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EDITED BY
Sanja Matic-Skoko,
Institute of Oceanography and Fisheries (IZOR), Croatia

REVIEWED BY
Sarah Wise,
National Marine Fisheries Service (NOAA), United States
Dimitrios K. Moutopoulos,
University of Patras, Greece
Alice Stocco,
Ca' Foscari University of Venice, Italy

*CORRESPONDENCE
Sieme Bossier
sbossier@sfu.ca

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How much time and who will do it? Organizing the toolbox of climate adaptations for small-scale fisheries

Sieme Bossier[1]*, Yoshitaka Ota[2], Ana Lucía Pozas-Franco[1] and Andrés M. Cisneros-Montemayor[1]

[1]Nippon Foundation Ocean Nexus, School of Resource and Environmental Management (REM), Simon Fraser University (SFU), Technology and Science Complex 1, Burnaby, BC, Canada, [2]Nippon Foundation Ocean Nexus Program, Department of Marine Affairs, University of Rhode Island (URI), Kingston, NY, United States

Adaptation to climate impacts will be necessary for small-scale fisheries and fishers (SSFs) to safeguard their food security, livelihoods, and cultural heritage. SSFs are often vulnerable to environmental impacts due to the place-based, multi-scale and direct dependencies on local ecosystems, and generally fewer resources or abilities for relocation, diversification, and modification of their fishing practices. Strategic adaptation is therefore essential. This study emphasizes the timelines, requirements, and burdens of implementing existing and proposed adaptations, e.g., who pays, who does the work, and how long would it take? To categorize possible actions (tools) for analysis, we adapt the FAO climate adaptation framework and propose five areas of action: Institutional, Communication, Livelihood, Risk Resilience, and Science. Our results highlight two interconnected trends; first, the burdens and benefits of proposed climate adaptations are unevenly distributed, usually against fishers themselves. Second, there is a general lack of research focusing on the equity implications of current governance structures that de-emphasize fisher's needs. This creates a lack of understanding among policy makers about the adaptation priorities of SSFs, and what resources or support they would need to implement them. We applied this framework to a case study involving octopus SSFs in Yucatán, Mexico. Interview results reinforce the finding that adaptation strategies that fishers thought would be most important for them (e.g. changes in policies/regulations to improve healthcare, reduce excess capacity, or reinforce fishing laws) were actions they could not often realize without external support; conversely, tools often proposed as "easier" by non-fishers (e.g. changing jobs, fishing gears, or going further out to sea) were not seen as particularly viable to fishers. Due to these mismatches, we argue there is a need to go beyond the classical focus on quantifying climate vulnerability towards a stronger emphasis on prioritizing adaptation strategies to meet the goals of fisherfolk themselves and aligning organizational and governance structures accordingly. The toolbox organization

framework we propose can serve as an initial guidance for many fishing communities, decision makers and other stakeholders to anticipate implementation needs and find the right tools to adapt to future climatic conditions and prevent negative socioeconomic and ecological impacts.

KEYWORDS

climate change adaptation, small-scale fisheries, adaptation needs and strategies, social equity, toolbox, octopus fisheries

1 Introduction

Fisheries face clear challenges beyond overfishing, with climate changes increasingly reflected in sea surface temperature, sea level rise, increased storm events, ocean acidification, and large shifts in species distributions (IPCC, 2014). Fishers directly experience these impacts as, for example, decreased catch and more incidence of invasive species, increased travel requirements and more need for vessel or gear replacement (Macusi et al., 2020), global market and demographic shifts, and safety issues as a result of increased storm events (Adger et al., 2005; Armitage and Johnson, 2006; Le Cornu et al., 2018). Small-scale fisheries/fishers (SSFs) in particular have been identified as more vulnerable to larger-scale changes such as climate change compared to large-scale fisheries (Allison et al., 2009; Macusi et al., 2020; Salagrama, 2012) because SSFs are generally more dependent on their catches for subsistence, i.e. for food security and basic income needs (Kittinger et al., 2015; Le Cornu et al., 2018), and have limited mobility and resources for changing technologies or to help them recover from impacts (IPCC, 2022; Leichenko and Silva, 2014).

Although adaptation—to new places, species, and fishing practices—is inherent to SSFs, their adaptive capacity is constrained due to the current speed and scale of economic, political, social, and cultural changes. For example, increasing effort or accessing new places or species is more restricted now due to formal regulations, the loss of traditional arrangements, and the impacts of past fisheries; inter-generational transfer of knowledge and skills is also decreasing, and socio-cultural changes are making it difficult to carry out traditional coping mechanisms (Ford et al., 2007, 2008; Ford et al., 2006a, 2006; Gearheard et al., 2006; Laidler et al., 2009; Sievanen, 2014). While SSFs therefore need urgent support in finding suitable adaptation strategies, the timelines and assistance necessary for implementation must be carefully considered to avoid misleading or otherwise harming fishers and their communities.

Recent studies on SSFs have mainly focused on increasing their adaptive capacity and reducing their vulnerability, as well as increasing their resilience and improving risk management (e.g. Cinner et al., 2013; Etongo and Arrisol, 2021; Furgal and Seguin, 2006; Himes-Cornell and Kasperski, 2015; Islam and Chuenpagdee, 2022; Lee et al., 2019; Payne et al., 2021). Most of these studies address climate impacts based on the now-classical framework of vulnerability as a function of exposure, sensitivity, and adaptive capacity (IPCC, 2001; Cinner et al., 2018; Dudley et al., 2021; Freduah et al., 2019; Islam and Chuenpagdee, 2022; Limuwa et al., 2018; Mamauag et al., 2013; Marshall et al., 2013). This framework is also widely used in ecological research (e.g. Bueno-Pardo et al., 2021) and there are therefore variations in usage of the terms. In practice, however, the three components of vulnerability are not easily delineated and often cannot be identified distinctly in observed adaptation strategies, particularly when individuals and communities are simultaneously responding to multiple stressors. Therefore, we focus here on the adaptation strategies themselves and their implementation process.

Despite the large number of vulnerability assessments at different scales, research into appropriate adaptation options for SSF are still scarce (Salgueiro-Otero and Ojea, 2020), and documented examples of implemented adaptation initiatives even more scarce (Miller et al., 2018). On top of that, a lot of the research so far on climate adaptation of SSFs has had an indirect approach mainly based on the internal logic of the vulnerability framework itself (e.g. Ford et al., 2006a; Hoang et al., 2020; Morzaria-Luna et al., 2014; Ruiz-Díaz et al., 2020). For instance, it is thought that, by reducing the vulnerability of SSFs, they will be more capable of withstanding potential effects of adverse climatic conditions and, therefore, will be 'better adapted' (Jara et al., 2020; Kalikoski et al., 2010). So, adaptations to become less vulnerable, less exposed, or to have a higher adaptive capacity, etc. can be indirectly identified as climate adaptation measures for SSFs (Adger, 2006).

Adaptation strategies of different communities will differ depending on the level of exposure, sensitivity and adaptive capacity and are therefore place, system, and time specific (Adger, 2006; Senapati and Gupta, 2017; Smit and Wandel, 2006). For instance, to be more resilient to comparable extreme weather events, some argue that fishers in the Galapagos need a better disaster risk management toolkit, while fishers in the Philippines need to restore the health of the coral reef ecosystem, mainly by planting mangroves (Monnier et al., 2020). Moreover, whether an adaptation strategy is 'appropriate' depends on social contexts including values and identity that community members share. Another example is that of pescatourism as income diversification for fishers, where tourists can experience activities on a commercial fishing vessel (Piasecki et al., 2016). With SSFs in Italy, this is very welcomed as it helps to preserve artisanal fisheries in coastal

communities while reducing catches (because revenue is supplemented by paying tourists). In other places, fishers would not agree to this 'adaptation' and might see this as a detrimental impact on their social identity because they would be identified as tour guides instead of fishers, or license rights might be given to charter operators rather than to fishers, turning it into a commercial activity which does not benefit the fishers (Piasecki et al., 2016; Prosperi et al., 2019). SSFs around the world can thus learn from one another and find inspiration on how to deal with the coming challenges, but there is no single 'best' way of adapting to climate change.

There are few yet thorough reviews focused on documenting the array of potential adaptation strategies of SSFs to climate change. Shaffril et al. (2020), for instance, found that government assistance is required to support social, economic, and environmental adaptations. More importantly, adaptations should be in line with the needs, abilities and interests of local people. Other reviews have found that most studies focus on adaptation theory and planning, but that there is a gap between research on adaptation theory and implementation (Miller et al., 2018; Salgueiro-Otero and Ojea, 2020). In this study we modified a framework based on past work by FAO (2018) which we expand by incorporating diverse strategies discussed and proposed in academic and grey literature. Here, we define adaptation strategies as a plan of action or policy designed to achieve a particular adaptation objective. Each adaptation strategy consists of several adaptation actions (tools) that work towards achieving the objective of that strategy. Because there will undoubtedly be more specific proposed strategies as challenges and responses continue, we focus this work on providing categories to help organize and evaluate any adaptation strategies and tools from the perspective of SSFs, namely, "how much time and support would SSF need to implement this climate change adaptation?". We then tested this new framework through an interactive exercise with small-scale octopus fishers in Yucatán, Mexico. By organizing the toolbox of strategies in this way, we aim to provide guidance to design climate adaptation strategies that are both environmentally, socially, and economically suitable for diverse SSFs and that could prove essential for maintaining fishing livelihoods while meeting local contexts and priorities. We also emphasize throughout this work, that it is important to listen to fisherfolk and their communities in terms of what they need to adapt, not only what we think they need. This information will then, hopefully, enable decision makers to make better decisions to prevent negative socioeconomic and ecological impacts, and create adaptation strategies with the necessary support so the burden of implementing would not be put on the fishers alone.

2 Methodology

There are three main steps in this research that are further detailed below: 1) we gathered adaptation tools and strategies from academic and grey literature to create a toolbox by classifying the tools and strategies according to five categories, 2) we developed a theoretical time-support framework, based on the toolbox, that allows to investigate the implementation requirements by highlighting the amount of internal capacity, external support, and time needed to implement different strategies, and 3) we applied a case study with small-scale octopus fisheries in Yucatán, Mexico, where we used the toolbox and the time-support framework to gather information on what those fishers need to adapt to the changing climatic conditions. While continuous adaptation to ecological conditions is an integral part of all artisanal fisheries, we focus here on specific adaptations specifically to the unprecedented large-scale and rapid effects of climate change.

2.1 Gathering adaptation strategies and tools

Though the objective of this study was not to perform a systematic literature review of proposed climate adaptation strategies and actions, we did use a scoping review to gather a sample of climate change adaptation tools for SSF communities around the world to inform our framework. To gather the sample of adaptation tools and strategies, the Google Scholar search engine was used with the search terms "climate change", "adaptation", "small-scale fisheries", "Indigenous fisheries" and "artisanal fisheries". Here, all relevant articles were reviewed but we only included articles that contained information in relation to adaptation and/or coping strategies that are either in place already or including specific future recommendations. The online software ResearchRabbit was used to identify additional publications not found through Google Scholar. This is an artificial intelligence-based program used to screen for literature with contents matching those of supplied files (www.researchrabbit.ai). ResearchRabbit links to reliable databases and delivers similar quality compared to traditional literature reviews (Tse, 2024). The tool is especially useful to support the workflow of unstructured searching and is designed to be used, supplementary, to complement comprehensive database searches (Cole and Boutet, 2023).

In total, 42 case studies of implemented climate adaptation strategies for artisanal fisheries were examined from different places in the world (See Figure 1; Supplementary Table S1), including 38 peer-reviewed publications and 4 NGO reports. Some publications presented case studies for multiple locations, so the total number of locations is 46. There was no time restriction of publication in the review; however, 75% of the selected publications were between 2015-2022 (perhaps prompted by the publication of the FAO guidelines on SSFs in 2015; see Discussion). Most case studies were conducted in developing countries.

Our first step was to classify the identified adaptation strategies according to five categories: Institutional, Communication, Livelihood, Risk Resilience, and Science. The methodology for categorizing the adaptation strategies was adapted from an FAO (2018) analysis of case studies which used three categories of adaptation activities—institutional adaptation, livelihood adaptation, and risk reduction and management for resilience—though with more attention on the assessment of vulnerability. However, while they merged Science with the Institutional category, we argue that Science should be a separate category

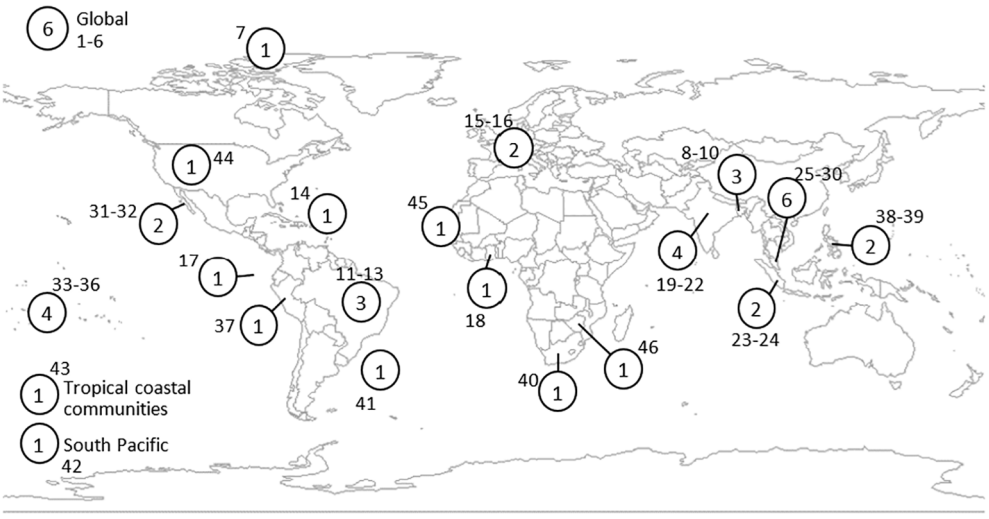

FIGURE 1
Overview of the geographical location and the amount of case studies in each location identifying climate adaptation strategies for SSFs (n = 46). Each location can be a specific place, country, or region, this is based on the scope of the literary articles reviewed. Numbers inside the circle note the number of literary articles for each location and the numbers outside the circle note the corresponding references of the articles. See Supplementary Table S1 for the corresponding list with references.

because work, research, and suggestions on the matter of adaptation needs of SSFs should be independent from institutional organizations. FAO (2018) also did not include a separate Communication category, but others have argued that the adaptation strategies that we grouped within this additional Communication category will increase adaptation success and will benefit strategies from other categories (Ayers, 2011; Gianelli et al., 2021; Hasan and Nursey-Bray, 2018). Therefore, because of its potential key role, we added this separate category. Each category consists of several strategies based on the focus of the intended change (Supplementary Table S2) and each strategy consists of several tools and actions to accomplish the adaptation needs (desired change). These are explained at length in the Results section.

