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Review Article

A review of adaptation options in fisheries management to support resilience and transition under socio-ecological change

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Social-ecological systems dependent on fisheries must be resilient or adapt to remain viable in the face of change. Here, we identified possible interventions (termed "adaptation options") from published literature, aimed at supporting social or ecological resilience and/or aiding adaptation to changes induced by environmental or social stressors. Our searches centered on nations/regions across North America, Europe, and the South Pacific, encompassing fisheries literature with and without a climate change focus, to compare how, when, and by whom interventions are currently or potentially implemented. We expected that adaptation options within a climate change context would have a greater focus on enhancing social resilience due to a connection with climate change adaptation assessment methodology. Instead, we found a greater focus on ecological resilience, likely indicating a focus on management adaptation. This pattern, along with the more extensive use of social adaptation options responsively and outside the context of climate change, along with an importance in bottom-up influences in implementing them, suggests a general lack of centralized planning and organization with regards to adaptation of stakeholders. Determining how adaptation options are created, chosen, and implemented is a crucial step within or external to ecosystem-based management, especially if planned stakeholder adaption is the goal.

Keywords: adaptation, adaptation option, climate change, fisheries governance, fisheries management, integrated assessment, planned adaptation

Introduction

Climate change is an extreme global phenomenon with far-reaching consequences for marine social-ecological systems (Brander, 2007; Grafton, 2010; Sumaila *et al.*, 2011; Bindoff *et al.*, 2019; Doney *et al.*, 2020; Ojea *et al.*, 2020), yet it is only one of many sources of systemic change inducing challenges currently faced by those whose livelihoods depend upon marine resources (see Jackson *et al.*, 2001; Srinivasan *et al.*, 2010; Vegter *et al.*, 2014). Within fisheries, awareness of the need for enhancing social-ecological capacity to adapt to both climatic and non-climatic changes and their interactions (Perry *et al.*, 2010; Poloczanska *et al.*, 2016) has, in part, contributed to the adoption of ecosystem-based management (EBM) frameworks.

In theory, EBM includes complex ecosystem connections and scales, species interactions, and environmental drivers, involves stakeholders and incorporates humans as a component of the ecosystem, considers social-ecological complexities and uncertainties (FAO, 2003; Marasco *et al.*, 2007; Long *et al.*, 2015; Harvey *et al.*, 2020), and spans multiple sectors (Marshak *et al.*, 2017; Smith *et al.*, 2017). As accounting for ecosystem dynamics, addressing uncertainty, and using adaptive management are also important EBM principles (Long *et al.*, 2015), it is logical to assume that implementing EBM in fisheries over more traditional management strategies (e.g. single species assessments) might confer greater capacity to pre-empt and/or respond to the impacts of new sources of change, climatic or otherwise. For example, EBM was perceived by practitioners to be the fisheries management approach best-positioned to adapt with climate change, especially as other adaptive or co-management approaches could be embedded within it hierarchically (Ogier *et al.*, 2016). Moreover, many of the strategies listed by West *et al.* (2009) as important for increasing resilience within EBM are already commonly used in fisheries management with an ecosystem focus (e.g. reducing anthropogenic stresses, protecting key features and refugia, maintaining diversity, replicating or restoring habitats or communities, and relocating organisms). Resilience, therefore, might be expected to be an important focus and/or outcome of implementing EBM in fisheries.

However, there is also a danger in assuming that greater resilience of the ecosystem alone, accomplished via better implementation of EBM in fisheries, will automatically lead to greater resilience of the people involved, or at least *all* people involved. Despite the theoretical strengths and hierarchical breadth of EBM, it is also thought to lack a clear social-ecological focus in implementation (Ogier *et al.*, 2016). Much of the literature surrounding climate adaptation and EBM in fisheries revolves around adaptation of the management system to maintain ecological resilience, i.e. the ability of an ecosystem to maintain structure and function in the face of disturbance ("management adaptation"; West *et al.*, 2009). In this case, managers and management institutions are adapting (see, for example, Melnychuck *et al.*, 2014; Pinsky and Mantua, 2014; Creighton *et al.*, 2016; Ogier *et al.*, 2016; Patterson *et al.*, 2016). People whose livelihoods depend on natural resources benefit from ecological resilience, as well as continued good performance of the management system designed to maintain it. However, ecological resilience does not necessarily translate into greater resilience of social groups or a greater capability for them to transition in response to major social or ecosystem changes (Adger, 2000). Ecological and social resilience are based on different processes, and how they are linked in an individual system may also differ (Adger, 2000; Folke, 2006; Sutton and Tobin, 2012). Furthermore, adaptation of the resource users involved (e.g. stakeholders) and social resilience are often studied and supported using the social-ecological approach that EBM is criticized for lacking in fisheries (e.g. Allison and Ellis, 2001; Folke, 2006; Cinner *et al.*, 2011).

Woods (2021) argued that when EBM is implemented without adaptive management pathways for facilitating planned adaptation of stakeholders, it cannot be expected to provide relevant policy recommendations to support positive social outcomes in the future (Woods, 2021). Essentially, expectations should match the tools employed. If adaptive management cycles are not designed to track and improve social conditions (Woods, 2021), expectations of the system's performance with regard to social conditions become murky and may even result in maladaptation (see, for example, Hamilton *et al.*, 2004; Criddle, 2012; Kates *et al.*, 2012). In contrast, climate change adaptation assessment and planning are, for example, intended to support changes in social resilience and adaptation of social groups, as well as management adaptation. They are historically based on the field of cultural adaptation (Füssel, 2007a) with modern applications often employed in a development context. Adaptation planning entails examining how the people involved currently respond to ecological (among other) change, possibly through vulnerability-based assessments, and determining how the anticipation of change or response planning can be supported to yield positive future outcomes (Füssel, 2007a; Jara *et al.*, 2020). "Adaptation options" are weighed to "reduce the risks and capitalize on the opportunities associated with … change" (Füssel, 2007a, p. 265, where "…" in this case refers to climate but does not need to). By focusing on evaluating social adaptation and resilience, adaptation planning may result in changes to policy, management procedures, or possible interventions with direct (rather than secondary) social consequences (Burton *et al.*, 2004; Füssel, 2007a).

