g. traditional ecological knowledge, local ecological knowledge), perspectives, and disciplines in scientific advice and decision processes surrounding fisheries climate-resilience may help to address some of these issues (St. Martin, 2001; St. Martin *et al.*, 2007; Lima *et al.*, 2017; Gianelli *et al.*, 2021; Murphy *et al.*, 2022).

Fortunately, an increasing emphasis on community engagement has accompanied the proliferation of resilience projects within fisheries science and management. Funders play a role in this; for example, the David Lucile and Packard Foundation ocean grants (rightfully) expect the centring of communities and underrepresented groups within their funded projects (https://www.packard.org/insights/perspectives/centering-people-in-our-commitment-to-a-healthy-ocean2/). In the US, significant new funding from the Bipartisan Infrastructure Law is being directed through multiple government agencies to spur coastal resilience, calling for specific attention to community engagement and considerations (e.g. https://coast.noaa.gov/funding/infrastructure.html).

While such engagement is critically needed, the costs of this engagement and participation for communities must also be recognized. There are risks of over-engagement and stakeholder fatigue (Reed, 2008; Goethel *et al.*, 2019). Fisheries stakeholders are already overstretched with mounting challenges and limited time, capacity, and resources. This problem is acute in the northeast US, where issues such as climate change, range expansions of novel species and contractions of native species, right whale conservation measures, offshore wind developments, aquaculture expansion, a lack of young entrants into fisheries, and lingering COVID-19 pandemic challenges are already demanding significant attention and resources (Pinsky and Fogarty, 2012; Johnson and Mazur, 2018; Methratta *et al.*, 2020; Pinsky *et al.*, 2020; Bisack and Magnusson, 2021; Britsch *et al.*, 2021; NMFS, 2021). Multiple projects seeking answers to often very similar resilience questions in the same communities can lead to further fatigue and overburdening of participants. These problems are compounded by often a perceived lack of tangible benefits back to those who participate. Municipalities and community planning organizations are likely also managing limited resources to implement resiliency planning across other issues in addition to fisheries (e.g. Vicarelli *et al.*, 2021). Climate resilience framings and implementation therefore not only need to account for the wider challenges that will affect the broader resilience of communities but must also consider *how* best to engage communities within these processes.

Progressing climate resilient fisheries in research and practice

In light of the above-described challenges, we suggest three overarching recommendations and considerations for resilience researchers and practitioners working within fisheries contexts. These are: (1) greater transparency and reflexivity among researchers; (2) increasing coordination and communication; and (3) co-developing and co-producing resilience research and strategies. We recognize that these will not always be possible to implement, but hope they might serve as guidance, spark conversations, and build awareness of sticky issues to be mindful of. As outlined in Box 1, we ourselves are navigating these challenges, and use these recommendations as much for ourselves as to inspire others. Where appropriate, we point to lessons or insights from the implementation of these recommendations, but given the ongoing nature of our work not all recommendations have yet been actioned, although we hope to continue making progress towards them.

Greater transparency and reflexivity among researchers

While completely aligning resilience metrics and approaches may not be possible or even desirable, more transparency to reduce confusion and ambiguity is an achievable and worthwhile goal. Researchers should be clear and upfront in how they are defining system scale and bounds (resilience of what, for whom, and for when), stressors (resilience to what), and for their motivations of building resilience (for why). This should also include whether they are approaching resilience as a property/state, process, or outcome (or combination), as we find this to be less defined in this field and a source of particular confusion. These distinctions should be clear in research questions, in interactions with community members and fishers during the research process, and with publications and communications of research outputs. This can allow for a diversity of approaches to suit different communities' needs, capturing the benefits of resilience's vagueness, while promoting clarity to make research be more understandable and therefore actionable.

As mentioned above, this moralizing about defining "resilience of what, to what" has become a resilience research paper cliché. And yet, we ourselves have been guilty of publishing research that does not make these clear distinctions, even while we wag our fingers in our discussion sections. Articulating system bounds and developing shared, clear resilience definitions is not trivial; it can be time-consuming and painful and may be perceived as a frustrating "semantics" exercise that precludes "real" work. But we have reached a point where the semantics are impeding policy progress (Meerow and Newell, 2019; Moser *et al.*, 2019), or, as others have argued, enabling maladaptive policies that go against the wishes of the communities they purport to serve (Soubry and Sherren, 2022). Through laying out these different approaches and challenges, we hope to prompt reflection and greater clarity in the work being conducted by this community going forward.

