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A framework for assessing community adaptation to climate change in a fisheries context

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Abstract: There is a rapidly growing body of scholarship on climate change adaptation in diverse contexts globally. Despite this, climate adaptation at the community level has not received adequate conceptual attention, and a limited number of analytical frameworks are available for assessing place-specific adaptations, particularly in a fisheries context. We use conceptual material from social-ecological systems (SES) resilience and human development resilience to build an integrated framework for evaluating community adaptations to climate change in a fisheries setting. The framework defines resilience as the combined result of coping, adapting, and transforming—recognizing resilience as a system's capacity and as a process. This understanding of resilience integrates with the three development resilience concepts of resistance, rootedness, and resourcefulness to develop 'place-based elements' which refer to collective action, institutions, agency, and indigenous and local knowledge systems. The proposed framework can capture a local setting's place-specific attributes relating to the well-being of individuals, households, and communities, and the through integration of SES and human development conceptualizations addresses some of the key critiques of the notion of resilience. We have proposed this framework for application in context-specific environments—including fisheries—as a means of assessing community adaptations.

Keywords: adaptation; climate change; conceptual framework; development; fisheries; place-based elements; resilience

1. Introduction

Fisheries and associated activities support millions of livelihoods and contribute to the creation of food security and to the wellbeing of coastal, freshwater systems and beyond. More than 400 million people globally, for example, critically depend on fish for their food security [1], and fisheries alone supply three billion people with almost 20 percent of their average [per] capita intake of animal protein [2: 452]. Globally, more than 850 million people live within 100 km of the coast and are being impacted by changing coastal systems [3]. Fisheries-dependent communities are distinct environments that maintain unique activities, cultures, and governance structures to face environmental and climate change [4]. People have always taken autonomous actions to adapt to change [5]. The meaning of the term "adaptation" in the context of climate change has evolved over the past decade [6], and adaptation research has grown rapidly with the idea that extensive preparedness is needed to manage climate-related risks, especially with respect to vulnerable fishing populations [7].

Combined with other factors that have already had profound consequences on socio-economically vulnerable populations [8], climate change impacts affect communities in an integrated fashion, increase the complexity of efforts to identify and understand adaptation [9, 10]. Research has

recently focused attention on the study of vulnerable human societies (for example, small-scale fisheries) in a global environmental change setting, using advancements in resilience thinking, development studies, and vulnerability apporaches, and drawing upon interdisciplinary approaches [11]. The concepts of climate change adaptation and resilience are becoming core concerns in international development with many donors advocating for the mainstreaming of climate change adaptation and resilience into development policy [12-14].

According to the IPCC fifth assessment report [2: 390], few frameworks are available for assessing the characteristics of community adaptation to climate change in terms of identifying which adaptations are needed and assessing the effectiveness of potential adaptation options. The lack of a conceptual framework for assessing community adaptation to climate change limits our ability to systematically analyse cases, build theory, upscale adaptations to the policy level, and answer practical questions including: How can local adaptation initiatives be designed such that they are effective and appropriate in different contexts? What enables or undermines the effectiveness of community adaptations? How can community adaptations effectively link with government policy to address national adaptation plans?

This paper seeks to fill this gap in the literature, developing a conceptual framework for examining community adaptations to social-ecological change with a focus on small-scale fisheries. Specifically, the paper examines how the integration of resilience thinking and development studies could create a better understanding of the implications of social-ecological change and policy development. The paper begins by examining what resilience is and states the two domains used to conceptualize this framework (SES and development studies), and then illustrated the conceptual framework, including definitions of the conceptual elements, characteristics of the framework, and indicators to evaluate community adaptation. Finally, the paper uses multiple case studies to illustrate applications of proposed framework.

2. Notion of resilience and two domains

This paper understands resilience as the combined result of coping, adapting, and transforming in response to a disturbance/change [15-17]. We conceptualise resilience as a function of coping capacity, adaptive capacity, and transformative capacity. The concept of resilience developed independently in diverse fields, such as psychology, engineering, disaster response, and systems ecology; these different applications provide various meanings for the term 'resilience' [13, 18] (Table 1). According to Folke [19: 2], "in resilience thinking, adaptation refers to human actions that sustain development on current pathways." A resilience approach takes advantage of disturbances (or changes) and uses them as opportunities to do "new things, for innovation, and for development" [20: 253]. For greater clarity, scientists have proposed the term "social-ecological resilience" [20, 21]. In the social-ecological systems (SES) domain (what we refer to as the first domain in this paper), resilience is a system's capacity to continually change and adapt while remaining within the same critical thresholds [22].

