CHAPTER 26

The impact of environmental change on small-scale fishing communities: moving beyond adaptive capacity to community response

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Chapter Outline

26.1 Introduction

Already threatened by overfishing, habitat loss, and inadequate systems of governance [1], the shocks and stressors associated with global environmental change represent a significant and daunting challenge for fishing communities worldwide [2–4]. Previous research on the

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responses of fisheries to climate change has focused on the geographic shifts of industrial fisheries in response to warming waters and changes in the abundance and distribution of target species. For example, industrial fisheries have displayed movements of 10s−1000s of kilometers in avoidance of warming waters [5−8].

Yet small-scale fisheries (SSFs), which employ over 90% of the world's capture fishers and provide livelihoods and food security for many millions of individuals around the globe [9], may be even more vulnerable to environmental change than their industrial counterparts (see special issue of Marine Policy, Volume 88, Feb 2018). Most SSFs lack the capacity for significant geographic redistribution, as they utilize small vessels with limited range and rely upon geographic features that are accessible by foot or small vessels (i.e., reefs, beaches, estuaries, etc.) within close proximity to the coastal communities they inhabit. Furthermore, SSFs in island, low-elevation, and ice-edge systems are disproportionately vulnerable to sea-level rise [10], which threatens to inundate coastal habitats as well as cause significant (if not catastrophic) damage to local homes and infrastructure. Climate adaptation strategies have been proposed for industrial fisheries [3], but adaptation of SSFs to climate change and other environmental stressors has received substantially less research attention (Marine Policy, Volume 88, Feb 2018). Even within the scholarship surrounding adaptation, much of the work has focused on hypothetical adaptive capacity indices [11], rather than the observed response of SSF communities to climate variability and/or change. Here, following a brief review of resilience and adaptive capacity theory (Section 26.2), we present an analytical framework for assessing observable responses and mediating attributes of SSF communities to environmental stressors (Section 26.3). We intentionally avoid abstract indices of resilience or adaptive capacity [11] and focus upon how communities empirically respond to those environmental perturbations whose frequency and intensity is expected to increase alongside climate change.

26.2 Resilience and adaptive capacity: theory and limitations

Social−ecological systems (SES), including SSFs, are comprised of complex networks of interactions. The idea of resilience is central to understanding the complexities of such systems and the human and natural communities which comprise them. Resilience has its origins in ecological theory, which focused on the ability of an ecological system to absorb change and disturbance while maintaining interactions and structures found within the system [12]. In the years since its introduction, the concept of resilience has expanded to include human contexts [13,14] and evolved to encompass many definitions. While social scientists and development scholars have adopted resilience theory to describe the ability of human communities to "withstand external shocks to their social infrastructure, such as environmental variability or social, economic, and political upheaval" [13], more recently

SES scholars have expanded the framework to investigate human–environment interactions and the ability of coupled systems to persist and develop with change [15,16].

Assessment of adaptive capacity, or "the ability of systems, institutions, humans, and other organisms to adjust to potential damage, take advantage of opportunities, or to respond to the consequences" [17] relies heavily on concepts from resilience theory [11]. The main bridging concept that integrates adaptive capacity and resilience is vulnerability [18,19], which in the social context can be broken down further into components of exposure to perturbations, the sensitivity of the system to this exposure, and a system's capacity to adapt [20]. Seminal theoretical contributions to the field have described the dimensions, indicators [21], and/or determinants [22] of adaptive capacity, emphasizing factors such as resource availability and distribution, human and social capital (i.e., education or property rights), technology availability, decision-making authority or agency [23], and institutional design [24]. Most recently, Cinner et al. [25] synthesized much of this work to outline five interlinked domains (assets, flexibility, social organization, learning, and agency) across which investment and efforts may be distributed in order to build adaptive capacity of tropical coastal communities.