We also acknowledge that explicitly defining these approaches and bounding our systems is fraught with trade-offs and is inherently value-laden. But we have to move past this, too. Not acknowledging these trade-offs is irresponsible; they still exist even when implicit. Being upfront is critical to informing policy implementation, promoting equity, and minimizing unintended consequences. To the extent possible, researchers faced with potentially controversial trade-offs might take an "honest broker" approach (Pielke Jr, 2007) while co-creating these approaches and bounds with managers and/or community members, laying out the possibilities or pathways that come with specific framings or boundings, to allow policymakers and communities to determine how to proceed given their values and aspirations.

Employing structured approaches to interrogating and critiquing our own methods and assumptions, such as the 5Ws table, would be a good practice at the outset of any resilience research initiative. Another practical measure to help increase transparency and reproducibility in resilience research is using open data approaches. Advances in and community advocacy and support for using open data science tools include simultaneous coding and documentation in script-based languages such as R and Rmarkdown, using version control software like Git, and publishing open-access data. For example, Openscapes provides coaching, training, and community development to support teamwork among researchers conducting data-intensive science (https://openscapes.org/; Lowndes *et al.*, 2017). Several of us as well as other fisheries researchers in the northeast region have been engaged in this training, which has had transformative impact in the way our teams collaborate and conduct and share our research, data, and lab workflows (e.g. Fay *et al.*, 2021)—these practices have also spurred multi-institutional collaborations that link fishing industry data with management impact.

Increasing coordination and communication

Given the tangled web of resilience framings, methods, and targets that exist currently, we see great potential for increased coordination and connection between those active in this field. Coordination and communication within and between groups are necessary: (1) among researchers; (2) between researchers and fisheries managers/policymakers; and (3) between fisheries sectors and broader sectors.

Increasing coordination among researchers can lead to positive progress but can be frequently overlooked. People navigating decisions of ways to frame and undertake resilience research can benefit from sharing and discussing their methods or metrics, research challenges and vulnerabilities, and stories of success, as well as providing avenues to build consensus and develop new collaborations. Greater coordination among researchers also enables understanding into who is doing work with what communities and when, potentially helping to reduce overburdening stakeholders. This can allow for potential "piggy-backing" onto existing projects, for example, combining two surveys with industry members into one or hosting joint community workshops, as well as spurring more thought into when and whether to engage communities in new research activities. Recognizing this need, the authors of this paper are part of the Northeast Climate Resilient Fisheries Network (https://www.neclimateresilientfisheries.com/), set up to encourage connection, collaboration, and coordination among researchers in the region. While in its infancy, the network has provided a useful platform for researchers to engage with each other on challenges and learnings as we work in the resilience space and facilitate future collaborations. Further, sharing unpublished, ongoing projects and initiatives in the region promotes awareness of what communities may be at risk of "too much" engage-

ment. More broadly, the recent UN Ocean Decade FishSCORE2030 programme aims to enable greater connections and coordination among a diversity of stakeholders, including researchers, practitioners, and decision-makers at a global scale (https://oceandecade.org/actions/fisheries-strategies-for-changing-oceans-and-resilient-ecosystems-by-2030/).

We also recognize that researchers and those in the management and policy spheres need greater dialogue and coordination. More communication between researchers and managers can help to better align research to management needs and priorities. For example, in the northeast, fishery management bodies produce research priorities lists, helping to spur research efforts to inform specific needs (ASFMC, 2018; MAFMC, 2022; NEFMC, 2021). Informal groups such as the northeast Social Science for Fisheries Management network and the national Social Scientists in Regional Fisheries Management group also facilitate exchanges between researchers and managers, creating space to not only share research findings but also connect earlier in research conceptualization and design while also building shared understanding of needs and challenges. Connecting these groups can also help to reveal the types and diversity of resilience research and approaches being produced and communicate the need to adapt management systems to better account for SES complexity and resiliency as opposed to continuing to focus on ecological metrics. These conversations can also be initiated through attending and participating in open public meetings, one-on-one conversations, engaging in ongoing management activities, or partnering with boundary-spanning organizations and individuals. Regarding the latter, sustained funding and support for these roles are critically needed to ensure greater alignment of science and management.

Finally, as management must address multi-scalar, sector, and stressor issues, integrated approaches are required that bridge management silos and perspectives to better achieve SES resilience. Increasing communication and coordination between different groups and sectors (e.g. public, third-sector, private, food policy vs. fisheries policy) working on operationalizing and achieving resilience is needed to share capacity and be more strategic about how resilience can be achieved in particular communities (McConney *et al.*, 2015; Gill *et al.*, 2023). Integrated approaches mean setting shared visions, values, and goals and identifying pathways to achieving them, requiring both communication and coordination to be prioritized in these processes (McConney *et al.*, 2015; Stephenson *et al.*, 2019, 2023).