Table 1: Various definitions of the term 'resilience'

Definition	Key emphasis	Reference
"The capacity of people to learn, share and make use of their knowledge of social and ecological interactions and feedbacks, to deliberately and	The capacity to face SES change.	[23: 8]

effectively engage in shaping adaptive or transformative social-ecological change."		
"The capacity of individuals, communities, and systems to survive, adapt, and grow in the face of stress and shocks, and even transform when conditions require it."	The capacity to face stress and shocks.	[13: 10]
"Resilience is about cultivating the capacity to sustain development in the face of expected and surprising change and diverse pathways of development and potential thresholds between them."	Cultivating the capacity to sustain development.	[19: 1]
"The capacity of a SES to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks. In other words, stay in the same basin of attraction."	The system's property and ability to withstand shocks and rebuild itself.	[24: 6]

As Berkes and Ross [25: 186] note, "the original idea of ecological resilience [26] is derived from complex adaptive systems thinking." An understanding of "complex adaptive SES" helps one better appreciate resilience as a systems property or an emergent property of a system [25]. According to Brand and Jax [21], however, tension exists between the initially defined concept of resilience in ecological literature (the system's ability to bounce back or return to equilibrium following disturbance) and the more recent notion of SES resilience. In contrast, Holling's [26] view of resilience says little about returning to the original state, assuming a constant range of change [22: 6, 27]. Holling's [26] proposes that ecological systems' behavior stems from the interplay between two different system properties: stability and resilience. "[…] there is another property, termed resilience, that is a measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables" [26: 14].

Increasingly, many scholars have identified capacity and agency as important components related to resilience definitions [13, 17, 28-31]. Agency is a central component of SES resilience [28]. According to Brown [13: 6], "resilience is understood not only as a response to change but also as a strategy for building the capacity to deal with and shape the change" which is increasingly applied in both scientific and policy discourse. More recently, resilience thinking has been increasingly adopted by development studies (second domain) to address problems such as climate change, food security, natural disasters, political instability, and economic volatility [13, 17, 32-35]. Scientists provide reasons why such a collaboration between these two domains has been triggered and why this collaboration should persist [32]. The proposed approach developed in this paper is a result of the integration of a wide range of conceptual elements from both domains of resilience, which are SES and development studies.

Baggio et al. [18] identify resilience as not only a boundary object [21] but a bridging concept [36], particularly in the SES field. Thus, the facilitation of discussions about the dynamics of complex systems could provide innovative theoretical and applied insights [18]. Brown [37] though, questions the extent to which the relabeling of existing and conventional approaches such as resilience embraces true innovation. Nevertheless, Brand and Jax [21] recognize that the redefinition of resilience (conceptual vagueness) could help foster communication across disciplines as well as between science and practice.

3. Conceptual framework for assessing community adaptations

The proposed framework integrates and advances the work primarily of two key international development scholars, who use the concept of resilience to study human development in the context of SES change. First, this framework uses Christophe Bene's three dimensions of resilience (3D), which considers resilience to be the combined result of coping, adapting, and transforming [17]. Second, this framework uses Katrina Brown's 3Rs of resilience, which refers to resistance, rootedness, and resourcefulness [13]. The framework's three key components are 3D, the 3Rs, and place-based elements (Figure 1). (Please refer to Table 2 for definitions of the conceptual framework.)

First, Bene et al. [17] identified (absorptive) coping capacity, adaptive capacity, and transformative capacity as the three critical features of resilience—the three dimensions, or 3D. Resilience emerges as a combined result of 3D capacities, leading to persistence, incremental adjustments, or transformational responses, respectively [16, 17, 35]. Adaptive capacity and transformative capacities are key emphases in social-ecological resilience literature [17, 20, 27]. Bene et al. [17], Bahadur et al. [35], and Brown [13] are explicit about coping capacity being a key aspect of resilience. Brown [13] and Bahadur et al. [35] also recognize three dimensions of resilience; this conceptualization has already been applied in a human development context [34]. Further, Bene explicitly discusses how resilience functions as a process in a human development setting [16]. **Second**, Brown [13] argues that a resilience-centered approach towards development studies might radically transform (bounce forward)—rather than "bounce back"—a version of resilience and responses to global problems [19]. By combining individual agency with adaptive capacity and a systems perspective, she re-conceptualises a vision of resilience with the notion of "everyday forms of resilience" to contribute a new development agenda with three core components: resistance, rootedness, and resourcefulness [13] (Table 2). **Third**, this place-specific framework captures unique attributes of a local setting that relates to the well-being of individuals, households, and communities. The core of the adaptation process represents a network of four elements (collective action, institutions, agency, and indigenous and local knowledge-ILK) derived from the 3Rs and related intimately to the notion of resilience. This paper calls such a network "place-based elements."