2.2 Creating the time-support framework

Despite its limitations discussed in the Introduction section, the classical vulnerability framework (vulnerability = exposure + sensitivity – adaptive capacity) is a good tool to map and quantify the different vulnerability aspects of a fishery/fishing community. The mapping and quantification of vulnerabilities are a first step in order to identify and support certain fisheries/fishing communities or households. However, most of the previously discussed adaptation tools cannot be easily placed in the three distinct groups since there is a lot of overlap between the three vulnerability properties, making it difficult to identify who has the power to realize what strategy. The linear vulnerability approach, therefore, needs to be transformed to bring it to the critical next phase, i.e., the implementation of the adaptation strategies, which is also an essential part of the process of selecting appropriate adaptation strategies. Thus, in a second step, we focus our initial toolbox on the implementation process, in line with the important work on adaptation planning done by e.g. Sowman (2020). To do so, we created a framework from the perspective of SSFs, who are the most directly impacted by the process (and, hopefully, outcomes) of adaptation, where we investigate the implementation requirements: How much external support (who will do it, who will pay) and how much time will fishers or fishing communities need to implement the strategies?

The time-support framework (Figure 2) consists of 5 boxes showing where the adaptation strategies fit in terms of time (short- or long-term) or external support (low-medium-high) needed to implement the strategies, as explained in Figure 2. We argue that, creating this diagram together with the fishers and plotting the strategies this way, is a relevant way to represent the strategies since this kind of information will help create a better understanding of the internal capacity of fishers and fishing communities and of the burdens and difficulties that they face to implement the strategies.

2.3 Case study – applying theory in practice

In this part, we tested our toolbox and the time-support framework in the field. The toolbox was used as a large pool of adaptation tools and strategies that can be presented to fishers (see Supplementary Material for the extensive list of tools and adaptations) to find the right tools to adapt to future climatic conditions and avoid negative socio-economic and ecological impacts. On the other hand, the time-support framework is used as a tool to gain insight into the perspective of the fishers and their communities into how much time and support a SSF community would need to implement this adaptation. The application presented here is an example of how the toolbox and framework can be applied in the field. The purpose of creating the toolbox and

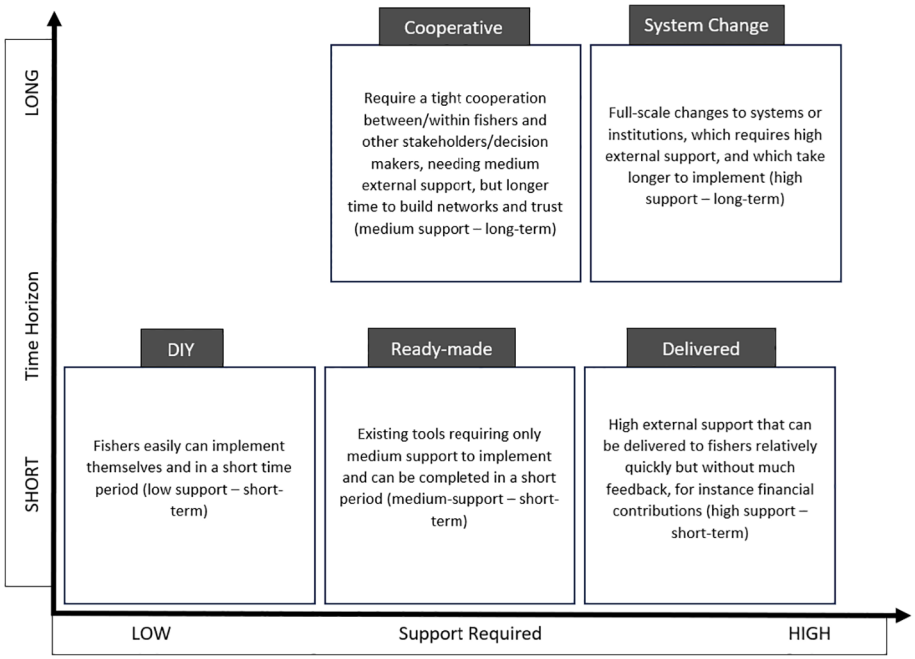

FIGURE 2
Time-support framework to investigate the implementation requirements of the adaptation strategies with the amount of support needed for the implementation of the strategy on the x-axis and the amount of time needed on the y-axis.

the time-support framework is for other researchers to adapt this method and apply it to other case studies around the world. By doing so, we hope that i) we start to listen more to the voices of the fishers and their communities, instead of us telling them what they need, and ii) we can improve the understanding among policy makers about the adaptation priorities of SSFs, and what resources or support they would need to implement them.

We applied this new framework to a case study of small-scale octopus fisheries in Yucatán, Mexico through an interactive exercise. The objective of this study was not to perform an in-depth analysis of the octopus fishers in Yucatán, but to assess the performance of the framework in the field and whether the time-support matrix was useful to understand the perspective of fishers themselves. The exercise was done in Spanish in group or individual, depending on the availability of the participants. Participants were invited through a local NGO COBI (Comunidad y Biodiversidad) with long-standing collaborations in the area. We had 5 groups of fishers with 5, 3, 3, 1, and 1 participant(s) respectively; and 2 groups of non-fishers of 1 and 2 participant(s) respectively, with people working in jobs related to the same fishing industry, but not as fishers themselves. We prepared a collection of sticky notes where we wrote down a condensed version of the adaptation tools from our framework, grouping similar tools together, and handed them over to the participant(s) (Figure 3). There were three rounds to the exercise: 1) the participant(s) had to go through all the sticky notes and identify which adaptation tools were important to them (important or not important), and add any

FIGURE 3
Participatory exercise with fishers in Yucatán, Mexico, to identify which adaptation strategies and tools are important to them and how much time and support those require to implement according to the participant(s) (Pictures by Sieme Bossier).

tool or strategy that they thought was important, but was missing from the ones on the sticky notes, 2) from all the adaptation tools that they identified as being important, they now had to arrange those important ones into how much time they thought was necessary to implement each tool (scale 1-3, 1 = short time, 2 = medium time, 3 = long time), and 3) from those same important tools, they now had to arrange them according to how much external support they thought they needed to implement the tool (scale 1-3, 1 = little support, 2 = medium support, 3 = high support). When non-fishers were doing the exercise, they were asked to think about what adaptation tools they thought were important for the fishers and how much time or external support the fishers needed to implement the important ones.

3 Results

3.1 Adaptation strategies and tools

We grouped all the adaptation strategies and tools that we gathered from literature into five categories depending on the foci of change: Institutional, Communication, Livelihood, Risk Resilience, and Science (Figure 4). Because SSFs strategies usually address a mix of aspects, the categories are represented as overlapping bubbles in Figure 4. Each category is briefly summarized in the following paragraph and then expanded upon in the sections below.

The Institutional category is placed centrally in Figure 4 because most of the strategies found in literature were phrased with a need for help/change in institutions in order for change to be created in the other categories. The Institutional category connects to the other specific types of adaptations through communication initiatives. Therefore, the Communication category is displayed around the Institutional category as it can be seen as the bridge between the Institutional and the other categories. Each category consists of several strategies (Figure 4) which consists of individual tools and actions (see Supplementary Table S2 in Supplementary Material for the full overview of all the strategies and tools and the respective sources). In the following sections, we will describe the adaptation strategies and tools under each category.

3.1.1 Institutional category

3.1.1.1 Policies

The first strategy in the Institutional category is policy. There is an explicit need for public policies to deal with the impact of climate variability and change (Islam and Chuenpagdee, 2022; Kalikoski et al., 2010), for improving governance of sustainable management (Bell et al., 2018; Hanich et al., 2018; Mabe and Asase, 2020; Monnier et al., 2020; Payne et al., 2021; Salagrama, 2012), and improving the enforcement of maritime laws (Bell et al., 2018; Islam et al., 2014; Macusi et al., 2020). Policies can also be aimed at reducing fishing pressure by changing fishing effort or excess capacity (Allison et al., 2009; IFAD, 2014), or at maximizing the efficiency of spatial management (Bell et al., 2018). Finally, successful local fisheries policies can be transferred to national fisheries management plans (GIZ, 2019).

3.1.1.2 Regulations

The second strategy is regulations. There is a call for governance-led actions that increase flexibility (Payne et al., 2021) both in terms of flexible, adaptive institutions (Allison et al., 2009) as well as flexible management measures and tools that allow for switching between adaptive responses (Cinner et al., 2018; Finkbeiner, 2015; Gianelli et al., 2021; Le Cornu et al., 2018). This

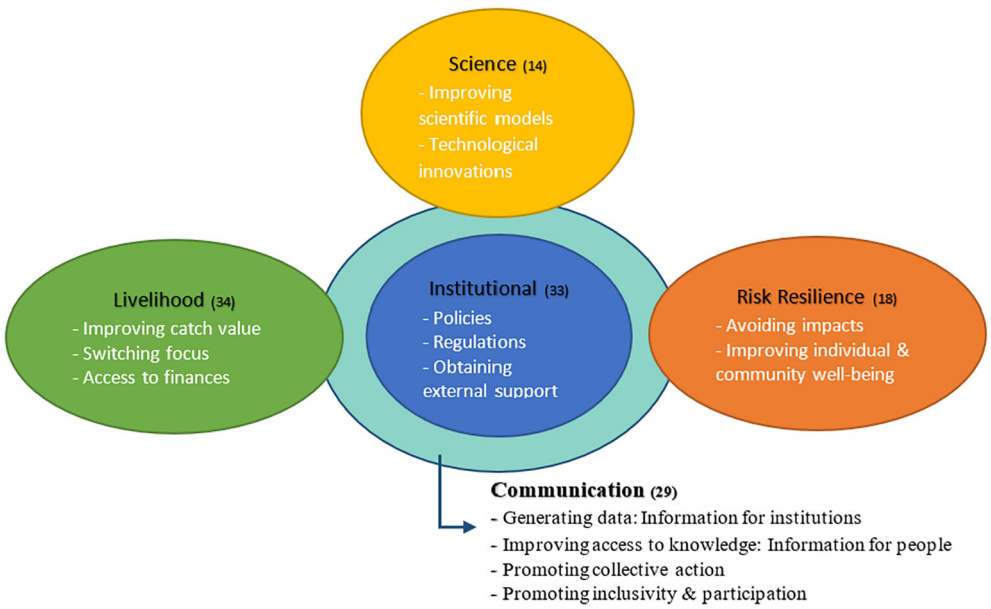

FIGURE 4
Adaptation categories and strategies from analysis of case studies collected from literature. Numbers in brackets denote the number of literary articles that mention adaptation strategies and tools in relation to each specific category (see Supplementary Table S1 for the reference list for the respective categories and adaptation tools).

includes creating flexibility in space, time (Aguilera et al., 2015; FAO, 2018; GIZ, 2019; Le Cornu et al., 2018; Sievanen, 2014), and effort (Aguilera et al., 2015) with regard to harvesting and group size (Berkes and Armitage, 2010), or continued flexibility in mobility, so that fishers can easily move around to other harbors or fishing areas depending on ecological and economic conditions (Berkes and Armitage, 2010; Sievanen, 2014). Some researchers go even further and suggest that fishing communities should also receive more power and freedom to respond to the challenges themselves (Cinner et al., 2018; Hanich et al., 2018; Payne et al., 2021), and therefore improve fisheries management through bottom-up adaptive processes such as co-management and community-based management that does not require institutional permission for specific changes to fishing activities (Salagrama, 2012).

3.1.1.3 Obtaining external support

The third strategy of the Institutional category is external support. This can be support from the government to the fishing community or individual households, or from other external organizations. Firstly, there is a need for government assistance of social, economic, environmental, and institutional and organizational supports to fishing communities (Islam and Chuenpagdee, 2022; Shaffril et al., 2020; Yuerlita et al., 2013). External support can target capacity building (Shaffril et al., 2013; Yuerlita et al., 2013) and specific climate change adaptations (GIZ, 2019), such as developing climate change action plans (GIZ, 2019) and mitigating future impacts (Allison et al., 2009). This can be done by, for instance, restoring the health of ecosystems (IFAD, 2014; Monnier et al., 2020), creating plans for managed retreats (Shaffril et al., 2017b), or reducing and/or sequestering greenhouse gas emissions (IFAD, 2014). In addition, they should support principles of fair governance based on legitimacy, equity, responsiveness, and accountability (Gupta et al., 2010).

Sometimes communities will need support to mobilize leadership qualities of social actors (Gupta et al., 2010), or to address conflicts, such as issues of migrant fishers or non-fisheries issues that affect fisheries resources and the quality of life of fishing communities (Salagrama, 2012), or to foster marketing initiatives (Gianelli et al., 2021). Firstly, by improving access to fish markets (Islam et al., 2014), e.g., providing support in marketing fish products in overseas markets (Deb and Haque, 2016). Secondly, by increasing the purchase of fish and increasing the quantities and types of fish eaten domestically, which traditionally might have been high (Bell et al., 2018; Prosperi et al., 2019), e.g., promoting the health benefits of fish, or increasing the availability of fish for urban populations (Bell et al., 2018). In some situations, however, strategies suggest to limit the export of specific fish to reserve them for local consumption (Bell et al., 2018), or a lessening of the consumption to reduce the fishing pressure (Deb and Haque, 2016).

A second part of the external support strategy is financial support both in terms of covering the specific costs of adaptation (Allison et al., 2009; Gupta et al., 2010) and broader direct economic contributions to fishers. Financial support could limit community dependence on third parties that otherwise can have leverage during periods of disruption in the fishing activity (Jara et al., 2020). Examples of such strategies are, e.g., wages during fishing bans (Deb and Haque, 2016; Finkbeiner, 2015; Kalikoski et al., 2010), fixing damaged gear (Kalikoski et al., 2010), subsidizing prices of fishing implements (Senapati and Gupta, 2017), or other targeted subsidy programs to support key adaptations (Allison et al., 2009; Bell et al., 2018), such as monitoring or restoration programs, improved management systems, reduction of post-harvest loss, and value-added processing (Cisneros-Montemayor et al., 2020).

3.1.2 Communication category

3.1.2.1 Generating data: information for institutions

Under most current policy approaches, there are implied or explicit requirements for users to collect and "report" data to formal institutions. For example, data collection and monitoring programs from the Science category (see below) are usually organized at the national level and are an essential aspect to first understand the functioning of the environment and the climate system, and then to direct the management of mitigation measures. Institutions should therefore support and improve the design, implementation and operation of reliable data collection, management, and dissemination systems (Gianelli et al., 2021; GIZ, 2019). This data will then provide important information as inputs to explanatory and predictive models, to better plan for resource variability (Jara et al., 2020), and to provide evidence on which national and international policies are based (Wilkinson, 2006). In addition, Brown (2015) argues that other types of information such as place-specific nature (rootedness), culture, identity, worldviews, and attachment are also important to integrate for a successful adaptation process.