Ultimately the utility of such frameworks and concepts is determined by the context of scale [11]. Studies conducted at broad spatial scale may be helpful in developing generalizable approaches to address problems in regions where empirical studies are scarce. For example, Berkes and Seixas [26] apply broad concepts of resilience theory to the assessment of lagoon fisheries from around the globe, extracting "potential surrogates" of resilience (i.e., proxy variables for assessing resilience) from their analysis. On the other hand, long-term studies conducted over limited spatial scales can provide nuance by revealing important information about the contextual and developmental factors influencing resilience and adaptive capacity within specific socioecological contexts. Cinner et al. [27] provide an example of this approach, using nine indicators to assess how the adaptive capacity of Kenyan SSF communities varied over a 4-year period.

As more researchers explore adaptive capacity, they have introduced new methods and theories. The field is becoming increasingly fragmented, however, with many case studies and few empirically validated or widely accepted definitions, theories, or methods [11,28]. Most studies on adaptive capacity have sought to identify the characteristics and conditions that determine a group's capacity to adapt (i.e., the "determinants" of adaptive capacity), but measuring or evaluating these determinants and linking them to specific goals and processes remains a challenge. When adaptive capacity is defined as a latent characteristic, an act in the future, there is no physical outcome to be measured [28]. In practice, adaptive capacity is likely to vary depending on the changes occurring, the systems with which they interact, and the specific objectives that are being pursued. To date little work examines the observable response of communities to change and the factors mediating these responses.

Monitoring adaptive response and considering how adaptive capacity is impacted as systems react to change may allow a deeper understanding of feedbacks, trade-offs, and potential improvements to techniques for assessing and building adaptive capacity [27]. But few post-assessment evaluations exist to quantify how social factors match with specific community responses to perturbations. Below we present an analytical approach to systematically investigate how the characteristics of coastal communities and the resource systems in which they are embedded mediate response to different kinds of environmental perturbations.

26.3 An analytical framework for community response and mediating factors

Here, we propose a framework for analyzing SSF community responses to climate change-related stressors (e.g., warming events, hypoxic outbreaks, more intense storms, coastal flooding, shifts in fish distribution). Our framework evolved from an extensive review of the existing literature describing the responses of fishing communities to environmental stressors. We identify both climate change-related stressors and community characteristics that affect community response. Our framework aims to categorize responses observed across communities as adaptive, reactive, or coping [46], and to decipher whether potential mediating factors amplify or dampen these responses (Fig. 26.1). Our framework allows

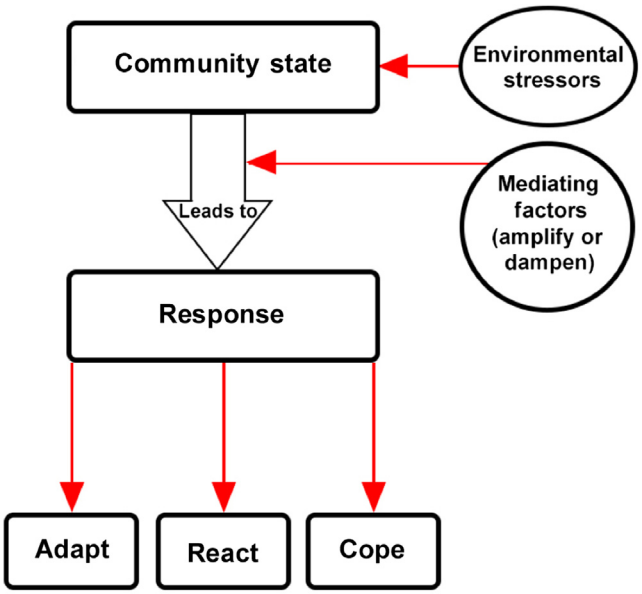

Figure 26.1
Framework for assessing observations of community response to environmental stressors as amplified or dampened by mediating factors.

for the analysis of observed responses (i.e., studies describing a climate-related perturbation, community response(s), and mediating community attributes), and may be supplemented and/or improved as adaptation initiatives progress worldwide and additional insight is accrued.