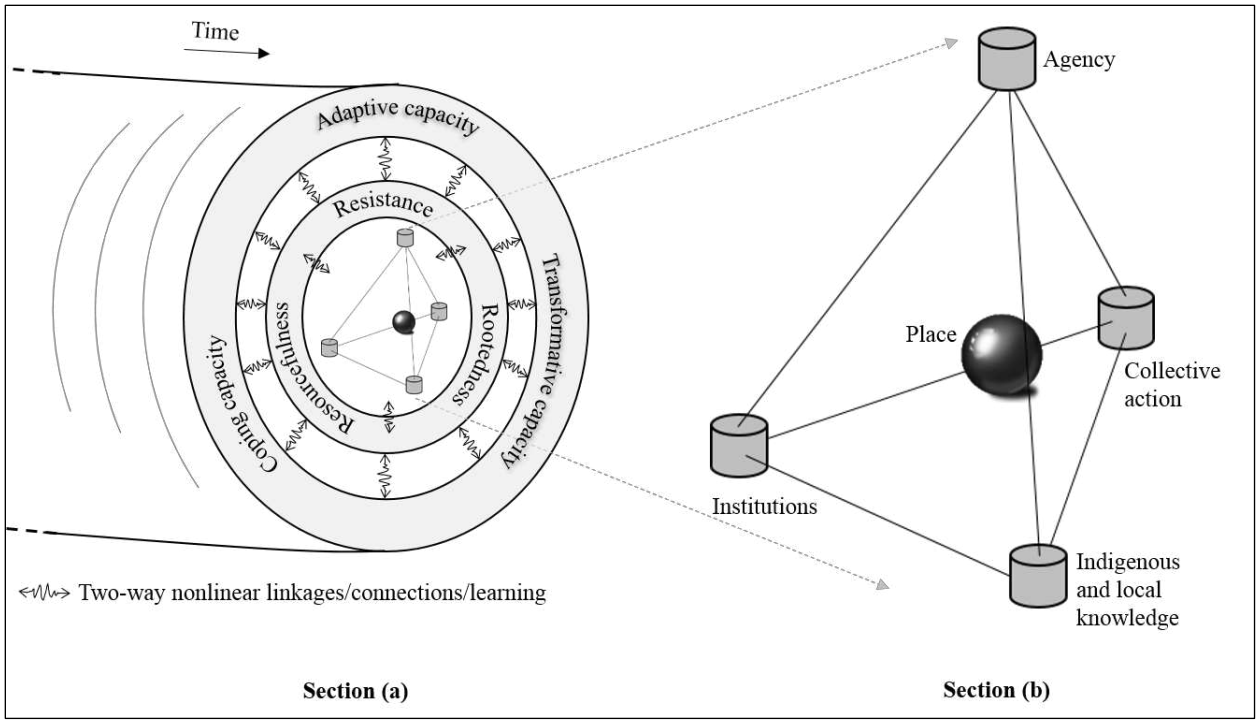

Figure 1: Conceptual framework (building on Brown [13] and Bene [17])
Section (a) shows a cross-section of the tube-shaped system that grows forward in the face of SES change (for example, climate change). The cross-section represents the framework's key components, which are place-based elements, 3Rs, and 3D capacities. All three components are connected through two-way nonlinear linkages. Section (b) illustrates the network of place-based elements located in the center of the framework. The zoomed-in version shows how such conceptual elements are positioned around the 'place.'

Place-based elements and the 3Rs constantly determine and cordinate the 3D capacities of resilience through multiple nonlinear linkages (connections) to face the social-ecological systems (SES) change (Figure 1). This two-way link between 3Ds and 3Rs, as well as the network of place-based elements and the 3Rs, reflects their interdependence on each other. Such linkages represent three key aspects of the system. First, continuous learning from past events and slight failure [38] returns to the place-based elements to improve their capacity—social-ecological learning [38-40]. Learning can take place within the network of place-based elements (for example, community institutions such as cooperatives). Also, such interactions can be negative and could disrupt learning (for example, the accumulation of vulnerability when community cooperatives are malfunctioning) [41]. Second, interconnectedness among such elements creates feedback across different levels and scales that change the dynamics and complexities of SES [42, 43]. This aspect includes an understanding of ecosystem processes and dynamics, and ecological knowledge helps tune human development with biosphere capacities [19]. Third, together they trigger a self- or re-organization as a means of adapting to changing conditions [25]. For instance, a farmer-initiated zonal crop calendar system that manages small-scale shrimp aquaculture in Sri Lanka is an effective adaptation approach toward confronting the outbreak of shrimp diseases [44-46].