3.1.2.2 Improving access to knowledge: information for people

This leads to the second strategy of the Communication category, namely that of continuous learning through knowledge co-production and the sharing of knowledge (Armitage et al., 2011; Cinner et al., 2018; Dale and Armitage, 2011; Shaffril et al., 2017b). Tools involve increasing the ability to learn (Gupta et al., 2010; Payne et al., 2021), easier access to knowledge (Shaffril et al., 2013, 2017), strengthening fishers' climate change knowledge (Abu Samah et al., 2016; Cinner et al., 2018; GIZ, 2019; IFAD, 2014; Islam and Chuenpagdee, 2022; Monnier et al., 2020; Muhammad et al., 2016; Shaffril et al., 2017a), and increasing climate awareness among fishing communities and other stakeholders (Hasan and Nursey-Bray, 2018; Monnier et al., 2020; Salagrama, 2012; Shaffril et al., 2013), e.g., regarding disasters and their perception of risks (Iwasaki et al., 2009; Shaffril et al., 2017b). Information and knowledge can be picked up in national strategies or can be directly used by fishers and other stakeholders (Finkbeiner, 2015; GIZ, 2019; Shaffril et al., 2020). For instance, a lack of climate change awareness or names in local languages for key concepts of climate change and adaptation could be a barrier to the effective implementation of adaptation policies (Hasan and Nursey-Bray, 2018). Similarly, better information and training towards safety at sea (IFAD, 2014; Salagrama, 2012; Shaffril et al., 2017a) and ways to respond to weather warnings (León et al., 2006) will reduce some of

the climate risks at sea and on land. In addition, besides detailed environmental knowledge, the knowledge of different skills, even non-fishery related ones, which will be further discussed in the Livelihood category, is also important in relation to adaptation strategies (Berkes and Armitage, 2010). Finally, it is also important to have good communication from government institutions about, for instance, existing and changing rules and regulations (Islam and Chuenpagdee, 2022), and from scientists in disseminating the findings and implications of their research (Shaffril et al., 2013).

3.1.2.3 Promoting collective action

Fishery communities can strengthen social relationships, family support and unity among local people and so improve their social capital (Fauzi and Anna, 2010; Iwasaki et al., 2009; Shaffril et al., 2017a). They can also link social capital by establishing networks between science, fisheries management, NGOs, and local communities that enable cooperation, sharing of knowledge and collective action (Berkes and Armitage, 2010; Cinner et al., 2018; Finkbeiner, 2015; Gianelli et al., 2021; GIZ, 2019; Iwasaki et al., 2009). Examples of collective activities are community services, and the sharing of work in repairing gear and equipment (Fauzi and Anna, 2010). A higher degree of such an involvement is the co-management of resources, involving community groups, fishers, and fish farmers associations to collectively manage marine resources (Bell et al., 2018; Berkes and Armitage, 2010; Galappaththi et al., 2021; Gianelli et al., 2021; GIZ, 2019; IFAD, 2014; Islam and Chuenpagdee, 2022; Jara et al., 2020; Le Cornu et al., 2018; Schipper et al., 2014). Furthermore, communities can also increase the degree of self-organization, for instance by creating fishers' assemblies (Gianelli et al., 2021; Gupta et al., 2010; Kalikoski et al., 2010; Ndhlovu et al., 2017; Payne et al., 2021), and so, according to (Deb and Haque, 2016), collectively resist external pressures.

3.1.2.4 Promoting inclusivity and participation

This strategy refers to the inclusion and participation of all stakeholders throughout the entire process of decision-making, consultation, policymaking, fisheries councils, and research, at fishery, regional and national levels (Gianelli et al., 2021; Gupta et al., 2010; Islam and Chuenpagdee, 2022; Jara et al., 2020; Kalikoski et al., 2010; Monnier et al., 2020; Salagrama, 2012; Shaffril et al., 2017a). Hasan and Nursey-Bray (2018) argue that a lack of community voices being heard at the local and national levels causes poor decision-making and poor compliance with whatever decisions are made. As such, involving fishing community representatives could help prioritize adaptation policies according to local needs and help policymakers understand local contexts in terms of environmental as well as social, cultural, and political aspects. This process can be supported by prior letters of agreement and by electing fishery leaders to participate throughout the decision-making process (Gianelli et al., 2021).

3.1.3 Science category

3.1.3.1 Improving scientific models

The call for more data is a typical scientific argument. Examples of adaptation tools under this strategy include improved modelling of fisheries resources (Jara et al., 2020), data collection using new technologies and approaches, and monitoring of the marine environment as well as pollution and wastewater treatments (Gianelli et al., 2021; GIZ, 2019; Jara et al., 2020; Monnier et al., 2020). Some broader suggestions are research on fisheries resources, fisheries adaptation to climate change (Fauzi and Anna, 2010; Monnier et al., 2020), and the impact of climate change on SSFs and its uncertainties (FAO, 2018; GIZ, 2019). Others call for more multi-disciplinary, cross-sectoral research (Islam and Chuenpagdee, 2022) on, e.g., diversified, supplementary and alternative livelihood opportunities (GIZ, 2019), or more community adaption studies (Abu Samah et al., 2019), participatory action research (Shaffril et al., 2013), and implementing a more holistic approach (Iwasaki et al., 2009), such as the ecosystem approach to the fisheries management (Bell et al., 2018; IFAD, 2014), or integrating fishery resources into a watershed perspective (Iwasaki et al., 2009).

3.1.3.2 Technological innovations

The other strategy under the Science category is technical innovations. It was mentioned that there was a need for, among others, aquaculture innovations such as genetic improvement programs (Allison et al., 2009), developing/identifying new commercially viable strains of aquaculture species (IFAD, 2014), or converting aquaculture and fishing residues into agricultural fertilizers using bacterial consortia (Jara et al., 2020). Other technological innovations, for instance in illegal, unreported, and unregulated (IUU) monitoring or data reporting technology, were not mentioned in the literature gathered for this project.

3.1.4 Risk resilience category

3.1.4.1 Avoiding impacts

The strategy of avoiding impacts, and so reducing risks, focusses mainly on the preparedness towards future challenges (IFAD, 2014; Salagrama, 2012). On the one hand, it includes tools that improve the disaster risk management toolkit (Monnier et al., 2020) creating, for instance, better weather forecast tools, early warning systems (e.g. for extreme weather and harmful algal blooms), disaster recovery programs (Allison et al., 2009; Gianelli et al., 2021; IFAD, 2014; Islam et al., 2014; Jara et al., 2020), and possibly recognizing fishing villages as 'disaster prone' or 'seasonally food deficit' zones (Deb and Haque, 2016). On the other hand, risks can also be reduced by increasing the current protection from storms and waves using structural and non-structural options (Shaffril et al., 2017b) by, for instance, rehabilitating coastal ecosystems such as mangroves, wetlands, marshes, and coral or artificial reefs (Bell et al., 2018; IFAD, 2014; Monnier et al., 2020; Muhammad et al., 2016), or to provide funding for landward migration of mangrove habitats or human communities themselves (Bell et al., 2018).

3.1.4.2 Improving individual and community well-being

The other strategy gathers tools that improve the overall well-being of individuals within the community beyond fisheries themselves, such as improved access to education, which can help to disseminate information and awareness and can help them

prepare to face the threats (Abu Samah et al., 2016; Monnier et al., 2020; Shaffril et al., 2013). Access to decent housing that are strong enough to withstand extreme waves and wind, and rural infrastructure which can help with market accessibility (Cinner et al., 2018; Islam and Chuenpagdee, 2022; Salagrama, 2012; Shaffril et al., 2017b). Better occupational health and safety facilities to prevent physical accidents and insecurity during fishing, especially with increased storm events being predicted (Islam and Chuenpagdee, 2022). Improved access to basic services e.g., access to health care or medication (Cinner et al., 2018; Salagrama, 2012), or introducing food aid programs for the most vulnerable individuals, e.g., widows, deserted women, physically weak persons, etc (Deb and Haque, 2016). Other tools aim to improve equitable access to the environment, through for instance a redistribution of quotas (Finkbeiner, 2015), or to eradicate children working in fisheries due to lack of money and racial/caste discrimination which creates an obstacle for children to continue their education (Iwasaki et al., 2009).

3.1.5 Livelihood category

3.1.5.1 Improving catch value

This strategy focusses on improving the fishing, storage, transport and processing methods and technologies (Allison et al., 2009; Payne et al., 2021). Examples of tools are improving the quality of fish products (Monnier et al., 2020), extending the shelf life of fish catches (Bell et al., 2018), reducing the cost of fishing (Islam et al., 2014), or improving commercialization (Monnier et al., 2020). Fisheries communities can also improve the post-harvest processing (GIZ, 2019; IFAD, 2014), for instance, by adopting new processing technologies (Gianelli et al., 2021), or establishing multi-species processing at local facilities (Aguilera et al., 2015). They can also promote direct consumption of dried fish products, or convert aquaculture and fishing residues into agricultural fertilizers (Jara et al., 2020). In addition, fisheries communities can also increase their food sovereignty, shorten the value chain, and have more control over the price of their products by not selling to a middleman, but directly to restaurants instead, at higher prices (FAO, 2018; Gianelli et al., 2021; Jara et al., 2020; Kalikoski et al., 2010; Monnier et al., 2020; Prosperi et al., 2019). Many of these tools will naturally depend on the access local communities have to these technologies (Abu Samah et al., 2016; Cinner et al., 2018; Shaffril et al., 2013, 2017).

3.1.5.2 Switching focus – species

Switching focus of species involves a change in the type of species targeted and who has access rights to them (Aguilera et al., 2015; Allison et al., 2009; Bell et al., 2018; Coulthard, 2008; FAO, 2018; Fauzi and Anna, 2010; Gianelli et al., 2021; GIZ, 2019; Monnier et al., 2020; Senapati and Gupta, 2017). Access to fish species that are not or less caught could be promoted (Bell et al., 2018) through, for instance, less expensive permits or less stringent regulation (Aguilera et al., 2015). In addition, in some regions, the new appearance of invasive species can lead to new fishing opportunities (Monnier et al., 2020). However, switching to another species may require new quotas (Bell et al., 2018; Prosperi et al., 2019), marketing initiatives to sell less known species (Behrens et al., 2019), or new fishing gear.

3.1.5.3 Switching focus – gear

Another strategy is to diversify fishing gear (Aguilera et al., 2015; Allison et al., 2009; FAO, 2018; Fauzi and Anna, 2010; Gianelli et al., 2021; GIZ, 2019; Senapati and Gupta, 2017). For instance, using static fishing gear instead of towed gear such as trawls (IFAD, 2014), or assessing the relevance of existing regulations on net mesh size, and maybe developing new ones (Yuerlita et al., 2013). Switching focus of gear also involves increasing fishing efficiency by implementing modern technologies and/or returning to traditional practices in fishing gear, equipment, or more fuel-efficient boats (IFAD, 2014; Islam et al., 2014; Monnier et al., 2020; Salagrama, 2012).

3.1.5.4 Switching focus – livelihood

Involving a deeper level of change, tools included in this strategy focus mainly on the livelihood diversification of individual households that can increase their income-generating activities, both inside and outside of artisanal marine fisheries (Allison et al., 2009; Coulthard, 2008; FAO, 2018; Fauzi and Anna, 2010; IFAD, 2014; Islam et al., 2014; Islam and Chuenpagdee, 2022; Leite et al., 2019; Monnier et al., 2020; Payne et al., 2021; Shaffril et al., 2013, 2020; Sievanen, 2014; Yuerlita et al., 2013). Examples include working on industrial fishing vessels, exploring fish resources in fresh water, agriculture (Kalikoski et al., 2010), ecotourism (Bell et al., 2018; Jara et al., 2020), pescatourism (Prosperi et al., 2019), sustainable aquaculture with improved planning and zoning (IFAD, 2014; Jara et al., 2020; Muhammad et al., 2016), establishing small-scale fish nurseries (IFAD, 2014), expansion of small pond aquaculture to increase access to fish for inland communities (Bell et al., 2018), integrated aquaculture and agriculture, or polyculture/integrated multi-trophic aquaculture systems (IFAD, 2014), creating new or diversifying market opportunities (Allison et al., 2009; Gianelli et al., 2021), employing more family labor (Deb and Haque, 2016), involvement in national livestock programs (Ndhlovu et al., 2017), land-based farming (e.g. coconut farming, rice farming, Jasmine tea farming), driving motorcycle taxis, short-term construction labor, boat financing, diversifying into other businesses (Fauzi and Anna, 2010; Macusi et al., 2020), etc.

Unlike switching focus in terms of species or gears, changing of traditional livelihoods require much more active support, and research notes that national institutes could encourage and facilitate the learning of alternative skills, introduce transformative measures to accommodate switching livelihoods and promote diversification through consultative processes (Abu Samah et al., 2016; GIZ, 2019; Salagrama, 2012; Shaffril et al., 2017a, 2017; Yuerlita et al., 2013). Additionally, when no alternative income is found, then national

institutes can take special initiatives to accommodate unemployed groups (Deb and Haque, 2016). Shaffril et al. (2017b) even argue for a periodical assessment of fishermen readiness to diversify their technology skills and knowledge.

3.1.5.5 Access to finances

Strategies under the livelihood category often depend on access to finances for individuals. Tools to improve this include better access to insurances (FAO, 2018; GIZ, 2019; IFAD, 2014; Islam et al., 2014; Jara et al., 2020; Ndhlovu et al., 2017; Senapati and Gupta, 2017), e.g. natural calamity insurance or disaster insurance to cover loss of fishing gear (Iwasaki et al., 2009), microfinance (Allison et al., 2009; FAO, 2018) such as credit (Cinner et al., 2018; Deb and Haque, 2016; FAO, 2018; Haque et al., 2015; IFAD, 2014; Islam et al., 2014; Iwasaki et al., 2009; Macusi et al., 2020; Shaffril et al., 2017a) and loans, e.g., for fishing gear and education expenses (Finkbeiner, 2015; Iwasaki et al., 2009). Financing also includes investments (FAO, 2018; Finkbeiner, 2015), e.g., investing in key infrastructure (IFAD, 2014) and climate resilient infrastructure (Iwasaki et al., 2009). However, the source of financing for these investments is often not mentioned except by some NGOs. Other financial opportunities are, for instance, mangrove planting for coastal restoration and carbon sequestration (IFAD, 2014). Finally, a distinction between financing and other types of funding is that the former can include many more streams of capital, but, unlike insurances or grants, loans must be repaid (with interest) by individual borrowers (especially in the case of microfinance), communities, or their legal representatives.

3.2 Time-support framework

In the next step, we plotted these same strategies we gathered from academic and grey literature onto the time-support framework according to the time and external support required to implement these strategies (Figure 5). This should be seen as a theoretical example of the application of this diagram because how much time and external support a specific strategy requires is, of course, case specific. We argue though that it is still relevant to show our theoretical interpretation here as we explain the placement of the strategies below.

3.2.1 Institutional category

3.2.1.1 Policies, regulations, and obtaining external support

Fishers and fishing communities will need a high external help to implement those strategies since other people will have to make these changes for them. Changes in policies and regulations and decisions on funding can be short and long-term, depending on the institutions and decision-makers.