Within fisheries literature, recognition has grown for the need to understand sources of and threats to social resilience, without specific reference to climate change (Marshall and Marshall, 2007; Sutton and Tobin, 2012; Himes-Cornell and Hoelting, 2015). Within the context of climate change, reference to adaptation options to facilitate resilience and adaptation has also become more common (Comte and Pendleton, 2018; Poulain *et al.*, 2018; Whitney and Ban, 2019; Bell *et al.*, 2020). In both cases, many features of resilience may be considered part of the wider realm of governance that extends beyond fisheries management, and sometimes even beyond fisheries. For example, fisheries disaster relief programs may be nationally controlled and fall institutionally outside any specific ecosystem (e.g. Conway and Shaw, 2008). In addition, community-based programs imparting social resilience may be sponsored and managed by non-government organizations, communities, or state/regional government bodies (Himes-Cornell and Hoelting, 2015; Poulain *et al.*, 2018). As a result, conceptually it can be difficult to envision how the creation, evaluation, and utilization of adaptation options, especially those intended to have direct social consequences for supporting social resilience and adaptation, can be supported by management adaptation. It may also be difficult to see how using adaptation options can fit in relation to an EBM process without having (i) a greater background on how fisheries and adaptation fields of research, assessment methods, and adaptive management cycles are related; and (ii) examples of how adaptation options can be conceptualized from interventions/actions currently utilized or proposed to support social resilience and adaptation of social groups in fisheries. Woods (2021) addresses (i) by providing historical background and a comparison of assessment frameworks designed to effect climate change adaptation vs. support EBM in fisheries. Here, we contribute to (ii) by reviewing fisheries literature sourced from 21 nations and regions to discretize the concept of adaptation options. We then compare how they have been used or proposed in the past in response to some real or potential "change" in a fisheries system, either within a climate change context (CC) or outside of it.

This paper is organized into two main sections. First, we conduct a review of fisheries literature in an unconventional manner. Reviewers are typically focused on synthesizing scientific literature related to a certain topic. This review instead focuses on how to materialize a relatively new concept of "adaptation options" within the field of fisheries, by identifying ways in which it could be considered to already have been used within the field. This task is done in a semi-quantitative manner, as we classify adaptation option records from sources returned from structured web-based searches using a systematic categorization scheme and compile all categorized records in an online repository for reference for fisheries practitioners. The repository is intended to aid in the brainstorming of adaptation options considered during future assessments. Moreover, it can help the creation of institutional pathways needed to allow for the brainstorming of such adaptation options to begin with. However, it should be kept in mind that because the vast majority of literature reviewed has diverse purposes that never included being used to define adaptation options, and because large individualistic differences are inherent among participants, it is unlikely that participants will record adaptation options from a reviewed source in exactly the same manner (see Supplementary Material Section 4). Including such a diversity of interpretation (rather than a single reviewer's interpretation) captures how a wide diversity of international fisheries scientists may interpret the presence of adaptation options. However, it can also provide methodological problems in specific or individual trends. Therefore, results represent content as filtered through a mix of perspectives from both the author(s) of reviewed literature and the reviewer reading that source. Over the whole study, conceptualization of adaptation options can be viewed as a multi-faceted perspective based on a diversity of fisheries experts, similar to how perspectives may be summarized from a survey.

With this in mind, we then analyse broad differences between whether these examples were taken within or external to a CC context under the following five topics: (i) which types of adaptation options were emphasized (ecological, social, or institutional), as well as their stressors; (ii) aspects of planning and implementation; (iii) who does the managing (management scales); (iv) patterns in community focus and implementation status; and, as institutional conditions and norms can vary spatially, (v) geographic trends in adaptation option usage across nations and regions.

Because EBM in fisheries already incorporates many tools used to support ecological resilience (West *et al.*, 2009), we expected that adaptation options found within a CC context would be more diverse and more frequently categorized as "social". This pattern would signal a greater use of an adaptation assessment toolbox aimed at facilitating resilience and adaptation of social groups to climate change (Burton *et al.*, 2004; Füssel, 2007a), including social-ecological approaches noted as lacking in EBM implementation (Ogier *et al.*, 2016).

Methods

A total of 29 participants (i.e. co-authors) conducted reviews within nations and regions spanning North America, Europe, and the South Pacific (21 regions in total, Table 1). Participants were re-

Table 1. Number of adaptation options recorded per region within the CC and N categories, and whether the adaptation option was implemented ("Imp/" present), community-focused ("/Com" present), both ("Imp/Com"), or neither ("/").