Table 2: Definitions of conceptual framework

Components of the framework	Definition	Reference

Coping capacity	Coping capacity is actors' ability to draw on available skills, resources, and experiences as immediate responses for managing adverse stresses or shocks and maintaining persistence. Coping refers to a set of cognitive or behavioral strategies an individual or system uses to manage the demands of disturbances by using coping capacities.	[8, 47: 91, 48, 49]
Adaptive capacity	Adaptive capacity is "the capacity to make adjustments and incremental changes in anticipation of or in response to change…" [35: 11]. Adaptation can be planned, spontaneous, reactive, or anticipatory-driven; regardless, it is a manifestation of social adaptive capacity, as adaptive capacity consists of pre-conditions necessary for adaptation.	[13, 35, 50, 51]
Transformative capacity	Transformative capacity is a system's ability to create a new system with new fundamental characteristics when the existing system is untenable. Transformation, as Bahadur et al. [35: 13] describe it, is the "radical action" of resilience that creates change in power structures and social and economic behaviors and that redefines drivers of risk and vulnerability regardless of specific shocks. Transformation goes beyond incremental adjustments that maintain the status quo; it brings more fundamental change to the social-ecological systems than does adaptation.	[24, 35, 52]
Resistance	Brown [13: 194] defines resistance as the "ability and capacity of people to withstand external forces and to shape their own strategies." Here, resistance indicates self-determination, strength, agency, and power. Brown establishes the direct linkages among resilience, agency, power, and resistance based on empirical evidence—resistance as power or the capacity to resist.	[13]
Rootedness	Rootedness recognizes the situated nature of resilience and the importance of culture and place, including the focus on identity and attachment. Rootedness is firmly associated with people, place, or space; cultural practices; social networks; and a wide range of affective ties to "home". Empirical evidence shows that attachment to place, and place-rooted identity, is a determinant of resilience, adaptation, and transformation.	[13, 53, 54]
Resourcefulness	Resourcefulness is about the resources upon which people can draw and their capacity to use these resources at the right time and in the right way to harness the resources and human capacity together [13]. This understanding emphasizes the ability to collectively deal with difficult situations that reflect human agency and capabilities, opportunities, and innovation. This framing links resourcefulness with a "sense of place being transformed into a resource in times of need" [55] and "is about bouncing back, adapting and transforming" [13: 198].	[13, 55]
Collective action	Refers to action taken together by a group of two or more people to meet a common desired objective.	[56, 57]
Institutions	Refers to local organizations formed by the society to facilitate collective action that meets a local goal (for example, community cooperatives and associations).	[56, 58, 59]
Agency	A general understanding of agency is the individual's capacity to act independently in making his or her own decisions, while McLaughlin and Dietz [60: 105] provide a more specific definition of agency as "capacity of individuals and corporate actors, with the diverse cultural meanings that they espouse, to play an independent casual role in history."	[28, 60]
Indigenous and local knowledge systems	Refers to the co-evolving cumulative body of knowledge (including observations, experience, lessons, and skills) belonging to a specific human-environment system (or place) and handed down through generations by cultural transmission; reflects Indigenous and/or local people's cultural identity.	[23, 61]
Place	Refers to a social and physical space that has place attachments to individuals (or cultural groups) and processors. Attachment to the place is understood as	[13, 62, 63]

	the bonding that occurs between people and their meaningful environments [47]. The place is an essential consideration of the idea of rootedness.	
Learning	Refers to the social learning, which itself refers to "collective action and reflection that occurs among different individuals and groups as they work to improve the management of human-environment interactions."	[64: 4]
Feedback	"The secondery effects of a direct effect of one variable on another, they cause a change in the magnitude of that effect. A positive feedback enhances the effect; a negative feedback diminishes it."	[13: 206]

We present the characteristics and indicators of the proposed conceptual framework to assess the ways in which communities adapt to change (Table 3). Examination of such characteristics will allow for a better understanding of community adaptations as it broadly evaluates the effectiveness of the process of adaptation and its needs that are unique to a fisheries context using a range of place-based elements. Populations respond to change individually as well as collectively. In addition, the framework's characteristics work together as an interconnected SES. For instance, collective action, local institutions, and learning and knowledge systems are process integrated with respect to adaptation strategies, such as the implementation of community-based resource management systems in small-scale fisheries [65]. However, for evaluation purposes, we break down a system into analysable pieces. As shown in Table 3, the indicators and measures of each characteristic will allow for both quantitative and qualitative outcomes (for example, research findings, results, and recommendations) that feed adaptation policy to link community adaptations with government policies. Such outcomes will support the effective implementation of national adaptation plans and the development of community-sensitive adaptation programs.

Table 3: Characteristics of the framework for assessing adaptation to change

Characteristic	Measures and indicators	Key methods	References
Place	Measured by recognising related context-specific data, such as natural capital, vulnerability, and meaningful attachments to the place. Indicators: 1) number of species available for fishing, 2) level of fishery resource availability, 3) level of vulnerabilities for fishing operations such as climatic uncertainties, 4) changes in livelihood activities relative to place (for example, hunting to fishing), and 5) culture, including belief systems and perceptions that link to the place.	Participant observation, interviews	[66]; [67]; [68]; [69]; [70, 71]; [72]
Human agency	Measured using fishers' individual ownership/access to resources, application of diversity as a strategy, and use of technology. Indicators: 1) ownership of or access to fishing gear (for example, number of assets such as boats, canoes, nets, engines), 2) fishing gear diversity (number of different items of fishing gear used), 3) occupational mobility (number of different fishing operations practiced), 4) occupational multiplicity (total number of jobs in the household), 5) access to credit (loans) and insurance, 6) use of technological advancements, and 7) perceptions, equality, and gender roles.	Questionnaire/ survey, participant observation	[73];[74, 75]; [76-81]
Collective action and collaboration	Measured by examining the level of sharing resources, information, and social networks. Indicators: 1) sharing of fish, 2) sharing of fishing gear, 3) spreading of weather information, 4) sharing of information related to fishing operations (for example, fish market prices, production quotas, and fishing techniques/management practices), and 5) social networks. Application of Ostrom's design principles [56] allows for further assessment.	Participant observation, interviews	[56]; [82]; [45]; [41]