3.2.2 Communication category

3.2.2.1 Promoting inclusivity and participation

Meaningful participation takes time because it requires strengthening ties between actors, building trust, and incorporating diverse and complementary knowledge (Semitiel-García and Noguera-Méndez, 2019). Communities might require support to compensate for time and money lost while not fishing and to help

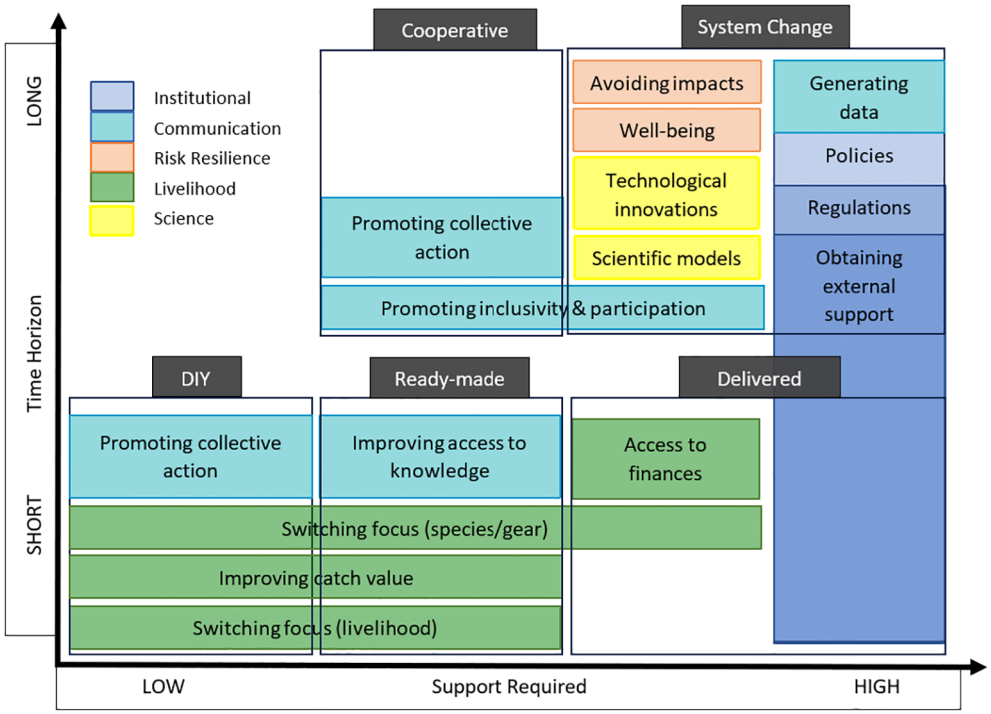

FIGURE 5
Time-support analysis of the adaptation strategies with the amount of support needed for the implementation of the strategy on the x-axis and the amount of time needed on the y-axis. The colored fields represent the categories (dark blue – Institutional, turquoise – Communication, orange – Risk Resilience, green – Livelihood, and yellow – Science).

facilitate long-term and effective leadership succession (Sutton and Rudd, 2016). This strategy is therefore placed on medium external support on the x-axis and longer time on the y-axis.

3.2.2.2 Promoting collective action

Similarly to participation, financial, human, and social capital can hinder or support participation in leadership activities and collective action (Sutton and Rudd, 2016). When a community is cohesive and good leadership is present, low external support and short time is required. When this is not the case, it can take more external support and time to reach a point where meaningful collective action is possible. This strategy is therefore placed under both low external support and short-term, and medium external support and long-term.

3.2.2.3 Improving access to knowledge: information for people

Information can be shared with and between fishers and fishing communities. To foster learning requires training programs to create a sustainable learning environment for both traditional and non-traditional knowledge, set up community platforms to create physical and/or online workshops - which can also enhance sharing insights and collective learning, improve digital access and training to overcome technological barriers and digital illiteracy, and encourage intergenerational dialogues to facilitate conversations and mentorship between age groups (Pratiwi et al., 2023). This strategy is therefore placed under medium support to organize conversations, dialogues, workshops, online platforms, and training opportunities.

3.2.2.4 Generating data: information for institutions

Traditional fisheries stock assessment methods and fishery independent surveys are costly and time-consuming exercises (Prescott et al., 2016). Although there are tools being developed and employed to speed up the processing or collection of data through, for instance, data collecting sensors attached to fishing vessels (Van Vranken et al., 2023), data collection and monitoring the environment and natural resources is still a timely and costly process (e.g. Darcy Bradley et al., 2019).

3.2.3 Science category

3.2.3.1 Improving scientific models

Similarly, we first need to collect data which are already costly and time-consuming. Secondly, improving our models so that managers can make science-based natural resource management decisions using climate models, marine ecosystem models, etc. will also take time and resources (Fulton et al., 2011).

3.2.3.2 Technological innovations

New technologies are usually expensive and are slow to implement (Reid et al., 2019). Both strategies are therefore placed under high external support and long-term.

3.2.4 Risk resilience category

3.2.4.1 Avoiding impacts

Restoring mangroves or other natural ecosystems to create a natural protection takes a long time and is usually very costly, often without a lot of success either (Lewis, 2001; Worthington and Spalding, 2018; Zimmer et al., 2022). On the other hand, hard infrastructure such as seawalls and breakwaters are also very expensive ranging from $1.6 to 2.7 billion to protect coral reefs in the Maldives – although this is low compared to the annual cost to protect and maintain these ecosystems which can be up to $47 million (Ogundele and Ubaekwe, 2019). Similarly, early warning systems & preparedness plans are costly (investments, data collection, hazard monitoring, operational expenses) and timely (train people for basic maintenance, data collection, to operate the systems, and to become good decision-makers). Systems like this need continuous updating and monitoring, so there's a constant cost rather than a one-time payment (Basher, 2006; Garcia and Fearnley, 2012; Hallegatte, 2012).

3.2.4.2 Improving individual and community well-being

Improving well-being through changes in access to education, health care, and decent housing and infrastructure can, depending on the local context, be a long and costly process. Both strategies are therefore placed under high external support and long-term.

3.2.5 Livelihood category

3.2.5.1 Switching focus – livelihood

There is an array of jobs that fishers can switch to, if they want to and if conditions allow. To some jobs they can comparatively easy switch to, i.e. jobs that do not require extra training when labor skill & mobility are matched with their current practices such as agriculture or livestock production, operating motorcycle transport services, managing a small general store, or other forms of manual labor such as construction work, wage labor for road construction, or factory work (Fabinyi et al., 2016). Other jobs require more training to learn new skills or crafts, or investments and in some cases fishers need external support to access a bigger city, land and/or capital (Hanh and Boonstra, 2019; Kc et al., 2019). This strategy is therefore spread across the x-axis from low to medium external support required.

3.2.5.2 Switching focus – species and/or gear

For some coastal communities, changing target species is a common tactic whereby a combination of vessels and gears are easily adapted to fish different species in different physical (spatial and temporal) and organizational contexts, allowing fishers to easily switch species and/or gear (Salas and Gaertner, 2004). For others, there can be constrains on the types of gear used, where and when to fish, which fish to target, the size of the fish that can be taken, and who and how many people can participate in which fishery and diversifying would require access to multiple permits, licenses, quota or territorial use rights acquired from various governing bodies or purchased or leased from private firms (Stoll et al., 2017). This strategy is therefore spread across the x-axis from low to medium/high external support required.

3.2.5.3 Improving catch value

Most tools focused on improving catch value from current practices through market-based interventions to increase prices of catch. This is easier when fishers have good personal contacts with chefs, or when they are able to have a fish stand to sell directly to local people or tourists (Ertör et al., 2023). In other cases, fishers will need external support in terms of investments, broader networks, or training and workshops to acquire new business skills and learn how to e.g. attribute the correct price to their own product or how to market it to improve their profit (Di Cintio et al., 2022). This strategy is therefore spread across the x-axis from low to medium external support required.

3.2.5.4 Access to finances

obtaining formal bank credit requires assets as collateral, education, knowledge of the credit system and good relationships with credit providers (Islam et al., 2014). This strategy is therefore placed under high external support and short-term.

3.3 Case study – application of the new framework

By asking the participants which strategies and tools are important to them, we can create an overview that helps us to identify which strategies and categories need more attention (Figure 6). We can also look for match-mismatch strategies between fishers themselves, or between fishers and non-fishers. Most participants from this exercise during our field work in Mexico, for instance, found that most of the tools to improve the livelihood strategy were not important. All participants, on the other hand, agreed that improved access to health care is important to them (Figure 6). Popular tools for almost all participants included aquaculture innovation, better surveillance so fishing laws are respected, capacity building and workshops for fishers, government assistance in terms of monetary contributions, government assistance in terms of specific material contributions, local tourism as a livelihood alternative, and increasing unity among local people. Most fishers thought excess capacity should be reduced, while non-fishers did not think this was important. Vice versa, non-fishers wanted more data on species being fished (where, when, how much) and their biology, while none of the fishers thought this was important. There are no restrictions on where to fish in the study area, except for one protected zone, so almost all participants marked the strategy of having more flexibility in where to fish as not important. If they wanted to fish elsewhere it would be more a matter of going further out to sea, but the barriers to do so are not having the proper boats nor money for gasoline.

When plotting the data of the Mexican field work exercise on the amount of time and support needed to implement the important strategies according to Figure 2, we can have an overview of those two important elements (time and support) and compare them across all participants. Supplementary Figure S1 in Supplementary Material gives a detailed overview of those results plotted on the time-support framework. In general, when comparing the amount of support indicated by fishers vs. non-fishers (Figure 7), then most fishers indicated that most (75%) of their important adaptation actions require high external support for implementation, while non-fishers think that fishers can implement more actions themselves, with less external support. Only 49% of the actions that non-fishers thought were important, were marked with a need for high external support (Figures 6, 7). For the time component, fishers indicated that implementing most adaptation actions will take either short, or long time, while non-fishers think that most actions will take medium amount of time to implement.

4 Discussion

We adapted the FAO adaptation framework for small-scale fisheries and organized the toolbox of climate change adaptations for SSFs and at the same time focused on its implementations. We also showed its usefulness with a practical example of its application in the field. To be clear, constant adaptation is a hallmark of SSFs, yet specific literature on examples of implemented climate adaptation strategies was mainly found since 2015. This increase in research interest is unsurprising given the overall recognition of escalating climate impacts, but could also be due to the publication of the FAO 'Voluntary Guidelines for Securing Sustainable Small-scale Fisheries in the Context of Food Security and Poverty Eradication' (FAO, 2015). This galvanized international recognition for SSF research focused on local scales and contexts (Jentoft et al., 2017) and contributed to the declaration of the 2022 International Year on Artisanal Fisheries and Aquaculture by FAO. Most SSFs adaptation strategies came from case studies from developing countries, even though there are many SSFs in developed countries as well. This may be due to a lower perceived resilience of SSFs (and broader communities) in developing countries, and because of the larger expected climate (and ecological) changes in the tropics compared with other regions. While these characteristics of SSFs in developing countries do warrant particular research attention and financial support, we note that SSFs from developed countries face their own challenges and will also require adaptation strategies to be identified and implemented. Nevertheless, the toolbox and time-support framework are still very useful in context of developed countries since there are significant overlaps of strategies for SSFs in both developed and developing countries, such as livelihood diversification, among other ecotourism, changing of quotas and species caught, increasing the added value of the catch, etc. (e.g. Aguilera et al., 2015; Payne et al., 2021; Prosperi et al., 2019).

Different climate adaptation strategies will apply to different local communities, as their needs are location and context specific. There is therefore no set of strategies that will guarantee success. Nevertheless, some studies argue to have identified some key elements of successful adaptation strategies, which are increased involvement and co-management, and livelihood diversification (Galappaththi et al., 2021; Gianelli et al., 2021; Kalikoski et al., 2010). In addition, due to the reduced variety in catchable species and ever tighter legislations (Symes et al., 2015), then many

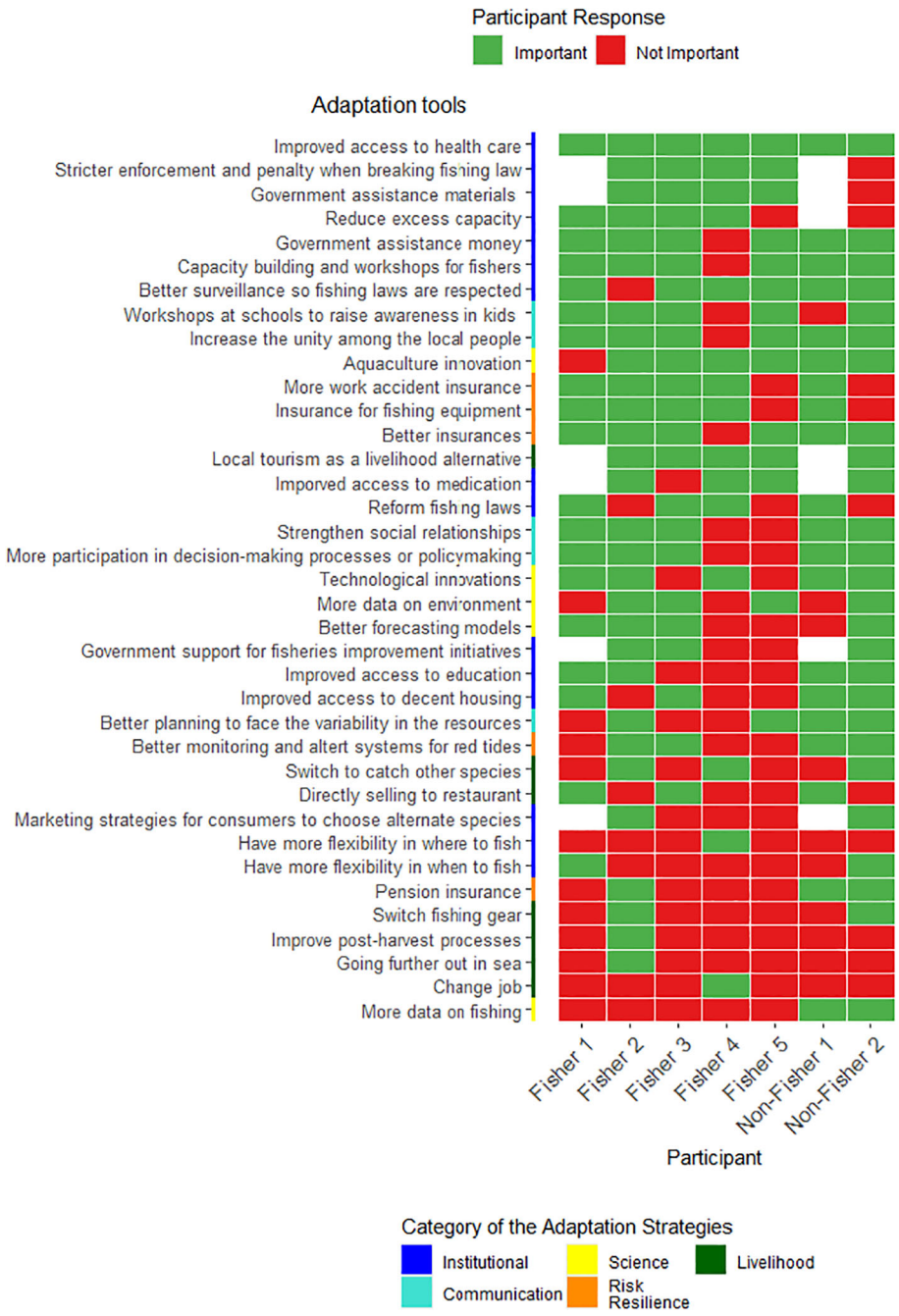

FIGURE 6
Adaptation strategies and tools indicated by respondents involved in Mexican octopus fishery (the tools are colored based on the categories in Figure 4). Green means the adaptation tool was indicated as important for that participant group, red means it was not important. Adaptation tools are in order according to number of fisher-respondents indicating each as important. Some show empty fields because new tools were introduced by participants after some participants already did the exercise, so these were not yet presented as options to previous participants.

researchers call for a higher degree of flexibility and adaptation strategies of flexible management tools, enabling a quicker response to a changing environment e.g., flexibility in livelihoods or fishing operations (temporal and spatial) of effort, target gear and species (Aguilera et al., 2015; Allison et al., 2009; FAO, 2018; Gianelli et al., 2021; GIZ, 2019; Le Cornu et al., 2018; Payne et al., 2021; Sievanen, 2014). Adaptive management like this should however be done properly, with full transparency, downward accountability and well-funded (Zulu, 2012). Otherwise there is a risk for incomplete decentralization, leading to competition, conflict, empowerment of privileged locals and mistrust, which would have the reverse effect and create more inequity within the community (Theesfeld and Schmidt, 2011; Zulu, 2012).