26.3.1 Climate-driven stressors

Although the full spectrum of climate-driven stressors remains unknown, we can learn about how communities will respond to climate-related threats by evaluating community responses to existing biophysical change. SSF communities throughout history have faced a plethora of threats, ranging from acute stressors (e.g., typhoons; [29]) to slow-accumulating stressors (e.g., chronic overfishing; [30]). The ability of SSF communities to respond and adapt to changing environmental conditions is a fundamental part of the culture and ethos that has enabled their long-term persistence. However, as the rate of environmental change accelerates, coastal communities may be unable to keep pace with increasing exposure to biophysical stressors. Emerging stressors will become more frequent and increasingly severe and may amplify impacts of existing stressors [31]. These stressors may fall into one of several categories: weather and climate, ocean conditions, and biological stressors. Examples of "weather and climate" stressors include sea level rise, long-term temperature changes, extreme temperatures, and changing rainfall patterns. "Ocean conditions" stressors include perturbations such as ocean acidification, ice loss, hypoxia, and ocean warming. Stressors in the "biological" category include species range shifts, smaller individuals, and disease. To understand how such emerging environmental perturbations challenge SSF communities, we identify three components of any given environmental stressor that could initiate the cascade of responses: what the stressor challenging the community is, what the impacts of that stressor are, and the specific groups of people affected by these impacts.

26.3.2 Mediating factors

Researchers have identified a host of social factors both theoretically and empirically linked to a community's response to environmental stress. These factors include access to assets; learning and knowledge; governance and institutions; and diversity and flexibility (Table 26.1). Factors that characterize access to assets include physical assets and infrastructure at the community and household level (e.g., housing, roads, vehicles, boats, fishing gear; [32]), access to technology [35], nonphysical assets affecting social interactions and status such as authority and education [24,33], and financial assets including capital, credit, markets, or aid [34,37,44]. Factors that characterize access to learning and knowledge include the extent to which local ecological knowledge (LEK) is maintained within the community [39], access to a diversity of knowledge sources [24], and capacity for local institutions to foster community members' learning and ability to

Table 26.1: Factors with potential to mediate community responses, sorted into four domains: diversity and flexibility, access to assets, learning and knowledge, and governance and institutions.

Domain	Factor	Description	Sources
Access to assets	Community infrastructure	Physical infrastructure in place that effects responses or variability to change, quality, isolation, presence, transportation, connectivity, etc.	[32]
	Household material assets	E.g., boat, house, specific gear, etc.	[11]
	Authority	Provision of accepted or legitimate forms of power; whether or not institutional rules are embedded in constitutional laws	[24,33]
	Human resources	Availability of expertise, knowledge and human labor	[24,34]
	Financial resources	Availability of financial resources to support policy measures and financial incentives	[24,34,35]
	Natural capital	Access to stocks of natural resources	[36]
	Access to credit	Financial support that is repaid	[11,27,32]
	Access to aid	Financial or material support that is not repaid	[32]
	Access to markets	Access to and/or diversification of markets (local, regional, or international)	[37]
	Access to information	Spaces and platforms for learning; can be achieved through multiple paths, e.g., formal education, informal education, media sources, electronic resources, etc.	[24]
	Fishing gear	Type of technology used for marine fishery resource extraction	[38]
	Technology use	Access to technologies that may directly or indirectly enable many of the adaptive strategies identified as possible in the management of climate change (e.g., warning systems, protective structures, crop breeding and irrigation, settlement and relocation or redesign, flood control measures)	[35]
Learning and knowledge	LEK	Influence of or access to LEK. "LEK is often considered a unique source of information in remote areas, far from research centers, where local ecological and social systems are poorly understood"	[39]
	Learning capacity	Presence of institutional patterns that promote mutual respect and trust; ability of institutional patterns to learn from past experiences and improve their routines; evidence of changes in assumptions underlying institutional patterns; institutional openness towards uncertainties; institutional provision of monitoring and evaluation processes of policy experiences	[24]
	Diversity of knowledge sources	Diversity of knowledge and information sources; intergenerational learning capacity	[11]
	Risk perception	Recognition of causality and human agency, perception of risk, knowledge of disturbances	[11]

(*Continued*)

Table 26.1: (Continued)