Institutions	Measured by examining local institutions such as fishers' cooperatives, fish plants, and other local institutions support local fisheries. Indicators: 1) the aim of institutions (for example, contribution to local fishing activities), 2) ownership (for example, communal, local/indigenous, private), 3) decision-making power, 4) existence of partnerships, and 5) leadership and influential individuals.	Key informant interviews, observations, secondary data	[58]; [83]; [47, 56, 58, 59, 81, 84]
Indigenous and local knowledge systems	Measured examining the use of Indigenous and/or local knowledge in fisheries SES. Indicators: 1) application of such knowledge, 2) the co-production of knowledge (combining indigenous knowledge with other kinds of knowledge such as local knowledge and/or traditional knowledge), and 3) loss of local/Indigenous/traditional knowledge throughout the SES change.	Interviews, observations	[61]; [69, 85-87]; [88-91]
Learning and feedback	Measured examining the aspects related to learning-by-doing, opportunities to learning, linkages, and philosophical worldviews. Indicators: 1) extent of the practice of learning-by-doing in fishing way of life, 2) the number of opportunities for learning, 3) the ways in which local philosophical worldviews are compatible with adaptive thinking, and 4) existence of two-way local and government linkages within the multi-level institutional structure.	Interviews, observations, secondary data	[81, 92]; [93]

The changing conditions in place-based elements can influence the 3D capacities, and vice versa, which may itself influence the SES options of persistent incremental adjustments or transformational responses. This interconnectedness implies that such elements have the ability to control or partly govern the trajectories (human development or SES) under complex and dynamic human-environment conditions. Both 3D capacities and the 3Rs—including place-based elements—together determine system trajectories (Figure 2). For instance, with the impacts of climate change, it is important to examine the adaptations of remote Arctic communities, as each community has unique conditions such as natural environment, capacities (local institutions, knowledge systems, Inuit skills), resources (multiple species for food), vulnerabilities (changes in sea ice conditions), and government policies affecting those communities [23]. An integrated framework will provide useful inputs for adaptation policy for decision making, as it captures insights related to resilience thinking as well as development studies. The practices of coping, adapting, or transforming—depending on the selected SES—are adaptation policy options to consider at various levels, from household to global.

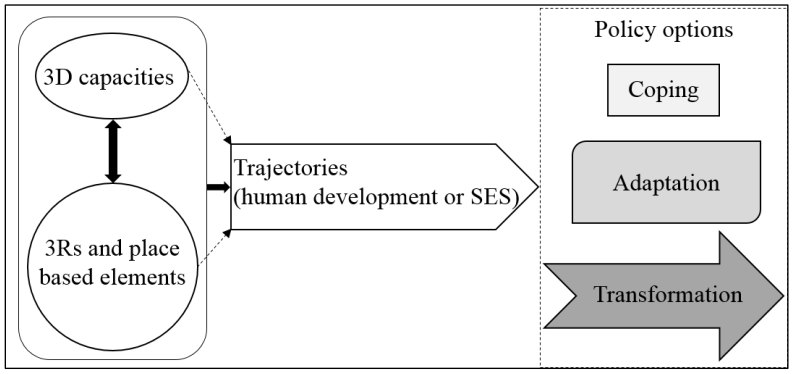

Figure 2: Trajectories and policy options

The suggested conceptual framework supports the assessment of climate adaptation and policy development for a few key reasons. First, the policy directly manages humans, not the climate, environment, or natural resources. Thus, human development aspects are key to assessing environment and climate adaptation policies. Second, some irreducible uncertainty always exists in any policy-level decision-making context. Thus, it is not advisable to assess policy goals using stability-oriented assumptions rather than resilience-oriented approaches [13]. Third, the widespread availability of information and technological advancements makes people overconfident about their future adaptations and leads them to disregard vital aspects required in policies [19]. Place-based considerations are among these missing aspects of the effective evaluation of adaptations, particularly in complex and highly uncertain SES such as fisheries.

The novelty of the approach lies in the use of resilience thinking and systemic perspectives to examine community adaptations aimed at a fisheries setting, and the integration of development and SES resilience domains, which collectviely addresses some of the prevailing key critiques in the notion of resilience. Multiple critiques of resilience are available in various disciplines, including development studies [13, 15, 17], and Table 4 illustrates how the proposed integration of development and SES domains addresses some of these critiques.