The most mentioned type of adaptation strategy comes from the Livelihood category, which broadly aims to diversify the activities and income of a fishing community. In practice, this comprises quite

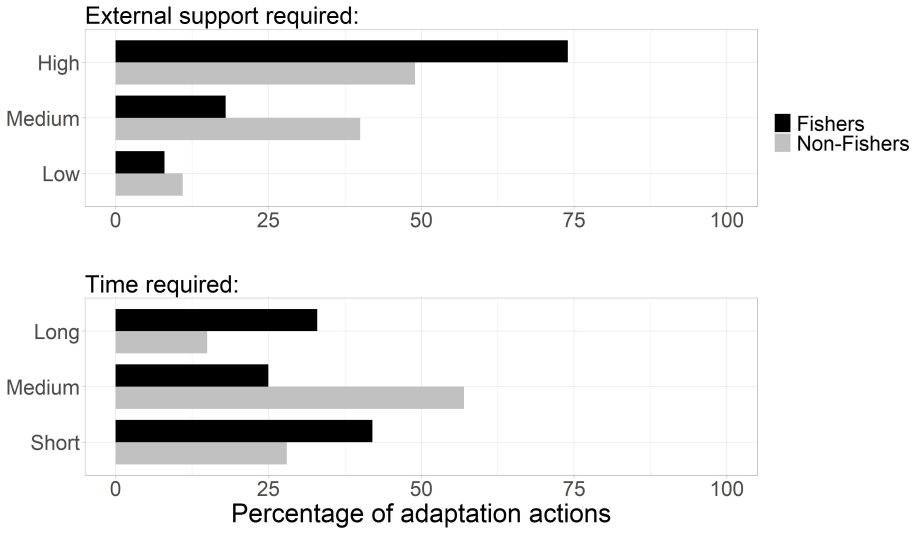

FIGURE 7
Fishers' and non-fishers' perceptions of the time and support required to implement climate change adaptation actions in the Mexican octopus fishery (% of all actions indicated, N = 37).

different specific tools and actions ranging from ones that can be readily adopted by fishers to others that need more support. These include, for example, switching fishing gears and/or target species, exploring freshwater resources, pescatourism, working on industrial fishing vessels, agriculture, or other temporary jobs (Deb and Haque, 2016; GIZ, 2019; IFAD, 2014; Islam et al., 2014; Jara et al., 2020; Kalikoski et al., 2010; Macusi et al., 2020; Payne et al., 2021; Prosperi et al., 2019; Salagrama, 2012; Shaffril et al., 2020; Sievanen, 2014). In this context, being less specialized is argued to be an advantage (Coulthard, 2008). Interestingly, diversifying activities has been found to occur more when individuals and households have a stronger social capital, especially family-centered systems of support (Leite et al., 2019). This links back to the element of self-organization. Even though diversification is mainly a bottom-up process, governmental support might be essential in order for it to be a successful adaptation strategy (Kalikoski et al., 2010), as was shown also during our exercises. Even though this adaptation strategy is mentioned most often, it's not always as straightforward. Switching to agriculture requires people to have access to land or farmers willing to hire fishers to work on their land, working in a factory is easier because it only requires little investment, on the other hand, it often requires them to move to a big city, while older people might be less mobile to move somewhere else or to learn new skills (Kc et al., 2019; Hanh and Boonstra, 2019). Even in developed countries, SSFs usually involve a high capital investment (bigger boats and engines, more expensive permits, etc.) which makes it harder for them to switch livelihood (Kc et al., 2019). Similarly, switching species/gear will not only depend on the available permits and regulations, but also on the market and price of the catch. When switching to a lower market value species, fishers might have more expenses on gasoline then the return of the catch (Stoll et al., 2017).

Following from the above, our framework based on required time and support highlights two differentiated groups of alternative livelihoods (Figure 5). One group requires minimal additional training where people switch between modes of fishing or between one manual labor occupation to another. For instance, switching from fishing to agriculture or becoming a driver (Fauzi and Anna, 2010; Kalikoski et al., 2010; Macusi et al., 2020). Another group requires more training, education, or financial support to do the switch. For instance, starting a new business—even in seemingly related activities such as marine tourism—or developing aquaculture facilities (Fauzi and Anna, 2010; Macusi et al., 2020). Finally, we must be cautious with the alternative livelihoods that are being suggested since some e.g., agriculture or livestock, are also equally at risk of being significantly impacted by climate change (Gebre et al., 2023; Griffin et al., 2023).

We were often not able to distinguish the adaptation strategies, suggested in literature, whether they originated from the local people themselves or proposed by the person conducting the research. One of the successful strategies identified throughout case studies is, nonetheless, the importance of inclusivity, participation and incorporating the voices of local people, for instance by engaging local communities and institutes at the beginning and throughout the policy-making processes (Ayers, 2011; Gianelli et al., 2021; Hasan and Nursey-Bray, 2018). The method we present here, does exactly this. The application of the toolbox and the time-support framework using the participatory exercise has shown that it allows for the voices of the fishers to be heard. It is important that we ask the fishers what *they* need to adapt and what the time and support requirements they think would be necessary to implement the adaptations. Such inclusion increases the chances of a successful adaptation and leads to a more desired outcome because firstly, it improves the understanding and integration of local perceptions of change and appropriate adaptation strategies (Hasan and Nursey-Bray, 2018). Secondly, the adaptation strategies will be more aligned with the needs, rights and values of the local communities (Barnett and Campbell, 2010), and thirdly, the inclusion can develop a sense of ownership over the project (Le Cornu et al., 2018). It is important though that participation is not

just symbolic, and includes a thoughtful consideration of the location and time of the meetings, the invitations, and transportation costs to the location (Kalikoski, 2002; Kalikoski et al., 2010), as well as people's motivations, their benefits, satisfactions, skills and capacities (Cinner, 2014). In addition, researchers should pay attention to existing power asymmetries, social inequities, and lack of trust that can impact broad participation and fairness in distributed outcomes (Barnaud et al., 2014; Quimby and Levine, 2018). Though participation can be a long and costly process, there are new methodologies being developed of, for instance, online tools to help engage with participants taking into account restrictions of time, budget and the ability of stakeholders to join physically (Markantonatou et al., 2016).

One way to improve inclusion is for local communities to organize themselves and/or enter into more formal co-management arrangements (Kalikoski et al., 2010). Having a community-based institution to cope with common challenges and resources (Ostrom, 1990) is a popular approach and adaptation strategy (Aguilera et al., 2015; Allison et al., 2009; Bell et al., 2018; Berkes and Armitage, 2010; Galappaththi et al., 2021; Gianelli et al., 2021; IFAD, 2014; Jara et al., 2020; Le Cornu et al., 2018). In practice however, whether people are willing to comply with co-management initiatives and engage in collective actions will also depend on their context, such as poverty, shortage of labor or capital, which should be taken into consideration (Cinner, 2014). Note, however, that accountability must still rest with the institutions charged with supporting well-being in these communities, as 'incomplete decentralization' can muddle jurisdictions and shift responsibility for providing basic needs onto communities themselves (Méndez-Medina et al., 2020; Schneider, 2019). A high-level involvement and sharing of knowledge, power and responsibilities in decision-making would be for the fishery community to fully co-manage its fishery resources with governments and other actors (Armitage, 2007; Berkes, 2009). The co-management of resources would be better at problem definition, social learning, innovation and more effective at conflict resolution (Berkes, 2009). d'Armengol et al. (2018) also found that co-managed SSFs have an increased abundance and habitat of species, fish catches, actors' participation as well as a higher adaptive capacity. In addition, they found that co-management is more successful if it is socially diverse. In these cases, the framework we suggest here could be useful in clarifying and making more transparent the specific responsibilities of different actors in the co-management system.

One group often absent from policy-making decisions are women (Choo et al., 2008; Heck et al., 2007; Santos, 2015). Millions of women are directly engaged in small scale fisheries (Thorpe et al., 2013; World Bank, 2012) with a wide range of activities including among others capture fishing, gleaning, trading, processing, net mending, management/administration (Deb et al., 2015; Santos, 2015; Weeratunge et al., 2010; Zhao et al., 2014). Thorpe et al. (2014) found that women would more often diversify their labor, instead of specializing, because of their varied roles within the household and the community. They could therefore play a key role in changes in commercial practices and value adding activities (Monnier et al., 2020). However, as women often already take on most responsibilities of childcare and household labor, being additionally responsible for the burdens of the costs of adaptation strategies will lead to increased stress and childcare concerns and decreased well-being (Coulthard and Britton, 2015). Accordingly, it is important that the role of women be acknowledged as their work and, more importantly, their rightful participation in community-level decisions has been systematically discounted, undervalued, and underrepresented (Deb et al., 2015; Fitriana and Stacey, 2012; Koralagama et al., 2017). This would moreover increase their inclusion in decision-making processes (Thorpe et al., 2014). Zhao et al. (2014) therefore encourage women to organize themselves in order to enhance their participation in both fisheries related activities as well as decision-making processes, e.g., the Women in Fisheries movement in the UK (Britton, 2012).

Some of the adaptation tools presented in this study are government related while others are, for example, livelihood related. Therefore, different actors will use different tools, which generates top-down or bottom-up adaptation pathways. Whether an adaptation strategy is top-down or bottom-up is again location and context specific. For example, the co-management approach for the yellow clam SSF in Uruguay was initially advised by the government, but in the end fishery leaders mainly developed it by changing their marketing strategies and selling high quality products directly to restaurants (Gianelli et al., 2021). In addition, institutional structures of SSFs also differ. the Arctic Inuit SSF institutional structure mostly has a top-down approach while the Sri Lankan Coastal-Vedda SSF structure has a bottom-up approach (Galappaththi et al., 2021), yet both are seen as legitimate avenues for local adaptation. In any circumstance, autonomous bottom-up actions first require specific awareness of climate change (Hodgkinson et al., 2014), which is influenced by exposure to and communications about it. Secondly, it requires communities to have suitable levels of access to formal power and assets (Pecl et al., 2019). This is also clearly shown by the Mexican octopus case-study presented, since most of the strategies indicated as important for the fishers, were also marked with a high need for external support to realize them. Some top-down strategies involve direct financial support from governmental or non-governmental organizations. Those short-term, high-support (Delivered category) strategies should be carefully selected to address underlying issues, not only symptoms (Cisneros-Montemayor et al., 2016), and they should aim to support fishers, not the fishing (Cisneros-Montemayor et al., 2020). They should be fostered by open dialogue and co-management frameworks in alignment with local priorities in order to avoid harmful subsidy programs to be set up with unpredictable and unclear results (Cisneros-Montemayor et al., 2016; Wabnitz and Blasiak, 2019). In addition, there is a risk that transnational financing favors geopolitical objectives from the nation funding the program (Wabnitz and Blasiak, 2019). Finally, external support in terms of physical and/or financial assets will be more successful when human and social capital foundations of the group are strong (Stanford et al., 2014).

Climate change adaptation is often a response to multiple stresses related to climatic impacts and will therefore not only focus on one area, but it is often a combination of several actions in

different fields such as livelihood, fishing gear, management, population dynamics, etc (Adger, 2006; Metcalf et al., 2015; Nelson et al., 2007). In addition, there will be other stressors than climate change that will put pressure on the ecosystem as well, such as pollution, habitat degradation, market demands, invasion of local waters by foreign vessels, etc (Freduah et al., 2017). An inter-disciplinary, integrated and holistic approach should therefore include all different aspects, also other stressors, in order to reach a successful adaptation (Bell et al., 2018; IFAD, 2014), though this was not common in the examples we gathered. The United Nations Decade of Ocean Science for Sustainable Development similarly calls for "transformative ocean science solutions for sustainable development, connecting people and the ocean." In general, only few studies mention the need for more science in fisheries and aquaculture (Allison et al., 2009) or technological innovations (Allison et al., 2009; Payne et al., 2021; Salagrama, 2012), while most NGO reports we reviewed cite this need based on workshops and interviews with fisheries communities (FAO, 2018; GIZ, 2019; IFAD, 2014; Monnier et al., 2020). Singh et al. (2021) however, points out that we must carefully consider the needs and priorities of ocean-dependent peoples and they argue that research should be done in collaboration with the people whose livelihood depends on the ocean to avoid unintended consequences and unjust outcomes. More/better science will not necessarily address their needs.

There are many barriers to successful, efficient, and equitable adaptations, and integrating multiple climate change stressors, adaptation strategies, and involved and affected actors, is a huge challenge (Pecl et al., 2019). Some were already discussed with respect to the Communication strategy, e.g., a lack of climate change awareness or names in local languages for key concepts of climate change and adaptation (Hasan and Nursey-Bray, 2018). However, other barriers related to basic needs, well-being, and enabling governance conditions beyond fish and fisheries themselves have not yet been emphasized. As Coulthard and Britton (2015) discussed in the case study for the Northern Ireland SSFs, there are some hard choices and trade-offs that fishers need to make that are often overlooked when talking about adaptation strategies, but that significantly impact their well-being. Examples are trade-offs in close relationships such as family relations and security when a spouse must go further out in sea, spending significant periods at sea, away from the family, often alone to reduce the costs of crew, but increasing safety risks. As well as at the community level where relations between boat owners and crew workers are declining due to poor integration of foreign workers and the lack of support for women in fishing communities. Adaptation strategies should therefore also focus on turning around the negative impacts of such wellbeing trade-offs, perhaps by focusing on health care, food security, basic housing, childcare support, improved social networks, or by focusing on the next generation through education. However, only few articles mentioned these strategies – e.g. Abu Samah et al., 2016; Cinner et al., 2018; Coulthard and Britton, 2015; Deb and Haque, 2016; GIZ, 2019; Islam and Chuenpagdee, 2022; Monnier et al., 2020; Salagrama, 2012; Shaffril et al., 2013. Generally, we also need to do better at carrying out social science methodologies in fishing and coastal communities (Le Cornu et al., 2014).