Country/region	CC				N				Total
	Imp/Com	Imp/	/Com	/	Imp/Com	Imp/	/Com	/	
AUS	16	89	13	355	51	123	3	11	661
CAN	13	11	37	24	22	1	8		116
EU			3	5					8
FAR						8	2	1	11
FIN		7	3	22	10	2	6	7	57
FIN-AX		1	1		6	9		1	18
GER		7	2	10	4	13	3	5	44
ICE					3	1	2	2	8
IT	12	4	1	12	33	21	19	21	123
NL			1	16	3	7	6	2	35
NOR						5			5
NZ	2	6	3		5	7	1	1	25
SW				12	1	3		1	17
UK	5	13	10	115		1			144
US-AK	1	2	18	3	16	10			50
US-HA	3	3	2	4	9		2		23
US-NE	4	3	14	27	24	11	27	4	114
US-NW	2	7	9	6	22	5	6	5	62
US-SE	5	10	12	27	5	12	11	9	91
US-SW	4	6	1	11	2	1			25
USA	13	19	11	71	22	4	17	7	164
Total	80	188	141	720	238	244	113	77	1801

AUS, Australia; CAN, Canada; EU, European Union (not country-specific); FAR, Faroe Islands; FIN, Finland; FIN-AX, Åland Islands; GER, Germany; ICE, Iceland; IT, Italy; NL, Netherlands; NOR, Norway; NZ, New Zealand; SW, Sweden; UK, United Kingdom; US-AK, Alaska; US-HA, Hawaii; US-NE, Northeast US; US-NW, Northwest US; US-SE, Southeast US; US-SW, Southwest US; USA, United States of America.

cruited generally as doctoral students or early-career researchers during a workshop held by a Nordforsk-funded Center of Excellence research network. This network was designed to increase interdisciplinarity surrounding the study of marine ecosystems and resources (NorMER; Holt *et al.*, 2017), so the backgrounds of participants varied considerably and were comprised of ecology, stock assessment or related modeling, oceanography, economics, or other social sciences. The workshop centered on brainstorming start-up projects related to climate change adaptation, but further individual recruitment via personal contact and later workshops was accomplished as needed.

Some of the selected regions were defined as areas within nations (e.g. states/regions or island entities), while the European Union (EU) and United States of America (USA) classifications were considered separately from component nations or regions. Teams of 1–3 researchers per region conducted internet-based literature searches mainly using the Google Scholar search engine, perhaps with augmentation using basic Google or Web of Science search engines. Searches were done in both the participant's native language and English and information retained from resulting documents was always related to fisheries. Searches were conducted for CC and non-climate change (N) related documents separately (see Box 1 and Supplementary Material Section 2). After completing literature searches, each team read through documents for instances of adaptation options being mentioned and classified each adaptation option according to a common categorization scheme (see next section), with completed categorizations compiled in a repository accessible online and in the Supplementary Material. Adaptation options (listed in Box 2) were broadly defined to include any actions or strategies that were suggested, planned, or taken in response to one or more "stressors" on the social-ecological system (Box 3 and Supplementary Material Section 3). Only white or grey literature or web pages containing enough information for classification were retained.

Box 1. Standard search terms used by all teams to find literature containing information on fisheries adaptation options. The term "region∗" was replaced with region name as searched by individual teams.

CC searches

"fisheries adaptation" "climate change" region∗
adaptation fishing "climate change" region∗
adaptation fisher "climate change" region∗
adaptation fish "climate change" region∗
same as above but replace "adaptation" with "adapt"
same as above but replace "adaptation" with "resilience"

N searches

"fisheries disaster" region∗
"small-scale fisheries" region∗
"fishing community" fisheries region∗
ecosystem "fisheries management" region∗
"financial assistance" fisheries region∗
"social investment" fisheries region∗
`"community development" fisheries region∗
"social science" fisheries region∗

Box 2. The 28 pre-defined adaptation options, listed under ecological, social and institutional banners.

Ecological
Harvest limitations
Enforcement
Research
Conservation measures
Marine protected areas (MPAs)
Restoration
Reductions in other stressors
Dynamic ocean management
Social
Leaving fisheries
Transition out of fisheries
Financial assistance to transition out of fisheries
Financial cushion/horizon
Education
Investment in new gear or innovation
Investments to improve value chain
Economic/community development
Dealing with risk
Diversify livelihoods
Market diversification
Financial assistance to survive bad fishing years
Financial assistance to enter/transfer/restructure business
Insurance
Permit/license/quota bank
Cooperative
Disaster risk management
Disaster funds
Institutional
Management adaptation
Adaptation programs
Review program/regulations
Coordination and organization
Social equity
Individual property rights
Community-based rights
Fair trade laws
International agreements

Box 3. Procedure for categorizing adaptation option records. Each record was assessed under the following headings (shown below in bold), with participants choosing from a series of descriptors for that record.

Context (choose 1)
CC/N
Stressor (rank 1–2, with 1 as most important)

Ecological:	*Social:*
Stock decline	Market change
Species distributional shifts	Regulation change
Ocean acidification	Consolidation (of fishing rights)
Extreme climatic events	Globalization
Uncertainty	Uncertainty

Intended goal (choose 1–2)
Reduce stressor directly
Reduce sensitivity or exposure to the stressor
Cope with stressor effects
Take advantage of stressor effects
Induce no change
Planning (choose 1):
Anticipatory/responsive/both
Implemented (choose 1)
Yes/No
Community*-focused (choose 1)
Yes/No
Manager (choose all that apply)

Top-down	**Bottom-up**
International	Community* association
National government	Business cooperative
Regional government	
Non-profit	**Individual**
Non-governmental organisation	Individual
University	Business

*Refers to groups with either spatial or economic commonalities (e.g. fishing villages or associations of fleet sectors)

Note that the literature searches and categorization methods used here were not meant to reflect random sampling, nor provide a complete assessment and evaluation of adaptation options. Because Google uses search history to modify results, and search effort and consideration of what was retained was not controlled for, searches cannot be considered standardized, but instead reflect a swath of what a typical fisheries researcher may encounter. As such, this limitation of searches perhaps enhances the broad multifaceted overview of how adaptation options could be viewed and applied within fisheries as presented here. Results should not be taken very specifically or as quantitative trends (see Supplementary Material Section 4) and instead represent a starting point for more specific investigations into the management and governance processes in specific systems.