Co-developing and co-producing resilience research and strategies

In addition to increasing coordination among groups, achieving resilience also critically depends on working with communities to co-develop and produce resilience meanings and strategies (Borquez *et al.*, 2017; Cooke *et al.*, 2021; Mills *et al.*, 2022; Pendleton *et al.*, 2023). Such approaches enable community contexts and priorities to be centred and considered, utilizing their local knowledge and lived experiences to ground research and strategies. As Borquez *et al.* (2017) argue, participatory and co-produced approaches can capitalize on the vagueness of resilience definitions due to their ability to be applied flexibly to different contexts. Aligning research and objectives to community needs can also promote factoring in other important considerations like wellbeing and sustainability, which cannot be assumed to be achieved when operationalizing resilience (Coulthard, 2012; Chaigneau *et al.*, 2021; Nelson *et al.*, 2022). This could include a greater deliberative focus on understanding the drivers of inequities communities face and the equity implications and considerations of the trade-offs being made when framing resilience goals and identifying solutions (Walsh, 2018; Gill *et al.*, 2023). Importantly, co-production approaches can also ensure that the ways researchers and decision-makers engage with communities are appropriate for the communities themselves and lead to more tangible outcomes and benefits, helping to reduce stakeholder fatigue.

We acknowledge that co-production can be a complex, messy, and challenging process. It can require considered and intentional thought and care to how (and why) stakeholders are engaged throughout the process (Mach *et al.*, 2020; Breckwoldt *et al.*, 2021; Cooke *et al.*, 2021; Zurba *et al.*, 2022). It depends on researchers actively listening and being ready to adapt their questions, methods, and tools, often outside of their "comfort zone" or traditional mindsets or modes of working (Breckwoldt *et al.*, 2021). In some cases, this may mean utilizing novel approaches that disrupt mainstream resilience approaches and push for more transformative changes (for example, see Reilly-Moman's (2021) work on using concepts of care in resilience for coastal communities) or investing significant time to build trust and relationships. Additionally, allowing stakeholders to choose whether they wish to be part of such endeavours rather than setting expectations for their participation is also important for these types of approaches. Frameworks such as those developed by Key *et al.* (2019) can assist researchers in understanding the continuum of community engagement in their research initiatives. Co-development may also require the willingness or flexibility from funders to allow work plans to develop and change as projects progress.

Engaging with multiple stakeholders can be at times resource-intensive, difficult, and challenged by power dynamics and imbalances, issues that researchers should consider prior to and during engagement. Current short-term funding mechanisms that do not account for the need to build relationships and trust or allow for long-term contracts for continued engagement with communities further challenge co-production approaches. Despite these challenges, co-production can be successful, and it is increasingly necessary to ensure that the ways we frame, build, and operationalize resilience are reflective of community needs and their desired futures. There are increasing numbers of co-developed research projects within the northeast US, in part facilitated through mechanisms such as the NOAA Fisheries northeast Cooperative Research Branch and the National SeaGrant American Lobster Initiative, which emphasize and encourage the need for community engagement and involvement within scientific studies (https://www.fisheries.noaa.gov/new-england-mid-atlantic/science-data/cooperative-research-northeast and https://seagrant.umaine.edu/extension/american-lobster-initiative/). Work such as the American Lobster Fishery Social Indicators Research Project also provides an innovative example of undertaking collaborative work with scientists, community and industry members, and fisheries managers to progress resilience research for the Maine lobster fishery (https://social-oceans-lab.github.io/social-indicators-project/).

Conclusion

We see this as an exciting and meaningful time to be working on climate resilience in fisheries. While the proliferation of resilience approaches and initiatives just in this region comes with challenges, it is heartening to see growing interest in resilience and social-ecological approaches among researchers and practitioners. The challenges we outline above that are more internal to research communities, around harmonizing, and coordinating definitions and methods, are signs of a growing field with much work to be done. The diversity of approaches to fisheries climate resilience in the northeast US is valuable, and we have much to learn from each other's work through greater communication and conversation. Those challenges that represent broader institutional barriers—such as research incentive structures, funding timelines, and limited management capacity to act on qualitative social-ecological information—are widely shared across applied research efforts and may require longer-term, more transformative change in how we conduct research, engage with communities, and manage fisheries. As unprecedented, unequivocal extreme heat events make climate change more apparent and urgent, and acceptance of and demand for holistic, interdisciplinary approaches in fisheries management, research, and funding initiatives becomes more widespread, we do seem to be at or approaching an inflection point with potential for real change and progress. In the meantime, we have benefited from learning more about each other's work and hope that continued coordination can help us overcome some of these challenges and create these opportunities.

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Author contributions

K.M.M., J.G.M and C.L.A: Funding acquisition, Conceptualization, Writing—original draft, Writing—review & editing. H.C., G.F., R.L.S. and L.W. Conceptualization, Writing—review & editing.

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