Finally, the implementation of the strategies will be a crucial part of the adaptation process. As was clear from our test case in Mexico where most of the adaptation actions that the fishers thought were important to them, were marked as high external support required to implement the actions. Interestingly, the non-fishers thought that fishers could do more of the adaptations themselves, without as much external support needed. In addition, the fishers thought that most of the livelihood adaptation strategies were not important to them, while in literature, this is the most cited strategy (Supplementary Table S1; Figure 4). Despite the small sample size and that one participant said yes to almost all adaptation tools presented because of the desperate need for change, the practical application of the adaptation toolbox and time-support framework still demonstrated its potential use in the field. The exercise is easy to comprehend, it can be done solo or in group, it gives a voice to the people and a good overview of the perspectives, livelihood challenges and problems the people are facing, and including information on time and external support will provide important information to create a starting point to then continue the planning of the implementation process. By conducting workshops with the local fishers and conducting the exercise as is described in the paper, we hope that governments, NGOs, and local communities can operationalize the framework and enabling them to listen to perspectives of these communities, drawn from their own contexts and lived experiences.

The implementation will, of course, depend on local infrastructure and capacity (Hallegatte, 2012). For example, instrumentation for monitoring is often either controlled by private companies or is part of a scientific project that runs for a limited period of time (Garcia and Fearnley, 2012). It will therefore be important to take a holistic approach and find out who has what role and power in the communities and their institutional organizations and how much resources and time is required for training and implementing the strategies (Sowman, 2020). Adaptation is an ongoing and iterative process that involves strong partnerships and networks and successful implementation requires planners, engineers, scientists, decision makers, etc., and the local stakeholders to sit together and engage in explicit discussions on the confronted problems of the stakeholders, which often have trans-organizational causes and impacts (Malekpour et al., 2017). Future research would therefore require looking into mechanisms towards the actual implementation of the strategies and in-depth information on the topics such as: What strategies require priority? Which partners are involved? How much funding is required and from whom? What kind of skills need to be acquired and how? Who is responsible for what? What are the challenges to be expected in this process? What is the role of cooperative governance in ensuring equitable outcomes for fishers? Etc. Additionally, developing proper mechanisms to monitor and evaluate the success of the adaptation strategies will be important to ensure the accountability and sustainability of the strategies.

Through the review we also noticed that there is a significant lack of discussion about equity and justice perspectives in climate adaptation. Social equity should be better integrated in marine policy (Bennett et al., 2021) as shown by the IPCC who has pointed to the disproportionate burden of certain communities due to their geographic contexts (IPCC, 2022), and others who are concerned

that environmental changes can exacerbate these inequities due to limited governance structures (Cheung et al., 2019). This concern has already been raised for ocean-based development under a Blue Economy approach involving broader ocean sectors (fisheries, renewable energy, aquaculture, etc.), but to date this has not been implemented and it is not clear if it will be successful (Cisneros-Montemayor et al., 2021). Thus, when selecting and implementing adaptation strategies we have to reflect on where, when, and why issues of equity are being considered and at which stages in the decision-making process, what is being distributed and amongst whom, and what the equity implications are of governance structures and policies (Crosman et al., 2022).

5 Conclusion

In this study, we first adopted the FAO climate change adaptation framework and modified it to fit a broader range of adaptation tools and actions. The modified framework consists of 5 categories (areas of actions): Institutional, Communication, Livelihood, Risk Resilience and Science—and associated strategies that recognize a diversity of fisheries contexts and climate challenges yet offer similarities that can inform adaptation plans. Each of these strategies are informed by examples of adaptation tools that were gathered from academic and grey literature. In a second part, we assessed the implementation requirements of the adaptation strategies in terms of resources of time and external support. Finally, because of a lack of discussion in the literature about the relevance of the adaptation strategies, we ended this study with a method to test their relevance through a participatory exercise.

Based on findings in this study, fishers can consider adaptation strategies such as improving current practices, diversification, and collective action, while they work and are supported towards gaining more power to co-develop other strategies such as targeted government aid, changes in policy, or technological innovations. Even though we created a very comprehensive toolbox, since adaptation is very case-specific, more examples of adaptation tools could be added to the adaptation strategy list (especially since more communities face climate impacts), but our focus is on helping clarify the main strategies and requirements so that other examples can be considered with in this framework. This can be done, for instance, while conducting the participatory exercise, as described in this paper. In addition, we have also shown that only identifying the strategies is not enough to make it meaningful to the local people. What theoretically would seem like an easy adaptation, could, in reality, be much more cumbersome based on local rules, regulations, or needs for permits, approvals, social cohesion, or specific equipment. Adaptation is an ongoing, iterative process (Barnett et al., 2015; Brooks and Adger, 2005) and more effort should go towards finding appropriate climate change adaptations that focus on the goals and needs of SSF communities, the implementation process, and synergies between adaptation strategies that may enable communities to leverage their own capacity to achieve greater successes (Pecl et al., 2019; Tompkins and Eakin, 2012). This was especially apparent in the practical application of the adaptation framework during field work in Mexico. First, the results of the participatory exercise can give a useful overview of where and how people struggle to adapt. It shows which strategies are relevant for them and at the same time which ones are out of reach and the match-mismatch of relevance and implementation. Secondly, the participants responded positively to the exercise as it can lead to very interesting discussions with and in-between the participants. Importantly, this exercise can help in contexts where multiple collaborating actors may nonetheless need to better understand the perceptions of expected work and time required of other actors in the system. Finally, more studies are needed for different areas where this framework is applied in the field to assess the alignment between the adaptation strategies, their implementation cost and accessibility, and their relevance for the people that rely on fisheries and marine systems to make a living.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Research Ethics Board (REB), Canada. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

SB: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. YO: Conceptualization, Funding acquisition, Methodology, Supervision, Writing – review & editing. AP-F: Conceptualization, Data curation, Methodology, Writing – review & editing. AC-M: Conceptualization, Funding acquisition, Methodology, Supervision, Visualization, Writing – review & editing, Data curation.

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Conflict of interest

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

Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2025.1521526/full#supplementary-material

References

Abu Samah, A., Hamdan, M. E., Abu Samah, B., Hamzah, A., and Shaffril, H. A. M. (2016). Adaptation towards climate change among small-scalefishermen: A comparison between the East Coast and West Coast fishermen in Peninsular Malaysia. *Soc. Sci.* 11, 3458–3462.

Abu Samah, A., Shaffril, H. A. M., Hamzah, A., and Abu Samah, B. (2019). Factors affecting small-scale fishermen's adaptation toward the impacts of climate change—Reflections from Malaysian fishers. *SAGE Open* 9, 2158244019864204. doi: 10.1177/21582440198642

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

Adger, W. N., Arnell, N. W., and Tompkins, E. L. (2005). Successful adaptation to climate change across scales. *Global Environ. Change* 15, 77–86. doi: 10.1016/j.gloenvcha.2004.12.005

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

Allison, E. H., Perry, A. L., Badjeck, M. C., Adger, W. N., Brown, K., Conway, D., et al. (2009). Vulnerability of national economies to the impacts of climate change on fisheries. *Fish Fisheries* 10, 173–196. doi: 10.1111/j.1467-2979.2008.00310.x

Armitage, D. (2007). *Introduction: Moving Beyond Co-Management*. Eds. D. Armitage, F. Berkes and N. Doubleday (University of British Columbia Press: Adaptive Comanagement: Collaboration, Learning and Multi-Level Governance). doi: 10.59962/9780774855457-004

Armitage, D., Berkes, F., Dale, A., Kocho-Schellenberg, E., and Patton, E. (2011). Co-management and the co-production of knowledge: Learning to adapt in Canada's Arctic. *Global Environ. Change* 21, 995–1004. doi: 10.1016/j.gloenvcha.2011.04.006

Armitage, D., and Johnson, D. (2006). Can resilience be reconciled with globalization and the increasingly complex conditions of resource degradation in Asian coastal regions?. *Ecology and society*. (Resilience Alliance) 11(1): Article 2.

Ayers, J. (2011). Resolving the adaptation paradox: Exploring the potential for deliberative adaptation policy-making in Bangladesh. *Global Environ. Politics* 11, 62–88. doi: 10.1162/GLEP_a_00043

Barnaud, C., d'Aquino, P., Daré, W., Fourage, C., Mathevet, R., and Trébuil, G. (2014). Power asymmetries in companion modelling processes. In: M. Étienne (eds) *Companion Modelling* (Dordecht: Springer), 127–153. doi: 10.1007/978-94-017-8557-0_6.

Barnett, J., and Campbell, J. (2010). *Climate Change and Small Island States (1st ed.)*. (Routledge: Earthscan). doi: 10.4324/9781849774895

Barnett, J., Evans, L. S., Gross, C., Kiem, A. S., Kingsford, R. T., Palutikof, J. P., et al. (2015). From barriers to limits to climate change adaptation: Path dependency and the speed of change. *Ecol. Soc.* 20, art5. doi: 10.5751/ES-07698-200305

Basher, R. (2006). Global early warning systems for natural hazards: Systematic and people-centred. *Philos. Trans. R. Soc. A: Mathematical Phys. Eng. Sci.* 364, 2167–2182. doi: 10.1098/rsta.2006.1819

Behrens, J. W., van Deurs, M., Puntila-Dodd, R., and Florin, A.-B. (2019). *Policy brief: Round goby – a threat or a new resource?* (Copenhagen, Denmark: Nordic Council of Ministers). doi: 10.6027/NO2019-037

Bell, J. D., Cisneros-Montemayor, A., Hanich, Q., Johnson, J. E., Lehodey, P., Moore, B. R., et al. (2018). Adaptations to maintain the contributions of small-scale fisheries to food security in the Pacific Islands. *Mar. Policy* 88, 303–314. doi: 10.1016/j.marpol.2017.05.019

Bennett, N. J., Katz, L., Yadao-Evans, W., Ahmadia, G. N., Atkinson, S., Ban, N. C., et al. (2021). Advancing social equity in and through marine conservation. *Front. Mar. Sci.* 8. doi: 10.3389/fmars.2021.711538

Berkes, F. (2009). Evolution of co-management: Role of knowledge generation, bridging organizations and social learning. *J. Environ. Manage.* 90, 1692–1702. doi: 10.1016/j.jenvman.2008.12.001

Berkes, F., and Armitage, D. (2010). Co-management institutions, knowledge, and learnin: Adapting to change in the Arctic. *Etudes/Inuit/Studies* 34, 109–131. doi: 10.7202/045407ar

Britton, E. (2012). Women as agents of wellbeing in Northern Ireland's fishing households. *Maritime Stud.* 11, 16. doi: 10.1186/2212-9790-11-16

Brooks, N., and Adger, W. N. (2005). "Assessing and enhancing adaptive capacity," in *Adaptation policy frameworks for climate change: Developing strategies, policies and measures* (Cambridge, United Kingdom: Cambridge University Press), 165–181.

Brown, K. (2015). *Resilience, development and global change (1st ed.)*. (London: Routledge). doi: 10.4324/9780203498095

Bueno-Pardo, J., Nobre, D., Monteiro, J. N., Sousa, P. M., Costa, E. F. S., Baptista, V., et al. (2021). Climate change vulnerability assessment of the main marine commercial fish and invertebrates of Portugal. *Sci. Rep.* 11, 2958. doi: 10.1038/s41598-021-82595-5

Cheung, W., Ota, Y., and Cisneros-Montemayor, A. (2019). *Predicting Future Oceans: Sustainability of ocean and human systems amidst global environmental change* (Amsterdam, Netherlands: Elsevier).

Choo, P. S., Nowak, B. S., Kusakabe, K., and Williams, M. J. (2008). Guest editorial: Gender and fisheries. *Development* 51, 176–179. doi: 10.1057/dev.2008.1

Cinner, J. E. (2014). Coral reef livelihoods. *Curr. Opin. Environ. Sustainability* 7, 65–71. doi: 10.1016/j.cosust.2013.11.025

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

Cinner, J. E., Huchery, C., Darling, E. S., Humphries, A. T., Graham, N. A. J., Hicks, C. C., et al. (2013). Evaluating social and ecological vulnerability of coral reef fisheries to climate change. *PLoS One* 8, e74321. doi: 10.1371/journal.pone.0074321

Cisneros-Montemayor, A. M., Moreno-báez, M., Reygondeau, G., Cheung, W. W. L., Crosman, K. M., González-espinosa, P. C., et al. (2021). Enabling conditions for an equitable and sustainable blue economy. *Nature* 591 (7850), 396-401. doi: 10.1038/s41586-021-03327-3

Cisneros-Montemayor, A. M., Ota, Y., Bailey, M., Hicks, C. C., Khan, A. S., Rogers, A., et al. (2020). Changing the narrative on fisheries subsidies reform: Enabling transitions to achieve SDG 14.6 and beyond. *Mar. Policy* 117, 103970. doi: 10.1016/j.marpol.2020.103970

Cisneros-Montemayor, A. M., Sanjurjo, E., Munro, G. R., Hernández-Trejo, V., and Sumaila, U. R. (2016). Strategies and rationale for fishery subsidy reform. *Mar. Policy* 69, 229–236. doi: 10.1016/j.marpol.2015.10.001

Cole, V., and Boutet, M. (2023). ResearchRabbit. *J. Can. Health Libraries Assoc.* 44, 43–47. doi: 10.29173/jchla29699

Coulthard, S. (2008). Adapting to environmental change in artisanal fisheries-Insights from a South Indian Lagoon. *Global Environ. Change* 18, 479–489. doi: 10.1016/j.gloenvcha.2008.04.003

Coulthard, S., and Britton, E. (2015). Waving or Drowning: An Exploration of Adaptive Strategies Amongst Fishing Households and Implications for Wellbeing Outcomes: An exploration of adaptation. *Sociologia Ruralis* 55, 275–290. doi: 10.1111/soru.12093

Crosman, K. M., Allison, E. H., Ota, Y., Cisneros-Montemayor, A. M., Singh, G. G., Swartz, W., et al. (2022). Social equity is key to sustainable ocean governance. *NPJ Ocean Sustainability* 1, 4. doi: 10.1038/s44183-022-00001-7

d'Armengol, L., Castillo, M. P., Ruiz-Mallén, I., and Corbera, E. (2018). A systematic review of co-managed small-scale fisheries: Social diversity and adaptive management improve outcomes. *Global Environ. Change* 52, 212–225. doi: 10.1016/j.gloenvcha.2018.07.009

Dale, A., and Armitage, D. (2011). Marine mammal co-management in Canada's Arctic: Knowledge co-production for learning and adaptive capacity. *Mar. Policy* 35, 440–449. doi: 10.1016/j.marpol.2010.10.019

Deb, A. K., and Haque, E. C. (2016). Livelihood diversification as a climate change coping strategy adopted by small-scale fishers of Bangladesh. In: W. Leal Filho, H. Musa, G. Cavan, P. O'Hare and J. Seixas (eds) *Climate Change Adaptation, Resilience and Hazards*. Climate Change Management. Switzerland: Springer, Cham. doi: 10.1007/978-3-319-39880-8_21

Deb, A. K., Haque, E. C., and Thompson, S. (2015). [amp]]lsquo;Man can't give birth, woman can't fish': Gender dynamics in the small-scale fisheries of Bangladesh. *Gender Place Culture* 22, 305–324. doi: 10.1080/0966369X.2013.855626

Di Cintio, A., Scianna, C., and Prato, G. (2022). Analysis of small-scale fisheries value chain: An interview-based approach in Italian marine protected areas. *Fisheries Res.* 252, 106358. doi: 10.1016/j.fishres.2022.106358

Dudley, P. N., Rogers, T. L., Morales, M. M., Stoltz, A. D., Sheridan, C. J., Beulke, A. K., et al. (2021). A more comprehensive climate vulnerability assessment framework for fisheries social-ecological systems. *Front. Mar. Sci.* 8. doi: 10.3389/fmars.2021.678099

Ertör, I., Ertör Akyazi, P., and YeniEv, G. (2023). Community supported fisheries: diverse strategies of direct sales practices in istanbul's small-scale fishing cooperatives. *Tarım Ekonomisi Dergisi* 29, 1–14. doi: 10.24181/tarekoder.1246003

Etongo, D., and Arrisol, L. (2021). Vulnerability of fishery-based livelihoods to climate variability and change in a tropical island: Insights from small-scale fishers in Seychelles. *Discover Sustainability* 2 (1), 48. doi: 10.1007/s43621-021-00057-4

Fabinyi, M., Dressler, W., and Pido, M. (2016). Do fish scales matter? Diversification and differentiation in seafood commodity chains. *Ocean Coast. Manage.* 134, 103–111. doi: 10.1016/j.ocecoaman.2016.09.023

FAO (2015). *Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication* (Rome: Food and Agriculture Organization of the United Nations).