Domain	Factor	Description	Sources
Governance and institutions	Trust	Levels of trust, social capital, and networks (Whitney); presence of institutional patterns that promote mutual respect and trust (Gupta)	[11,24]
	Leadership	Presence of local environmental institutions and strength of social norms, accountability of managers and governance bodies; can fall under three categories: visionary, entrepreneurial, or collaborative	[11,24]
	Gender	Gender and race relations; gender of individuals in a community affects their ability to adapt or respond to a certain stressor or change, women and men are responsible for certain tasks, or more able to adapt to change, education of women can be another role, and traditional gender roles can play into the response	[11,40]
	Social capital	Levels of trust, social capital, and networks; describes relationships of trust, reciprocity, and exchange; the evolution of common rules; and the role of networks. How do individuals use their relationship to others for their own and the collective good? Are there connections or relationships that affect how communities respond?	[11,41]
	Regulations	Quality of governance and leadership in environmental policies and agencies; accountability of managers and governance bodies; active risk management and adaptive governance processes	[11]
	Stakeholder engagement	Levels of participation and quality of decision-making processes; implies a process of active participation of diverse stakeholders working together in concert to develop a unified proposal or common focus (in terms of visions, objectives, points of view, and concerted action)	[11,42]
Diversity and flexibility	Livelihood diversity	Options for altering one's livelihood within fishing portfolios or outside the fishing sector entirely	[11,43]
	Occupational mobility	Options for changing one's occupation completely	[11,27]
	Geographic isolation	Ability or willingness to move in times of uncertainty; includes elements of place attachment	[11]
	Room for autonomous change	Also can be described as agency; has three key attributes: (1) continuous access to information, (2) the ability to act according to a plan, and (3) the capacity to improvise	[24]

Brief descriptions of each factor are included along with sources for more detailed information. *LEK*, Local ecological knowledge.

perceive risk [11]. The effect of governance and institutions depends on a broad suite of factors that include levels of trust and engagement among community members—elements that reflect social capital held by individuals and across social networks in the community [11,24,42,45]. Leadership shown by local institutions and community members is highly related to the ability of communities to respond through its effect on regulations, social norms, and government accountability [11,24]. The domain of diversity and flexibility extends across many elements of communities and their members' lives. The effect of

diversity and flexibility across this spectrum can be characterized by livelihood diversity and occupational mobility [11], geographic flexibility or isolation (the ability or willingness to relocate; [11]), and the concept of agency, or room for autonomous change [24]. While a full accounting of metrics is beyond the scope of this chapter, each of these factors and literature that can provide insights into their measurement are found in Table 26.1.

26.3.3 Response framework—adapt, react, or cope

Impacted communities can respond to stressors in a variety of ways, but any response will set communities on pathways that can lead to resilient futures or that can leave communities highly vulnerable to future threats. To understand the spectrum of community responses, we draw on a conceptual framework that divides responses into three categories: adapt, react, and cope (Fig. 26.1) [46]. Communities that exhibit adaptive responses take a proactive and anticipatory approach to change. Adaptive responses of communities are based on knowledge or experience of past threats, and these responses are structured to anticipate future change. These adaptive responses allow communities to ensure that that their SES will be resilient to stressors that occur in the future. Anticipated stressors may be general or specifically defined [29]. For example, communities may prepare in advance for poor fishing conditions during future hypoxia events by diversifying livelihoods in anticipation. By contrast, communities that exhibit a reactive response to change take actions that are unplanned and occur in response to impacts. Because reactive responses tend to address symptoms rather than drivers of impacts, reactive responses may impede the capacity of communities to adapt to future change. Switching target species in response to a range shift of a community's primary target species during El Niño conditions, for example, is a reactive response. Coping occurs when communities passively accept the consequences of an event; communities do not change their behavior or the system to alter the outcome of the current stressor or to reduce the potential impacts from any future stressors. Examples include cases in which communities "wait it out" rather than adaptively or reactively responding. The adapt, react, cope framework [46] is useful to assess responses to existing threats, and the community response to a particular threat may foster a more robust response to future threats. But with climate change, the novel threats and enhanced intensity of perturbations may exceed adaptive responses generated by single threats or those previously experienced. How previous community responses might enable responses to novel threats or new interacting threats remains an open question.