Categorization methods

Pilot study

Before beginning searches, participants were first tasked with two activities: (i) reviewing any relevant climate-change related national/regional documents for listed vulnerabilities related to the effects of climate change on the fisheries sector (Supplementary Material Section 3); and (ii) conducting a pilot categorization study on two selected reports (i.e. Conway and Shaw, 2008; EAC, 2013) to improve consistency in categorization across teams. Results were also used to improve definitions used in the final categorization process. Participants were given a pre-recorded presentation that explained categorization methods and definitions and set out the framework and objectives of the pilot exercise. Practice adaptation option lists were then submitted by participants and the results analyzed by project organizers (PW, JM, and HB). Categorization methodology was then refined and simplified, and a second pre-recorded presentation was used to disseminate to participants information to improve the consistency of categorizations. Key refinements emerging from the pilot study included the need for participants to list each record of an adaptation option mentioned as a separate entry to their categorization tables, even if these records stemmed from a single mechanism, and to refrain from personal judgement in categorizations. For example, a single quota bank program implemented for two distinct fisheries would be listed twice. A quota bank that doubled as a development fund would also be listed twice. Characteristics such as “community-focused” and “implemented” would only be present when the source specifically mentions these, and not inferred by the reader. Therefore, as many adaptations as possible were listed from each source to aid in consistency, and the number of records from an individual literature source varied greatly depending on its topic and breadth.

Final categorization scheme

Following the pilot study, final searches and categorizations were conducted between June 2017 and September 2018. Participants scanned literature for records in which an adaptation option was mentioned and classified this record as 1 of 28 pre-defined adaptation options designed to map similar types of adaptation to common themes *a priori* (Box 2 and Supplementary Material Section 3). Although using pre-defined adaptation options reduces the diversity of adaptation options recorded in our study, it was found to be necessary (according to pilot study results) to standardize participant categorizations and enable comparisons in terms of frequency of adaptation options recorded. For example, “forecasting”, “monitoring”, and “research” adaptation options used in the pilot study were lumped together as “research” because so many instances of “monitoring” and “research” were justified as facilitating current or planned forecasting efforts. Each of these 28 pre-defined adaptation options were then broadly grouped under 1 of 3 banners: “ecological”, “social”, or “institutional”, which correspond with the 3 adaptive management cycles described by Woods (2021) (adaptation option banners and sub-banners were changed slightly after categorizations were made and prior to analysis; see Supplementary Material for original definition). Although there are several ways to classify adaptation options (e.g. see Comte and Pendleton, 2018; Poulain *et al.*, 2018; Bell *et al.*, 2020), here, we *a priori* categorize “socially” vs. “ecologically” oriented adaptation options, similar to Whitney and Ban (2019). Distinctions are based on whether supporting ecological or social resilience or adaptation appears to be its intended *direct* consequence, as opposed to a secondary consequence of that option. A third set of adaptation options categorized as “institutional” are those intended to cause direct changes to features of management or governance. They tend to have both social and ecological consequences at a system-wide level that are not as clearly direct (Box 2). Note that several adaptation options we categorized are actually features of governance that could fall under the “institutional” banner, but these were excluded from this category when their definitions had clear intentions of directly supporting either ecological or social resilience or adaptation (e.g. “enforcement”, “research”, and “education”). As definitions were based on preliminary literature analysis and the pilot project, such placements are the result of the way they were mainly used within the fisheries-related context found thus far; however, note that in actual categorization of final results, in some less frequent instances, records may be more akin to another banner. Metadata noted for each record include the “stressor” inducing the change (or risk of a change), the purpose of the adaptation option (e.g. “reduce sensitivity” or “cope”), whether it was a reactive or proactive approach, whether it was implemented, had a community focus, and which actors were involved. Notably, some metadata fields were designed to follow conceptualizations of risk and vulnerability used by the International Panel on Climate Change (IPCC), while others were intended to indicate potential differences in governance. According to the definition used by the IPCC, vulnerability is the “propensity of exposed elements such as human beings, their livelihoods, and assets to suffer adverse effects when impacted by hazard events” (Cardona *et al.*, 2012). Note that vulnerability is defined in relation to an event but can also be defined in relation to a “stressor”, or a “potentially damaging influence on the system of analysis” (Füssel, 2007b, p. 157). “Cope” indicates an intention to “react to and reduce the adverse effects of experienced hazards” (Cardona *et al.*, 2012, p. 72) (see the Methods for further details on the search criteria used and categorization scheme employed). To simplify results, “manager” categorizations were broadened to fall within “top-down”, “bottom-up”, “non-profit”, and “individual” categories (Box 3), which reflect actors involved in implementing an adaptation option (e.g. through decision-making or funding). The “individual” level for example reflects personal, family, or business planning, financial or otherwise. The country, participant, source, comments, and confidence rating were also recorded. Each record was then categorized under the headings set out in Box 3. Definitions for all terms shown in Boxes 2 and 3 are provided in the Supplementary Material Section 3 and spreadsheets.