FAO (2018). *Impacts of climate change on fisheries and aquaculture—Synthesis of current knowledge, adaptation and mitigation options* (Rome, Italy: Food and Agriculture Organization of the United Nations).

Fauzi, A., and Anna, Z. (2010). Social resilience and uncertainties: the case of small-scale fishing households in the north coast of Central Java. *MAST*, 9 (2), 55-64.

Finkbeiner, E. M. (2015). The role of diversification in dynamic small-scale fisheries: Lessons from Baja California Sur, Mexico. *Global Environ. Change* 32, 139–152. doi: 10.1016/j.gloenvcha.2015.03.009

Fitriana, R., and Stacey, N. (2012). The role of women in the fishery sector of Pantar Island, Indonesia. *Asian Fisheries Sci.* 25S, 159–175.

Ford, J. D., Pearce, T., Smit, B., Wandel, J., Allurut, M., Shappa, K., et al. (2007). Reducing vulnerability to climate change in the arctic: the case of Nunavut, Canada. *ARCTIC* 60, 150–166. doi: 10.14430/arctic240

Ford, J. D., Smit, B., and Wandel, J. (2006a). Vulnerability to climate change in the Arctic: A case study from Arctic Bay, Canada. *Global Environ. Change* 16, 145–160. doi: 10.1016/j.gloenvcha.2005.11.007

Ford, J. D., Smit, B., Wandel, J., Allurut, M., Shappa, K., Ittusarjuat, H., et al. (2008). Climate change in the Arctic: Current and future vulnerability in two Inuit communities in Canada. *Geographical J.* 174, 45–62. doi: 10.1111/j.1475-4959.2007.00249.x

Ford, J. D., Smit, B., Wandel, J., and MacDonald, J. (2006b). Vulnerability to climate change in Igloolik, Nunavut: What we can learn from the past and present. *Polar Rec.* 42, 1–12. doi: 10.1017/S0032247406005122

Freduah, G., Fidelman, P., and Smith, T. F. (2017). The impacts of environmental and socio-economic stressors on small scale fisheries and livelihoods of fishers in Ghana. *Appl. Geogr.* 89, 1–11. doi: 10.1016/j.apgeog.2017.09.009

Freduah, G., Fidelman, P., and Smith, T. F. (2019). A framework for assessing adaptive capacity to multiple climatic and non-climatic stressors in small-scale fisheries. *Environ. Sci. Policy* 101, 87–93. doi: 10.1016/j.envsci.2019.07.016

Fulton, E. A., Link, J. S., Kaplan, I. C., Savina-Rolland, M., Johnson, P., Ainsworth, C., et al. (2011). Lessons in modelling and management of marine ecosystems: The Atlantis experience. *Fish Fisheries* 12, 171–188. doi: 10.1111/j.1467-2979.2011.00412.x

Furgal, C., and Seguin, J. (2006). Climate change, health, and vulnerability in Canadian northern Aboriginal communities. *Environ. Health Perspect.* 114, 1964–1970. doi: 10.1289/ehp.8433

Galappaththi, E. K., Ford, J. D., Bennett, E. M., and Berkes, F. (2021). Adapting to climate change in small-scale fisheries: Insights from indigenous communities in the global north and south. *Environ. Sci. Policy* 116, 160–170. doi: 10.1016/j.envsci.2020.11.009

Garcia, C., and Fearnley, C. J. (2012). Evaluating critical links in early warning systems for natural hazards. *Environ. Hazards* 11, 123–137. doi: 10.1080/17477891.2011.609877

Gearheard, S., Matumeak, W., Angutikjuaq, I., Maslanik, J., Huntington, H. P., Levitt, J., et al. (2006). It's Not that Simple": A collaborative comparison of sea iceenvironments, their uses, observed changes, and adaptations in barrow, Alaska, USA, and ClydeRiver, Nunavut, Canada. *Ambio* 35, 203–211. doi: 10.1579/0044-7447(2006)35[203:INTSAC]2.0.CO;2

Gebre, G. G., Amekawa, Y., Fikadu, A. A., and Rahut, D. B. (2023). Farmers' use of climate change adaptation strategies and their impacts on food security in Kenya. *Climate Risk Manage.* 40, 100495. doi: 10.1016/j.crm.2023.100495

Gianelli, I., Ortega, L., Pittman, J., Vasconcellos, M., and Defeo, O. (2021). Harnessing scientific and local knowledge to face climate change in small-scale fisheries. *Global Environ. Change* 68, 102253. doi: 10.1016/j.gloenvcha.2021.102253

GIZ (2019). *Climate change and small-scale fisheries* (Germany: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH).

Griffin, C., Wreford, A., and Cradock-Henry, N. A. (2023). [amp]]lsquo;As a farmer you've just got to learn to cope': Understanding dairy farmers' perceptions of climate change and adaptation decisions in the lower South Island of Aotearoa-New Zealand. *J. Rural Stud.* 98, 147–158. doi: 10.1016/j.jrurstud.2023.02.001

Gupta, J., Termeer, K., Klostermann, J., Meijerink, S., van den Brink, M., Jong, P., et al. (2010). The Adaptive Capacity Wheel: A method to assess the inherent characteristics of institutions to enable the adaptive capacity of society. *Environ. Sci. Policy* 13, 459–471. doi: 10.1016/j.envsci.2010.05.006

Hallegatte, S. (2012). *A Cost Effective Solution to Reduce Disaster Losses in Developing Countries: Hydro-Meteorological Services, Early Warning, and Evacuation* (Sustainable Development Network, Office of the Chief Economist: The World Bank). doi: 10.1596/1813-9450-6058

Hanh, T. T. H., and Boonstra, W. J. (2019). What prevents small-scale fishing and aquaculture households from engaging in alternative livelihoods? A case study in the Tam Giang lagoon, Viet Nam. *Ocean Coast. Manage.* 182, 104943. doi: 10.1016/j.ocecoaman.2019.104943

Hanich, Q., Wabnitz, C. C. C., Ota, Y., Amos, M., Donato-Hunt, C., and Hunt, A. (2018). Small-scale fisheries under climate change in the Pacific Islands region. *Mar. Policy* 88, 279–284. doi: 10.1016/j.marpol.2017.11.011

Haque, E. C., Idrobo, J. C., Berkes, F., and Giesbrecht, D. (2015). Small-scale fishers' adaptations to change: The role of formal and informal credit in Paraty, Brazil. *Mar. Policy* 51, 401–407. doi: 10.1016/j.marpol.2014.10.002

Hasan, Z., and Nursey-Bray, M. (2018). Artisan fishers' perception of climate change and disasters in coastal Bangladesh. *J. Environ. Plann. Manage.* 61, 1204–1223. doi: 10.1080/09640568.2017.1339026

Heck, S., Béné, C., and Reyes-Gaskin, R. (2007). Investing in African fisheries: Building links to the Millennium Development Goals. *Fish Fisheries* 8, 211–226. doi: 10.1111/j.1467-2679.2007.00251.x

Himes-Cornell, A., and Kasperski, S. (2015). Assessing climate change vulnerability in Alaska's fishing communities. *Fisheries Res.* 162, 1–11. doi: 10.1016/j.fishres.2014.09.010

Hoang, H. D., Momtaz, S., and Schreider, M. (2020). Assessing the vulnerability of small-scale fishery communities in the estuarine areas of Central Vietnam in the context of increasing climate risks. *Ocean Coast. Manage.* 196, 105302. doi: 10.1016/j.ocecoaman.2020.105302

Hodgkinson, J. H., Hobday, A. J., and Pinkard, E. A. (2014). Climate adaptation in Australia's resource-extraction industries: Ready or not? *Regional Environ. Change* 14, 1663–1678. doi: 10.1007/s10113-014-0618-8

IFAD (2014). *Guidelines for Integrating Climate Change Adaptation into Fisheries and Aquaculture Projects* (Rome, Italy: The International Fund for Agricultural Development (IFAD).

IPCC (2014). "Summary for policymakers," in *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Ed. C. B. Field New York, NY: Cambridge University Press.

IPCC (2001). *Climate change 2001: Impacts, adaptation, and vulnerability: Contribution of Working Group II to the third assessment report of the Intergovernmental Panel on Climate Change (Vol. 2)*. Cambridge University Press. J. J. McCarthy, O. F. Canziani, N. A. Leary, D. J. Dokken and K. S. White Eds.

IPCC (2022). Climate change 2022: impacts, adaptation, and vulnerability. *Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Eds. H.-O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem and B. Rama (Cambridge, UK and New York, NY, USA: Cambridge University Press), 3056 pp. doi: 10.1017/9781009325844

Islam, M. M., and Chuenpagdee, R. (2022). Towards a classification of vulnerability of small-scale fisheries. *Environ. Sci. Policy* 134, 1–12. doi: 10.1016/j.envsci.2022.03.023

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

Iwasaki, S., Razafindrabe, B. H. N., and Shaw, R. (2009). Fishery livelihoods and adaptation to climate change: A case study of Chilika lagoon, India. *Mitigation Adaptation Strategies Global Change* 14, 339–355. doi: 10.1007/s11027-009-9167-8

Jara, H. J., Tam, J., Reguero, B. G., Ganoza, F., Castillo, G., Romero, C. Y., et al. (2020). Current and future socio-ecological vulnerability and adaptation of artisanal fisheries communities in Peru, the case of the Huaura province. *Mar. Policy* 119, 104003. doi: 10.1016/j.marpol.2020.104003

Jentoft, S., Chuenpagdee, R., Barragán-Paladines, M. J., and Franz, N. (2017). *The small-scale fisheries guidelines: Global implementation (Vol. 14)* (Switzerland: Springer).

Kalikoski, D. C. (2002). The forum of the Patos Lagoon: An analysis of co-managementarrangement for conservation of coastal resources in Southern Brazil. University of British Columbia, Vancouver, Canada.

Kalikoski, D. C., Neto, P. Q., and Almudi, T. (2010). Building adaptive capacity to climate variability: The case of artisanal fisheries in the estuary of the Patos Lagoon, Brazil. *Mar. Policy* 34, 742–751. doi: 10.1016/j.marpol.2010.02.003

Kc, K. B., Seng, R., and Fraser, E. (2019). Should I stay or should I go? Fishers' ability and willingness to adapt to environmental change in Cambodia's Tonle Sap Lake. *Fisheries Manage. Ecol.* 26, 211–223. doi: 10.1111/fme.12341

Kittinger, J. N., Teneva, L. T., Koike, H., Stamoulis, K. A., Kittinger, D. S., Oleson, K. L. L., et al. (2015). From reef to table: Social and ecological factors affecting coral reef fisheries, artisanal seafood supply chains, and seafood security. *PLoS One* 10, e0123856. doi: 10.1371/journal.pone.0123856

Koralagama, D., Gupta, J., and Pouw, N. (2017). Inclusive development from a gender perspective in small scale fisheries. *Curr. Opin. Environ. Sustainability* 24, 1–6. doi: 10.1016/j.cosust.2016.09.002

Laidler, G. J., Ford, J. D., Gough, W. A., Ikummaq, T., Gagnon, A. S., Kowal, S., et al. (2009). Travelling and hunting in a changing Arctic: Assessing Inuit vulnerability to sea ice change in Igloolik, Nunavut. *Climatic Change* 94, 363–397. doi: 10.1007/s10584-008-9512-z

Le Cornu, E., Doerr, A. N., Finkbeiner, E. M., Gourlie, D., and Crowder, L. B. (2018). Spatial management in small-scale fisheries: A potential approach for climate change adaptation in Pacific Islands. *Mar. Policy* 88, 350–358. doi: 10.1016/j.marpol.2017.09.030

Le Cornu, E., Kittinger, J. N., Koehn, J. Z., Finkbeiner, E. M., and Crowder, L. B. (2014). Current practice and future prospects for social data in coastal and ocean planning. *Conserv. Biol.* 28, 902–911. doi: 10.1111/cobi.12310

Lee, L. C., Reid, M., Jones, R., Winbourne, J., Rutherford, M., and Salomon, A. K. (2019). Drawing on indigenous governance and stewardship to build resilient coastal fisheries: People and abalone along Canada's northwest coast. *Mar. Policy* 109, 103701. doi: 10.1016/j.marpol.2019.103701

Leichenko, R., and Silva, J. A. (2014). Climate change and poverty: Vulnerability, impacts, and alleviation strategies. *Wiley Interdiscip. Reviews: Climate Change* 5, 539–556. doi: 10.1002/wcc.287

Leite, M., Ross, H., and Berkes, F. (2019). Interactions between individual, household, and fishing community resilience in southeast Brazil. *Ecol. Soc.* 24, 2. doi: 10.5751/ES-10910-240302

León, J. V. D., Bogardi, J. J., Dannenmann, S. R., and Basher, R. E. (2006). Early warning systems in the context of disaster risk management. *Entwicklung Landlicher Raum* 40, 23–25.

Lewis, R. R. (2001). "Mangrove restoration-Costs and benefits of successful ecological restoration," in *Proceedings of the Mangrove Valuation Workshop*, vol. 4. (Universiti Sains Malaysia, Penang).