26.3.4 Dampen or amplify?

Each of the mediating factors described above may dampen or amplify the three potential response types (adapt, react, cope) of a community faced with anthropogenic environmental stressors. For example, increased access to physical, financial, and social resources may

amplify adaptive responses, and thus reduce the tendency for communities to react or to cope, because these assets support the development and maintenance of alternative livelihoods. Similar relationships may exist for communities that have access to extensive knowledge and learning opportunities. High levels of trust and connectivity among community members may support adaptive responses by widely disseminating information about potential future risks and opportunities for mitigation from key knowledge holders throughout the community. Weak local institutions that are unable to influence social norms or regulations are unlikely to foster accountability by governing bodies and individuals to adaptively manage risks to resources, and thus may result in reactive or coping strategies. Adoption of coping strategies may also be enhanced by geographic isolation, as adaptive or even reactive relocation may not be feasible. Similar inflexibility in occupation may also result in lower likelihood of adaptive response.

26.3.5 Example framework application

In an example of a study which has documented the adaptive response of SSF communities impacted by an environmental stressor, Coulthard [38] describes the responses of artisanal fishing communities on the lagoon of Pulicat Lake in Southeast India to the adverse impacts of weakening monsoon seasons. The study discusses the responses of two villages on the lagoon: the traditionally higher-caste Nadoor kuppam and the traditionally lower-caste Dhonirevu. These communities, targeting primarily white (*Fenneropenaeus indicus*) and tiger (*Penaeus monodon*) prawns, experienced declining catch (and subsequent lower income and food security) as a result of increasing salinity and temperature during weak monsoon seasons. This environmental stressor, categorized as an acute, climate and weather stressor (as described in Section 26.3.1) elicited three responses across two distinct communities: (1) waiting it out (Nadoor kuppam); (2) occupational multiplicity outside of fishing-related livelihoods (Dhonirevu); and (3) using different SSF gear (Dhonirevu). Under the framework described here, response (1) is classified as a coping response, whereas responses (2) and (3) are classified as adaptive responses. In this case study, all three responses were mediated primarily by factors in the domains of "diversity and flexibility" and "access to assets" (Table 26.1). The coping response of Nadoor kuppam was amplified by their access to financial resources (i.e., family members with jobs and income from fish trade, due to social status) that allowed for "waiting it out" (i.e., continuing standard fishing practices even with low catch, while relying upon another income source). Their lack of willingness to diversify their occupations (beyond fishing-related livelihoods) or fishing gear (largely due to their higher-caste status, according to the author) dampened the likelihood of reactive or adaptive responses. Both adaptive responses by Dhonirevu were amplified by factors under the domains of diversity and flexibility, specifically occupational mobility and livelihood diversity. The gear shift in response (3) from regulated stake nets to smaller, unregulated handheld cast and gill nets, was also

amplified by access to such gear, a factor in the domain of access to assets. This example categorization of observed responses and mediating factors, in combination with categorization of observed responses found elsewhere in the literature, allows for an analytical approach to understanding the community characteristics driving specific response types of SSF communities to climate-driven stressors.

26.4 Conclusions

Here we provide a framework for the assessment and monitoring of observed community responses to climate-related stressors and their links to a variety of social factors. We are currently implementing this framework using observations of SSF community response to climatic stress events from the existing literature, as in the example found in Section 26.3.5. Our analysis will highlight the relative importance and interdependence of social factors in eliciting adaptive, reactive, or coping responses by communities. Yet to continue to test and apply this framework, we will need research teams to collect data on stressors, responses, and the factors that mediate them simultaneously in SES. Currently, few studies include the appropriate suite of factors to fully evaluate community response to climate perturbations. Such interdisciplinary studies will facilitate understanding the "why" of community response. To facilitate adaptation at the local level, resilience science must appraise the developmental and contextual processes by which communities negotiate adversity and respond to change [47]. The ongoing application of our framework to existing observations is a significant step in this direction, and can help communities dependent on marine resources with identifying, developing, or strengthening factors linked to community responses to best prepare them for future environmental variation.

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