Analyses

Analyses were structured under five topics, each comprising a series of questions/objectives, as follows:

1. Adaptation option types and stressors: What adaptation options were most emphasized in our literature review within the CC and N contexts? Which stressors were these associated with?
2. Planning and implementation: Was there a difference in how certain adaptation options were treated as anticipatory vs. responsive (or both) between the CC and N contexts? Did this influence whether they were implemented?
3. Management scales: Were some adaptation options more frequently implemented by top-down vs. bottom-up styles of management, with the aid of non-profit organizations, or as individual choice actions? Does this pattern change with context?
4. Community focus: Were there differences in the suite of adaptation options most frequently listed as having a community focus or not, as being implemented or not, and between CC and N contexts?
5. Regions: Were there national/regional differences in which adaptation options were used and how they were applied?

Analyses related to differences in goal assignment were excluded due to large difficulties in consistently categorizing goals (see Supplementary Material Section 4).

For topic 1, rankings ($r_{i,d}$) of stressor descriptors (d) of each adaptation option record (i) were converted to scores ($s_{i,d}$) using Equation (1) to control for differences in the number of stressors ranked and slight variations in ranking methods (e.g. reporting ties). Options with no rank were assumed 0.

$$s_{i,d} = \left(\max_{d} r_{i,d} + 1 - r_{i,d} \right) / \sum_{d} r_{i,d} \tag{1}$$

The $\max_{d} r_d$ was the maximum for each record i, so that a row with $r_{i,\, d=1} = 1$, $r_{i,\, d=2} = 2$, and $r_{i,\, d=3,4,5} = 0$ had a maximum value of 2, and these scores were calculated as $s_{i,\, d=1} = \frac{2}{3}$,

$s_{i,\ d=2} = \frac{1}{3}$, and $s_{i,\ d=3,4,5} = 0$. The scores therefore summed to 1 across all stressors, and each score indicated relative importance of the stressor. The sum of scores over all adaptation option records ($\sum_i s_{i,\ d}$) were then compared between CC and N contexts. Because each adaptation option record had equal weighting in this sum, sums also reflected the overall popularity of adaptation options. That is, no scaling was done among adaptation options to control for the relative frequency of records.

When adaptation options were analyzed in relation to other categorization attributes (topics 2–4), attribute frequencies were calculated relative to all records of that adaptation option. Because only one choice was allowed under "planning", and "implemented" and "community-focused" were binary choices (Box 3), these frequencies were straightforward (i.e. percentage of "Anticipatory" or "Yes" counts for an adaptation option). Since participants were free to categorize as many managers as they liked for a given record, "manager" records were transformed to percentages of four management types ("Top-down", "Bottom-up", "Non-profit", and "Individual"; Box 3). Proportions were calculated as counts of a manager's presence within a particular category, divided by the sum of all indicated managers (count of all presences) for that record. Management-type proportions were then summed across all records of a certain adaptation option within a given subset (i.e. some combination of CC or N context, implementation, and community focus), to analyze trends in how and when adaptation options were implemented under specified conditions (topics 2–4). Sums were divided by the number of records of that adaptation within a subset to remove the effect of popularity.

Finally, for topic 5, we ran correspondence analyses on adaptation option record counts by nation and region grouped under the three banners: "ecological", "social", and "institutional", within each of the four subsets of adaptation records, i.e. CC or N, and community-focused or not. Analyses and visualizations used packages "ca" (Nenadic and Greenacre, 2007) and "ggord" (Beck, 2017) in R version 4.0.2 (R Core Team, 2020).

Results

The literature searches returned a total of 1834 adaptation option records (1801 used for analyses) sourced from across 21 regions/nations (Table 1). The publication years of the papers reviewed spanned 1996–2018, but records were most frequently found to have been published 2008 or later (see Supplementary Material for access to the full repository containing all adaptation option records and literature reviewed). These classifications represent, to our knowledge, the most comprehensive repository of information on fisheries adaptation options yet assembled. We note, however, that our research documents *scientific knowledge* of adaptation, which may be biased towards countries that allocate more funding towards climate change or fisheries research, and for which a larger body of literature was available. For example, 29% of the examples are from the USA, and 36% originate from Australia (Table 1).

Adaptation option types and stressors

The order of the adaptation options listed in Figure 1 are indicative of the relative frequency of the adaptation options recorded within the CC vs. N searches. Higher ranked adaptation options were cited more often. Circle size indicates the total score ($\sum_i s_{i,\ d}$), which is affected by both frequency and within-record importance [Equation (1)]. In the CC context, research was by far the most highly cited adaptation option, with the other highly cited adaptation options spread across all three "ecological", "social", and "institutional" banners. Investment in new gear or innovations, education, diversify livelihoods, market diversification, and international agreements were all listed as important socially based adaptations (with "importance" indicated by being ranked among the top 12 of all adaptation options and scoring > 20 for at least one stressor). Reviewing programs/regulations, adaptation programs, and coordination and organization were important institutionally based adaptation options. However, institutional adaptation options were not easily differentiated from certain ecological and social adaptation options, including research. For example, coordination and organization may signal the formation of a cooperative, while reviewing programs and regulations may also address issues of enforcement, and adaptation programs may have a strong component of research (see Supplementary Material Section 4). Reduction in other stressors, enforcement, marine protected areas (MPAs), and restoration were also cited as important ecological adaptation options (Figure 1). However, instances of these three adaptation options were also easily confused with each other within the ecological banner. As a result, patterns among these three ecological adaptations are sometimes not independent and should be considered as a similar trend together. Distinctions between ecological and social adaptation options were more easily classified, as was the distinction between CC and N contexts (although exceptions exist, see Supplementary Material Section 4).