Table 4: Addressing key critiques of resilience thinking using the proposed framework

Key critiques of resilience thinking	How integration (3D-Rs) addresses these critiques
Field is dominated by a small network of scholars—"discursive dominance."	The framework is a combination of two schools of thought: resilience thinking and development studies [32]. This integration will enable the connections between the two domains to meet challenges related to food security, poverty, and environment and human health. Resilience is already considered both a boundary and a bridging object [18]. This conceptual vagueness allows resilience to blend across disciplines and create more useful frameworks for human development [94].
Fails to account for power, politics, and agency.	The central idea of 3D framing is capacity. Resourcefulness refers to the use of such capacities with the human agency to govern resources. Rootedness refers to the power of place and identity and the strengths associated with local knowledge. Power-related aspects can be explicitly examined by including resistance as an element of resilience. Power, politics, and agency are central to the suggested 3D-R integrated framework [13, 17].
Vague and normative; for example, resilience is considered an antonym of vulnerability. A large body of literature does not clearly distinguish resilience and adaptive capacity.	In our framing, resilience is not seen as an "outcome" but as a "capacity" surrounded by agency and power that reflects the "ability" of humans to make decisions involving positive or negative outcomes in their own lives. First, this human "ability" creates the critical distinction between resilience and vulnerability. Bene et al. [15: 125] describe vulnerability "as a passive condition that results from people's sensitivity and exposure to shocks and their lack of capacity that prevents them from managing adverse events" and state that "resilience is an active ability to develop and implement strategies/responses in an attempt to counter these vulnerability conditions." Thus, resilience is not merely the inverse of vulnerability. Second, this integrated framework of resilience reflects adaptive capacity as one important element of resilience among many others—explicitly distinguishing adaptive capacity from resilience.
Focus on maintaining the status quo.	Resilience as conceptualized in the framework involves coping (absorbing), adapting, and transforming, challenging the concept of resilience as only maintaining the status quo. In the new understanding, resilience reflects stability, flexibility, and transformational change. The status quo is only one aspect of resilience (bouncing-back version), and the

	suggested framework caters to a border response to global change aiming at transformational change (a bouncing-forward version of resilience).
A resilience approach underplays the internal or endogenous drivers and focuses on a system disturbed by external or exogenous drivers.	Agency, institutions, local knowledge, and collective action are place-based elements of the integrated framework. This network of elements, together with 3D capacities, can capture a broad range of endogenous and exogenous drivers that are important to the understanding of SES change, as well as to better contributing to human development.

4. Case study application of the framework

This section brings together different case study examples from Sri Lanka, Kenya, Bangladesh, India, South East Asia, and the Canadian Arctic to illustrate the applications of each framework characteristic (Table 5). Case studies were purposively selected to best explain the particular characteristic.

Table 5: The extent to which cases address the proposed framework characteristics

Case	Description of methods			Key emphasis on the characteristics of the framework					
	Approach	Data collection methods	Analysis	Place	Human agency	Collective action and collaboration	Institutions	ILK systems	Learning and feedback
Sri Lanka **[44]**	Qualitative	Participant observations, interviews, focus groups	Content analysis, descriptive statistics, institutional mapping	√	X	√	√	√	X
Kenya **[73]**	Quantitative	Household surveys, interviews	Statistical analysis, linear mixed models	X	√	X	X	X	X
Bangladesh **[95]**	Qualitative	Secondary data	Descriptive statistics, flow diagrams, content analysis	X	X	√	√	X	X
India **[96]**	Mixed	Interviews, focus groups, household surveys	Descriptive statistics, quotes, content analysis	√	√	X	√	√	X
South East Asia **[97]**	Qualitative	Workshops, focus groups	Observations, documentation, validation, and categorization	X	X	X	X	√	√
Canadian Arctic **[93]**	Qualitative	Secondary data	Descriptive statistics, network diagrams, content analysis	X	X	X	√	√	√

4.1 Place

The case from northwestern Sri Lanka examines how shrimp farmers adapt to the challenges of shrimp disease and climate change by managing their lagoon system [44, 98]. Using a qualitative narrative approach, this study captures how small-scale shrimp farmers collectively managed their brackish water source, which is a combined system of three lagoons (Puttalam, Mundel, and Chilaw) and a human-made canal named ‘Dutch canal’ that connects all three lagoons. Shrimp

farmers rely on this common body of water to get salty water for shrimp farming ponds as well as to release used aquaculture water back into the lagoon system. This practice allows shrimp disease to spread throughout the lagoon system and shrimp farms. Changing climate impacts such as droughts, unusual monsoon patterns, and floods, as well as unexpected temperature fluctuations and changes in lagoon salinity, increase the complexities surrounding shrimp disease control. Thus, climate change becomes a threat to shrimp aquaculture management. This shrimp aquaculture is a small-scale, environmentally friendly operation (for example, protecting a mangrove forest) that does not move from place to place, unlike large-scale commercial operations. This study shows the importance of place to local livelihoods (i.e., shrimp disease spreading along the lagoon system) and place attachments (i.e., managing the lagoon system and protecting the environment) in adaptations to climate change.