Limuwa, M. M., Sitaula, B. K., Njaya, F., and Storebakken, T. (2018). Evaluation of small-scale fishers' perceptions on climate change and their coping strategies: Insights from lake Malawi. *Climate* 6 (2), 34. doi: 10.3390/cli6020034

Mabe, F. N., and Asase, A. (2020). Climate change adaptation strategies and fish catchability: The case of inland artisanal fishers along the Volta Basin in Ghana. *Fisheries Res.* 230, 105675. doi: 10.1016/j.fishres.2020.105675

Macusi, E. D., Macusi, E. S., Jimenez, L. A., and Catam-isan, J. P. (2020). Climate change vulnerability and perceived impacts on small-scale fisheries in eastern Mindanao. *Ocean Coast. Manage.* 189, 105143. doi: 10.1016/j.ocecoaman.2020.105143

Malekpour, S., Brown, R. R., De Haan, F. J., and Wong, T. H. F. (2017). Preparing for disruptions: A diagnostic strategic planning intervention for sustainable development. *Cities* 63, 58–69. doi: 10.1016/j.cities.2016.12.016

Mamauag, S. S., Aliño, P. M., Martinez, R. J. S., Muallil, R. N., Doctor, M. V. A., Dizon, E. C., et al. (2013). A framework for vulnerability assessment of coastal fisheries ecosystems to climate change-Tool for understanding resilience of fisheries (VA-TURF). *Fisheries Res.* 147, 381–393. doi: 10.1016/j.fishres.2013.07.007

Markantonatou, V., Noguera-Méndez, P., Semitiel-García, M., Hogg, K., and Sano, M. (2016). Social networks and information flow: Building the ground for collaborative marine conservation planning in Portofino Marine Protected Area (MPA). *Ocean Coast. Manage.* 120, 29–38. doi: 10.1016/j.ocecoaman.2015.11.023

Marshall, N. A., Tobin, R. C., Marshall, P. A., Gooch, M., and Hobday, A. J. (2013). Social vulnerability of marine resource users to extreme weather events. *Ecosystems* 16, 797–809. doi: 10.1007/s10021-013-9651-6

Méndez-Medina, C., Schmook, B., Basurto, X., Fulton, S., and Espinoza-Tenorio, A. (2020). Achieving coordination of decentralized fisheries governance through collaborative arrangements: A case study of the Sian Ka'an Biosphere Reserve in Mexico. *Mar. Policy* 117, 103939. doi: 10.1016/j.marpol.2020.103939

Metcalf, S. J., Putten, E. I., Frusher, S., Marshall, N. A., Tull, M., Caputi, N., et al. (2015). Measuring the vulnerability of marine social-ecological systems: A prerequisite for the identification of climate change adaptations. *Ecol. Soc.* 20 (2), 35. doi: 10.5751/ES-07509-200235

Miller, D. D., Ota, Y., Sumaila, U. R., Cisneros-Montemayor, A. M., and Cheung, W. W. L. (2018). Adaptation strategies to climate change in marine systems. *Global Change Biol.* 24, e1–e14. doi: 10.1111/gcb.13829

Monnier, L., Gascuel, D., Alava, J. J., Barragán, M. J., Gaibor, N., Hollander, F. A., et al. (2020). "Small-scale fisheries in a warming ocean: Exploring adaptation to climate change," in *Scientific report* (WWF Germany: International WWF Centre for Marine Conservation, Hamburg).

Morzaria-Luna, H. N., Turk-Boyer, P., and Moreno-Baez, M. (2014). Social indicators of vulnerability for fishing communities in the Northern Gulf of California, Mexico: Implications for climate change. *Mar. Policy* 45, 182–193. doi: 10.1016/j.marpol.2013.10.013

Muhammad, M., Idris, K., Ariffin, E. H., Shaffril, H. A. M., Abu Samah, B., and Suandi, T. (2016). The impact of climate change on small-scale fishermen in Malaysia. *Soc. Sci.* 11, 3352–3356.

Ndhlovu, N., Saito, O., Djalante, R., and Yagi, N. (2017). Assessing the sensitivity of small-scale fishery groups to climate change in Lake Kariba, Zimbabwe. *Sustainability* 9 (12), 2209. doi: 10.3390/su9122209

Nelson, D. R., Adger, W. N., and Brown, K. (2007). Adaptation to environmental change: Contributions of a resilience framework. *Annu. Rev. Environ. Resour.* 32, 395–419. doi: 10.1146/annurev.energy.32.051807.090348

Ogundele, O. M., and Ubaekwe, R. E. (2019). "Early warning system and ecosystem-based adaptation to prevent flooding in ibadan metropolis, Nigeria," in *Handbook of Climate Change Resilience*. Ed. W. Leal Filho (Switzerland: Springer International Publishing), 1–25. doi: 10.1007/978-3-319-71025-9_112-1

Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective action* (Cambridge, United Kingdom: Cambridge university press).

Payne, M. R., Kudahl, M., Engelhard, G. H., Peck, M. A., and Pinnegar, J. K. (2021). Climate risk to European fisheries and coastal communities. *Proc. Natl. Acad. Sci.* 118, e2018086118. doi: 10.1073/pnas.2018086118

Pecl, G. T., Ogier, E., Jennings, S., Putten, I., Crawford, C., Fogarty, H., et al. (2019). Autonomous adaptation to climate-driven change in marine biodiversity in a global marine hotspot. *Ambio* 48, 1498–1515. doi: 10.1007/s13280-019-01186-x

Piasecki, W., Głąbiński, Z., Francour, P., Koper, P., Saba, G., Molina García, A., et al. (2016). Pescatourism—A European review and perspective. *Acta Ichthyologica Piscatoria* 46 (4), 325–350. doi: 10.3750/AIP2016.46.4.06

Pratiwi, M. A., Wahyu, H. R., and Erwin Normande, B. (2023). Understanding knowledge acquisition, adaptive strategies, challenges, and preservation methods among traditional fishermen in a digital age. *Bio Web Conferences* 70, 5008. doi: 10.1051/bioconf/20237005008

Prescott, J., Riwu, J., Stacey, N., and Prasetyo, A. (2016). An unlikely partnership: Fishers' participation in a small-scale fishery data collection program in the Timor Sea. *Rev. Fish Biol. Fisheries* 26, 679–692. doi: 10.1007/s11160-015-9417-7

Prosperi, P., Kirwan, J., Maye, D., Bartolini, F., Vergamini, D., and Brunori, G. (2019). Adaptation strategies of small-scale fisheries within changing market and regulatory conditions in the EU. *Mar. Policy* 100, 316–323. doi: 10.1016/j.marpol.2018.12.006

Quimby, B., and Levine, A. (2018). Participation, power, and equity: examining three key social dimensions of fisheries comanagement. *Sustainability* 10, 3324. doi: 10.3390/su10093324

Reid, G., Gurney-Smith, H., Flaherty, M., Garber, A., Forster, I., Brewer-Dalton, K., et al. (2019). Climate change and aquaculture: Considering adaptation potential. *Aquaculture Environ. Interact.* 11, 603–624. doi: 10.3354/aei00333

Ruiz-Díaz, R., Liu, X., Aguión, A., Macho, G., deCastro, M., Gómez-Gesteira, M., et al. (2020). Social-ecological vulnerability to climate change in small-scale fisheries managed under spatial property rights systems. *Mar. Policy*. 121, 104192. doi: 10.1016/j.marpol.2020.104192

Salagrama, V. (2012). *Climate Change and Fisheries: Perspectives from Small-scale Fishing Communities in India on Measures to Protect Life and Livelihood* (Chennai, India: International Collective in Support of Fishworkers).

Salas, S., and Gaertner, D. (2004). The behavioural dynamics of fishers: Management implications. *Fish Fisheries* 5, 153–167. doi: 10.1111/j.1467-2979.2004.00146.x

Salgueiro-Otero, D., and Ojea, E. (2020). A better understanding of social-ecological systems is needed for adapting fisheries to climate change. *Mar. Policy* 122, 104123. doi: 10.1016/j.marpol.2020.104123

Santos, A. N. (2015). Fisheries as a way of life: Gendered livelihoods, identities and perspectives of artisanal fisheries in eastern Brazil. *Mar. Policy* 62, 279–288. doi: 10.1016/j.marpol.2015.09.007

Schipper, E. L., Ayers, J., Reid, H., Huq, S., and Rahman, A. (2014). *Community-based adaptation to climate change: Scaling it up* (Abingdon, United Kingdom: Routledge).

Schneider, N. (2019). Decentralization: An incomplete ambition. *J. Cultural Economy* 12, 265–285. doi: 10.1080/17530350.2019.1589553

Semitiel-García, M., and Noguera-Méndez, P. (2019). Fishers' participation in small-scale fisheries. A structural analysis of the Cabo de Palos-Islas Hormigas MPA, Spain. *Mar. Policy* 101, 257–267. doi: 10.1016/j.marpol.2018.04.009

Senapati, S., and Gupta, V. (2017). Socio-economic vulnerability due to climate change: Deriving indicators for fishing communities in Mumbai. *Mar. Policy* 76, 90–97. doi: 10.1016/j.marpol.2016.11.023

Shaffril, H. A. M., Abu Samah, A., and D'Silva, J. L. (2017a). Adapting towards climate change impacts: Strategies for small-scale fishermen in Malaysia. *Mar. Policy* 81, 196–201. doi: 10.1016/j.marpol.2017.03.032

Shaffril, H. A. M., Abu Samah, B., D'Silva, J. L., and Yassin, S. (2013). The process of social adaptation towards climate change among Malaysian fishermen. *Int. J. Climate Change Strategies Manage.* 5, 38–53. doi: 10.1108/17568691311299354

Shaffril, H. A. M., Ahmad, N., Samsuddin, S. F., Abu Samah, A., and Hamdan, M. E. (2020). Systematic literature review on adaptation towards climate change impacts among indigenous people in the Asia Pacific regions. *J. Cleaner Production* 258, 120595. doi: 10.1016/j.jclepro.2020.120595

Shaffril, H. A. M., Hamzah, A., D'Silva, J. L., Abu Samah, B., and Abu Samah, A. (2017b). Individual adaptive capacity of small-scale fishermen living in vulnerable areas towards the climate change in Malaysia. *Climate Dev.* 9, 313–324. doi: 10.1080/17565529.2016.1145100

Sievanen, L. (2014). How do small-scale fishers adapt to environmental variability? Lessons from Baja California, Sur, Mexico. *Maritime Stud.* 13, 1–19. doi: 10.1186/s40152-014-0009-2

Singh, G. G., Harden-Davies, H., Allison, E. H., Cisneros-Montemayor, A. M., Swartz, W., Crosman, K. M., et al. (2021). Will understanding the ocean lead to "the ocean we want"? *Proc. Natl. Acad. Sci.* 118, e2100205118. doi: 10.1073/pnas.2100205118

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

Sowman, M. (2020). Participatory and rapid vulnerability assessments to support adaptation planning in small-scale fishing communities of the Benguela Current Large Marine Ecosystem. *Environ. Dev.* 36, 100578. doi: 10.1016/j.envdev.2020.100578

Stanford, R. J., Wiryawan, B., Bengen, D. G., Febriamansyah, R., and Haluan, J. (2014). Improving livelihoods in fishing communities of West Sumatra: More than just boats and machines. *Mar. Policy* 45, 16–25. doi: 10.1016/j.marpol.2013.11.013

Stoll, J. S., Fuller, E., and Crona, B. I. (2017). Uneven adaptive capacity among fishers in a sea of change. *PLoS One* 12, e0178266. doi: 10.1371/journal.pone.0178266

Sutton, A. M., and Rudd, M. A. (2016). Factors influencing community fishers' Leadership engagement in international small-scale fisheries. *Front. Mar. Sci.* 3. doi: 10.3389/fmars.2016.00116

Symes, D., Phillipson, J., and Salmi, P. (2015). Europe's Coastal Fisheries: Instability and the Impacts of Fisheries Policy: Europe's coastal fisheries. *Sociologia Ruralis* 55, 245–257. doi: 10.1111/soru.12096

Theesfeld, I. T., and Schmidt, O. (2011). "Decentralization failures in post-socialist fishery management," in *Studies on the Agricultural and food sector in Central and Eastern Europe*, vol. 58. (Halle, Germany: Perspectives on Institutional Change – Water Management in Europe).

Thorpe, A., Pouw, N., Baio, A., Sandi, R., Ndomahina, E. T., and Lebbie, T. (2014). Fishing na everybody business": women's work and gender relations in Sierra Leone's fisheries. *Feminist Economics* 20, 53–77. doi: 10.1080/13545701.2014.895403

Thorpe, A., Whitmarsh, D., Sandi, R., Baio, A., Lebbie, N., Lebbie, T., et al. (2013). Pathways out of poverty: Women—The 'forgotten gender'—And the artisanal fisheries sector of Sierra Leone. *Afr. Historical Rev.* 45, 46–61. doi: 10.1080/17532523.2013.796131

Tompkins, E. L., and Eakin, H. (2012). Managing private and public adaptation to climate change. *Global Environ. Change* 22, 3–11. doi: 10.1016/j.gloenvcha.2011.09.010

Tse, Y. L. (2024). *Evaluation of AI-based Research Assistance Tools: A Case Study Research* (Germany: Diss. University of Graz).

Van Vranken, C., Jakoboski, J., Carroll, J. W., Cusack, C., Gorringe, P., Hirose, N., et al. (2023). Towards a global Fishing Vessel Ocean Observing Network (FVON): State of the art and future directions. *Front. Mar. Sci.* 10. doi: 10.3389/fmars.2023.1176814

Wabnitz, C. C. C., and Blasiak, R. (2019). The rapidly changing world of ocean finance. *Mar. Policy* 107, 103526. doi: 10.1016/j.marpol.2019.103526

Weeratunge, N., Snyder, K. A., and Sze, C. P. (2010). Gleaner, fisher, trader, processor: Understanding gendered employment in fisheries and aquaculture. *Fish Fisheries* 11, 405–420. doi: 10.1111/j.1467-2979.2010.00368.x

Wilkinson, J. (2006). Fish: A global value chain driven onto the rocks. *Sociologia Ruralis* 46, 139–153. doi: 10.1111/j.1467-9523.2006.00408.x

World Bank, W. (2012). *Hidden harvest: The global contribution of capture fisheries* (Washington, DC: World Bank). Available at: http://documents.worldbank.org/curated/en/515701468152718292/Hidden-harvest-the-global-contribution-of-capture-fisheries (Accessed December 4, 2023).

Worthington, T., and Spalding, M. (2018). Mangrove Restoration Potential: A global map highlighting a critical opportunity. doi: 10.17863/CAM.39153

Yuerlita Perret, SR, and Shivakoti, GP (2013). Fishing farmers or farming fishers? Fishing typology of inland small-scale fishing households and fisheries management in Singkarak Lake, West Sumatra, Indonesia. *Environ. Manage.* 52, 85–98. doi: 10.1007/s00267-013-0050-8

Zhao, M., Tyzack, M., Anderson, R., and Onoakpovike, E. (2014). "Women in english fisheries: roles, contributions, barriers and prospects," in *Social Issues in Sustainable Fisheries Management*, vol. 9 . Eds. J. Urquhart, T. Acott, D. Symes and M. Zhao (Springer, Dordrecht). doi: 10.1007/978-94-007-7911-2_13

Zimmer, M., Ajonina, G. N., Amir, A. A., Cragg, S. M., Crooks, S., Dahdouh-Guebas, F., et al. (2022). When nature needs a helping hand: Different levels of human intervention for mangrove (re-)establishment. *Front. Forests Global Change* 5. doi: 10.3389/ffgc.2022.784322

Zulu, L. C. (2012). Neoliberalization, decentralization and community-based natural resources management in Malawi: The first sixteen years and looking ahead. *Prog. Dev. Stud.* 12, 193–212. doi: 10.1177/146499341101200307