The most important adaptation option cited under the N context was enforcement, followed by research. Surprisingly, these were the only ecological adaptation options, along with MPAs (ranked 11th), that were within the top 12. Two institutional adaptation options were also highly ranked: coordination and organization and review programmes or regulations. Also note the interchangeability of these institutional and ecological adaptation options as noted in the CC context. The remainder of the top 12 included a variety of social adaptation options: investments in new gear or innovations, investment to improve the value chain, economic or community development, diversify livelihoods, education, transition out of fisheries and cooperatives. By contrast, in the CC context, many of these same social options were ranked much lower, in the bottom half. Other ecological and institutional adaptation options cited within the N context ranked quite low. These included restoration, dynamic ocean management, reductions in other stressors, individual property rights, and international agreement. Though disaster risk management, disaster funds, and insurance were low scoring in both contexts, these were far lower in the N context (Figure 1).

Although there was substantial overlap in which stressors were emphasized with certain adaptation options in both CC and N contexts, some distinct differences were also evident (Figure 1). In the CC context, ecological uncertainty was the most cited stressor. Stock declines and species distributional shifts were also cited, although note that these were not easily distinguished from ecological uncertainty during classification (Supplementary Material Section 4). To a lesser extent, extreme climatic events were also cited. Unsurprisingly, social uncertainty was often associated with social- or institutional-type adaptation options; however, these types of adaptation options also had a solid grounding in ecological uncertainty or other ecological stressors. Socially based stressors, such as consolidation, globalization, market changes, and regulation change, were not often cited within the CC context. Ocean acidification did

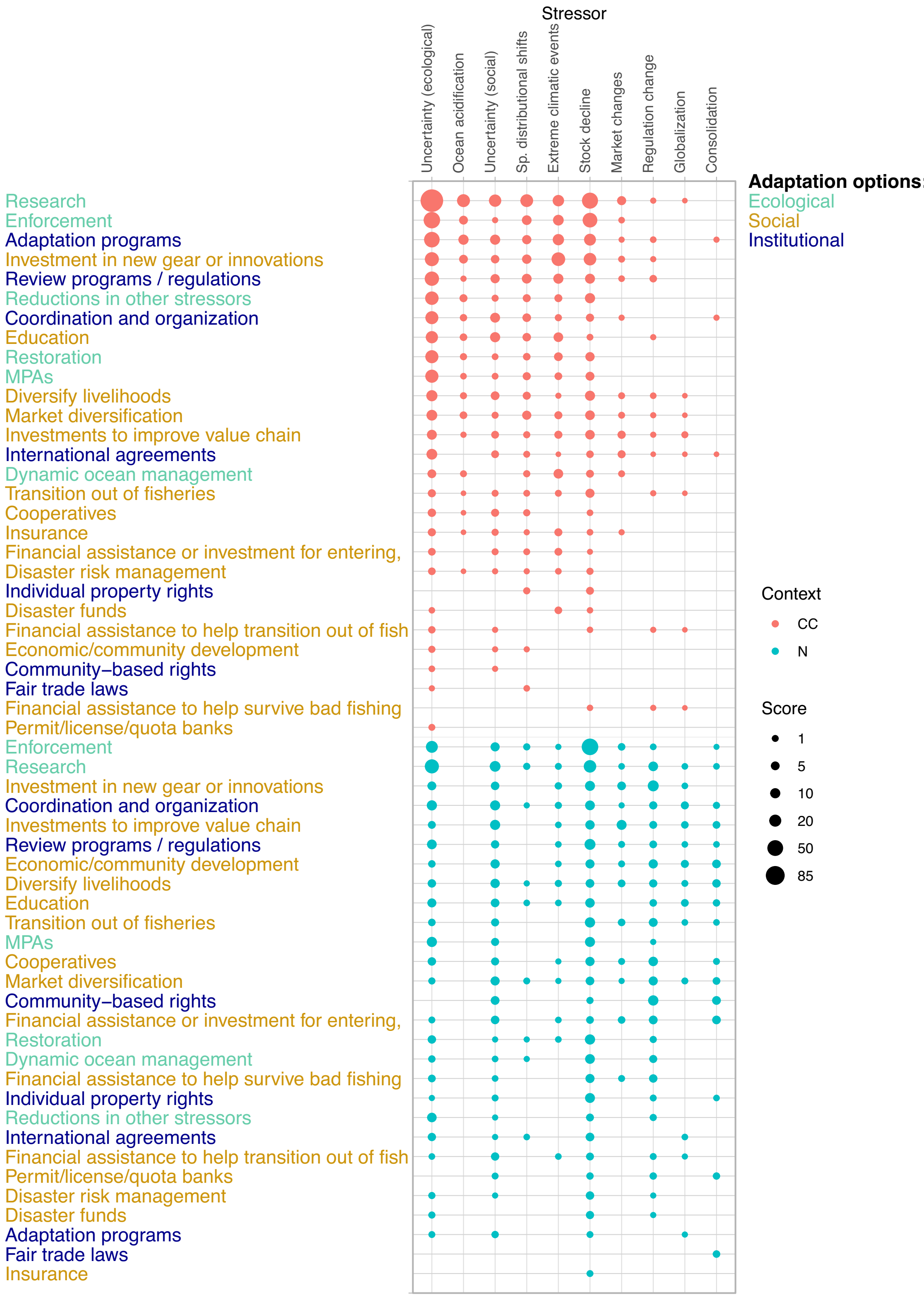

Figure 1. Adaptation options recorded in the study, along with the relative importance of stressors identified from CC (top, red circles) and N (bottom, blue circles) literature searches. Adaptation options (at left) are ordered by frequency across all records, while circle size reflects the total score, which is affected by both frequency across all records and stressor rank within a record [see Equation (1)]. Adaptation option names are color-categorized under three broad banners: ecological, social, and institutional.

not have a particularly strong presence in the review, except with reference to research, but it was mentioned infrequently across a wide variety of adaptation options (Figure 1).