4.2 Human agency

Cinner et al. [73] study the changes in the adaptive capacity of Kenyan fishing communities. Using a qualitative approach, they examine the changes, over time, in nine indicators of communities' adaptive capacity with respect to climate-change-related change. Such indicators are: access to credit, occupational mobility, occupational multiplicity, social capital, material style of life, gear diversity, community infrastructure, trust, and human agency. For example, 'Access to credit' is measured according to whether the respondent feels they can access credit through formal institutions or informal means such as family and friends. 'Occupational mobility' is measured in terms of the respondent's experience with job changes, within the past five years, that led to an occupation they preferred (vertical occupational mobility). 'Occupational multiplicity' is the total number of jobs in the household. 'Social capital' is measured as the total number of community groups to which the respondent belongs. This study shows various capacities of individual fishers that help them build adaptive capacity at a community level to face the implications of change, including climate change.

4.3 Collective action and collaboration

The case from southwest Bangladesh examines collective action and collaborations surrounding community-based climate change adaptation strategies in integrated prawn-fish-rice farming [95]. Using a qualitative approach, this study explores how prawn-fish-rice culture systems adapt to climate impacts such as floods, drought, sea-level rise, and sea surface temperature. Locals respond to climate change impacts using a bottom-up community-based adaptation approach that employs collective action and collaboration (for example, the promotion of livelihood diversification, floating vegetable gardens, and duck rearing through community-based organizations to increase community adaptive capacities). The translocation of prawn-fish-rice farming from coast to inland is another crucial adaptation strategy implemented using the community-based approach and collaborations among industry stakeholders. This study shows how collaborations and collective action surrounding community-based initiatives support climate adaptation in integrated prawn-fish-rice culture systems.

4.4 Institutions

The case from south India's Pulicat lagoon provides insights into how local fisheries institutions are involved in adaptations to environmental and climate change [96]. Using mixed methods, this

study illustrates how a village fisheries society coordinates the management of the lagoon system. The fishing society for the Pulicat lagoon reinforces the 'Padu' system, which regulates lagoon access for fishing and fishing methods. The Padu system gives priority to members of the fishing society in undertaking specific fishing activities in certain fishing spots in the lagoon [99]. The Padu system is a context-specific resource management system in small-scale fisheries that helps address local culture and power dynamics, such as the caste system. The Padu system involves making and implementing community-level rules, and it requires majority consent (for example, a lottery system). Most recorded Padu systems in South Asia (for example, stake net fishery, Sri Lanka [100, 101]; southern Tamil Nadu, India [102]) are managed by local institutions; such institutions play a significant role in managing livelihood vulnerability and adaptation to environmental and climate change [96].

4.5 Indigenous and local knowledge systems

The case from South East Asian small island communities examines the process of integrating local and indigenous knowledge with science for climate change adaptation and disaster risk reduction [97]. This study presents the process of combining local and indigenous knowledge of climate change in coastal fishing communities in Indonesia, the Philippines, and Timor-Leste. This process includes observation, documentation, and validation with the participation of local people, and lets them select potential integration with scientific knowledge (for example, consideration of the sky and the environment as a means of predicting strong winds and high waves in Indonesian coastal communities). By promoting knowledge integration and the application of multiple knowledge, systems increase local and indigenous people's resilience to climate change impacts and ability to adapt to the risk of disaster. For instance, selected local and indigenous knowledge can be disseminated among policymakers to support high-level climate adaptation decision making. This study shows how different knowledge systems can collectively support adaptations to climate change impacts.

4.6 Learning and feedback

The case from the three Canadian Arctic coastal communities examines the role of knowledge co-production as a mechanism that enables learning and adapting [93]. Using a qualitative approach, this study draws on narwhal co-management in Arctic Bay, beluga co-management in Husky Lakes, and char co-management in the Western Arctic to understand how knowledge co-production enables learning and adaptation to change, including climate change. In the long term, knowledge co-production within a co-management context leads to positive social and ecological outcomes, while crises (or small errors) play an important role in catalyzing the production of knowledge necessary for implementing change. For instance, one of the policy implications of the char case study is to recognize crises as windows of opportunity for rethinking knowledge and the learning processes for adaptation. This study shows how learning at the community level and sharing such learnings with co-management institutions (i.e., feedback) can influence the long-term climate adaptation process.

Given the concise narratives of multiple case studies, the proposed framework can create additional insights into community adaptations [2]. For instance, the framework provides insights

into the situated nature of small-scale shrimp aquaculture in the Sri Lankan case study. Here, rootedness can refer to how firmly the shrimp farmers are associated with the lagoon system (place), the social value system (protect mangrove), the community-based institutions, and the maintenance of a wide range of ties to the community. In part, this rootedness allows the shrimp farmers to face and live with the changing climate and shrimp disease conditions. Resourcefulness provides insights into accessible natural resources in the community. For instance, in the Indian case study, and sharing fishing sites and fishing days using a rotational system in stake net fishery in Negombo estuary Sri Lanka [101] manages fishers' access to lagoon fishing spots. These resource management systems are implemented by local institutions (i.e., the village fishing society) with the guidance of government institutions. Shrimp farmers' worldviews (for example, a belief in collective action), along with their capabilities (including local knowledge systems and institutions), are key to the sustainable management of fisheries resources. In the Kenyan case study, resistance provides insights into how fishers use nine human-agency-related capacities (for example, access to credit, occupational mobility, occupational multiplicity, and social capital) to withstand change and shape their strategies against vulnerabilities of climate change impacts. None of the selected cases can address the associated nature of framework characteristics (Table 5). Application of the proposed framework can provide additional insights into how such framework characteristics are interconnected for better outputs in terms of climate change adaptation.