In the N context, stock decline was most frequently cited as a stressor, followed by ecological uncertainty, social uncertainty, and regulation change (although note that the last was not easily distinguished from market change during classification—see Supplementary Material Section 4). Extreme climatic events, species distributional shifts and ocean acidification were mentioned very rarely or not at all, indicating that these are all mainly dealt with in the CC context. Globalization had very little presence in the review, although notably more in the N context than the CC context. The remaining socially based stressors: consolidation and market changes, had relative high rankings for select, predominately social adaptation options, and were also more frequently cited in the N context (Figure 1).

Planning and implementation

Under all three banners (ecological, social, and institutional), adaptation options were recorded more often as responsive when found in the N context rather than the CC context (more green area in pie charts under the two rightmost columns, Figure 2, left panel). In both contexts, adaptation options were also more frequently categorized as responsive or both when they were already implemented (more purple area in the right column compared with the left within each context, Figure 2, left panel). Almost all adaptation options were recorded at least once in each of the three planning modes (anticipatory, responsive, both), indicating no clean-cut differences among adaptation option records in the process by which they were or could be implemented.

Management scales

Patterns in the actors involved in implementing the adaptation options, or actors expected to be involved (what we call the "manager" in this study), was similar between CC and N contexts. However, consistent differences could be seen among banners (Figure 2, right panel). Ecological and institutional adaptation options were managed top-down by centralized government institutions in most cases (more blue area in pie charts, Figure 2, right panel), although some of these adaptations were implemented by bottom-up processes, non-profit organizations, or individuals (e.g. dynamic ocean management, reductions in other stressors, research and restoration). Community-based rights, cooperatives, and economic or community development, were characterized by bottom-up and top-down management with similar frequency (more even red/blue mix in pie charts, Figure 2, right panel), while diversification of livelihoods, insurance, investment in new gear or innovation, investments to improve the value chain, and transition out of fisheries were all frequently associated with individual or business actions and decisions (more yellow, Figure 2, right panel). The few social adaptation options that were usually associated with top-down management (mostly blue, Figure 2, right panel) included education and all forms of financial assistance; however, bottom-up processes also contributed to these (some red, Figure 2, right panel). Bottom-up and top-down management were often found to both having contributed to records of a certain adaptation option, possibly because "local government" (top-down) was not easily distinguished from "community association" (bottom-up, see Supplementary Material Section 4). Although comprising a smaller percentage in most cases, non-profit organizations were associated with many ecological and social adaptation options across both CC and N contexts (Figure 2, right panel).

Community focus

When split by subsets defined by context (CC or N), whether implemented or not, and whether focused on communities or not, it becomes clear that the dominance of research and enforcement as adaptation options in both CC and N contexts (Figure 1) was highly dependent on having no community focus (see the top ten scored adaptation options in Figure 3). With no focus on communities, the pattern was similar to that found in Figure 1: ecological adaptation options tended to dominate, with the emphasis placed squarely on research, and in the N context, also on enforcement (Figure 3, bottom four panels). Other ecological measures, such as MPAs, reductions in other stressors, restoration, and dynamic ocean management, were cited more often in CC context papers. Of these, only MPAs were consistently mentioned within the N context (i.e. occurred in >0.05 of adaptation options, Figure 3). Within the N context, social or institutional adaptation options were more prevalent. These included coordination and organization, review programs/regulations, transition out of fisheries, investments to improve value chain, and market diversification. One consistently highly ranked social adaptation option was investment in new gear or innovations, found in both the CC and N contexts, and included in the top ten options in seven of the eight panels in Figure 3.

When community was a focus (Figure 3, top four panels), institutional adaptation options including adaptation programs, coordination and organization, and community-based rights were prominent along with education. Enforcement ranked far lower when communities were a focus, less important than the social adaptation options including diversify livelihoods, investments to improve value chain, economic/community development and cooperatives (Figure 3, top four panels).

Although research generally ranked lower when communities were the focus, this pattern depended slightly on implementation: research ranked highly in the CC context, particularly in the "not implemented" subset (Figure 3, top four panels). Social and institutional adaptation options were also particularly prominent in the implemented, community-focused, N context literature, with emphasis spread broadly across economic/community development, investments to improve value chain, community-based rights, cooperatives, research, coordination, and organization and financial assistance, or investment for entering, transferring, or restructuring fishing businesses.