Place-based elements and their insights into the 3Rs reflect systems' 3D capacities. This allows us to understand community adaptation pathways. For instance, in Kenyan fishing communities, reliance on short-term credit/loans to continue fishing helps individuals cope with short-term challenges. Bangladesh's prawn-fish-rice systems provide examples of such adaptations as livelihood diversification, floating vegetable gardens, and duck rearing to face climatic challenges like floods. The introduction of effective resource management systems such as the Padu system (India) or the translocation of prawn-fish-rice farming (Bangladesh) can make fundamental changes in these small-scale fisheries systems (transformation).

5. Discussion and conclusions

This paper proposes a conceptual framework for evaluating community adaptations to change, including climate change in a fisheries setting. This framework is built primarily on Bene's and Brown's work on development resilience. The notion of resilience is not a single concept, but rather a cluster of multifaceted concepts that are lightly organized and sometimes overlapping [18, 21]. The paper uses this characteristic of resilience to develop an integrated framework that represents a wide range of conceptual elements from the domains of human development and resilience thinking. The paper recognizes resilience as a combined result of coping, adapting, and transforming aimed at three capacities (coping, adaptive, and transformative) of resilience—the three dimensions (3D) [13, 15, 17, 35]. This understanding is different from the usual definition of resilience as stated by Walker et al. [24: 6]. However, building resilience requires the strengthening of these three components at multiple levels—coping (absorptive) resilience, adaptive resilience, and transformative resilience [16]. Here, resilience is seen as a "capacity" of a system and as a process.

We proposed this framework for application in context-specific environments, including fisheries, to assess community adaptations to change. The purpose of the integrated framework is to create a better understanding of the SES change and assess adaptations for effective policy development. Basic characteristics of the integrated framework are: i) consists of 3D capacities, 3Rs, and place-based elements [8, 13, 16]; ii) pays attention to feedback and connections among capacities and place-based elements [103]; iii) recognises resilience as a process and not an outcome [17]; and iv) is concerned with trajectories of change that eventually lead to policy development [32]. The strengths of this framework are: a) flexibility and adaptability for use in both SES resilience and human development domains to achieve specific (inter)disciplinary goals; b) addresses most of the prevailing critiques of the previous (bounce back) version of resilience, including conceptual aspects undermined in previous versions of resilience thinking (for example, power dynamics, politics, and agency); c) integrates two domains to open doors for collaboration across disciplines, such as resource governance, anthropology, development, vulnerability, and adaptation; and d) provides information for policy development for adaptive governance considering complex human-environment interactions, uncertainties, and processes. This framework can be further developed for specific applications, incorporating specifics related to levels, scale, and "desired state" [104, 105].

The proposed framework provided insights into three main areas of adaptation. **First**, how can local adaptation initiatives be designed (for example, collectively using the participatory approach) and facilitated (for example, through local institutions) so that they are effective and appropriate in unique community environments? Detailed consideration of place-based elements is critical for designing adaptation initiatives for communities (i.e., place, human agency, collective action and collaboration, institutions, Indigenous and local knowledge systems, and learning and feedback). **Second**, what enables (for example, social media and local institutions) and undermines (for example, loss of local knowledge or inappropriate technology) the effectiveness of community adaptations? Identification of enabling and undermining factors for adaptation initiatives is important for ensuring successful community adaptations [106, 107]. **Third**, how can community adaptations be effectively linked with government policy to address national adaptation plans? For instance, local institutions and their leadership play a central role in linking the community and the government. Overall, this proposed framework can create a link between concepts (such as resilience and adaptation) and real-world applications (such as the case examples from Sri Lanka/Kenya/Bangladesh/India/South East Asia/the Canadian Arctic).

Why is this proposed integrated conceptual framework important to the advancement of adaptation research? **First**, a combination of various kinds of knowledge domains will improve adaptive capacity by increasing the range of information available for knowledge co-production [108, 109]. The importance of fostering the complementarity of different knowledge systems is explicitly recognized as one of the key methods of building resilience [109]. **Second**, as Folke [19] argues, human-centered sustainable development actions can benefit from the guidance of development approaches (such as climate adaptation) that seek a better understanding of complex human-environment interactions. **Third**, collaboration is a timely approach for two selected reasons: 1) increasingly, in certain human development arenas, "use resilience as a unit of analysis" has become a condition for applying for project financing [32], and 2) collaboration has been triggered with conceptual developments that provide the intellectual tools required for effective integration

(for example, 3D and the 3Rs) to create the timely atmosphere; conceptual elements missing from the SES literature are featured in the human development literature [13, 15, 19, 32, 110]. **Finally**, essentially, this collaboration helps address aspects related to key critiques of resilience thinking.

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