Regions

Results related to region-specific trends should be taken with caution because only one to three researchers contributed to classifying literature from a region. Individualistic search and classification tendencies can therefore confound some trends among regions, along with other uncontrolled differences among regions in what literature was available for searching. In the N context, Sweden and Finland displayed consistently strong use of social adaptation options, while other northern European nations placed greater emphasis on institutional adaptation options either without a community focus (Faroe Islands) or in both cases (Iceland, Figure 4, right panels). Documents from Canada tended to

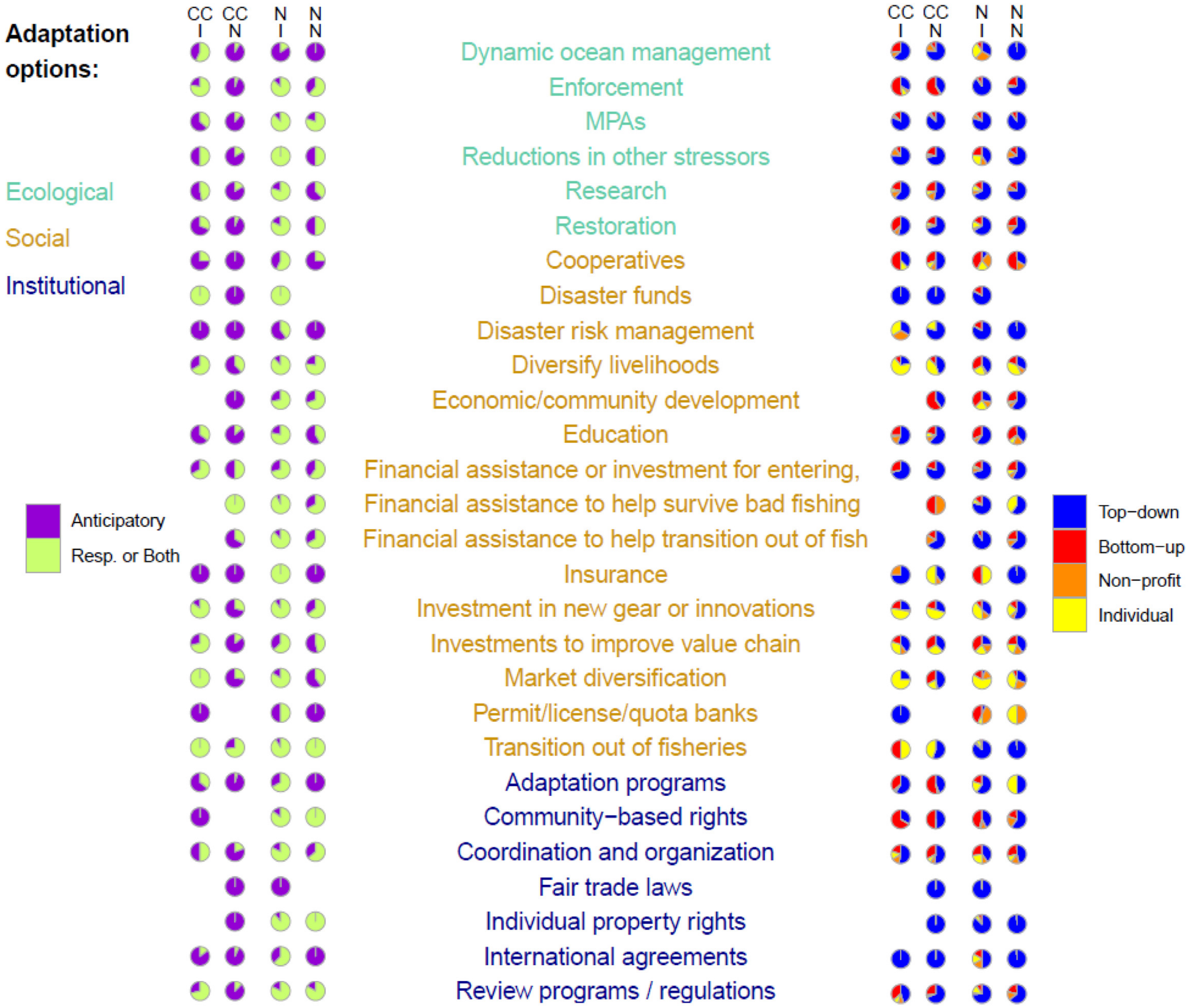

Figure 2. Proportion of adaptation option records that were considered anticipatory, responsive, or both in planning (left) and managed by top-down processes, bottom-up processes, non-profit organizations, or individuals (right) are represented as pie charts, calculated within a CC or N and split by whether the adaptation option was implemented or not (I or N). Adaptation option names are color-categorized under three banners: ecological, social, institutional.

mention more social adaptation options when community was a focus, with Canada, UK, and New Zealand referencing ecological adaptation options when community was not a focus. In the United States, social adaptation options were common, while Australia, New Zealand, and Italy tended to always mention more ecological and/or institutional adaptation options (Figure 4, right panels).

In the CC context, the EU and the UK tended to mention more social adaptation options when community was a focus (Figure 4, top left panel). Without a community focus under CC, ecological adaptation options were mentioned more often by the UK, Sweden, and New Zealand, whereas institutional adaptation options were heavily emphasized in Canada and the EU (Figure 4, bottom left panel). Italy instead showed greater emphasis on ecological adaptation options when community was a focus, and both institutional and social when not. Literature from Germany, the Netherlands, and Finland documented strong preferences for social adaptation options regardless of whether the community was a focus or not (Figure 4, left panels). No clear trends emerged for the United States of America or Australia.

Discussion

A key lesson that can be taken from this exercise in conceptualizing adaptation options is that there is a general need for clarifying expectations regarding who or what is resilient or adapting, as management adaptation does not necessarily equate to adaptation of stakeholders. Here, distinguishing "ecological" from "social" types helped to demonstrate an emphasis on management adaptation in fisheries research related to climate change, with lesser emphasis placed on supporting positive stakeholder adaptation. For example, temperature-dependent harvest control rules or variable closure dates (Melnychuck et al., 2014; Pinsky and Mantua, 2014) may provide more rapid and accurate predictions or more effective restrictions of harvesting opportunities in the face of climate change, thereby preventing reductions in ecological resilience. Such

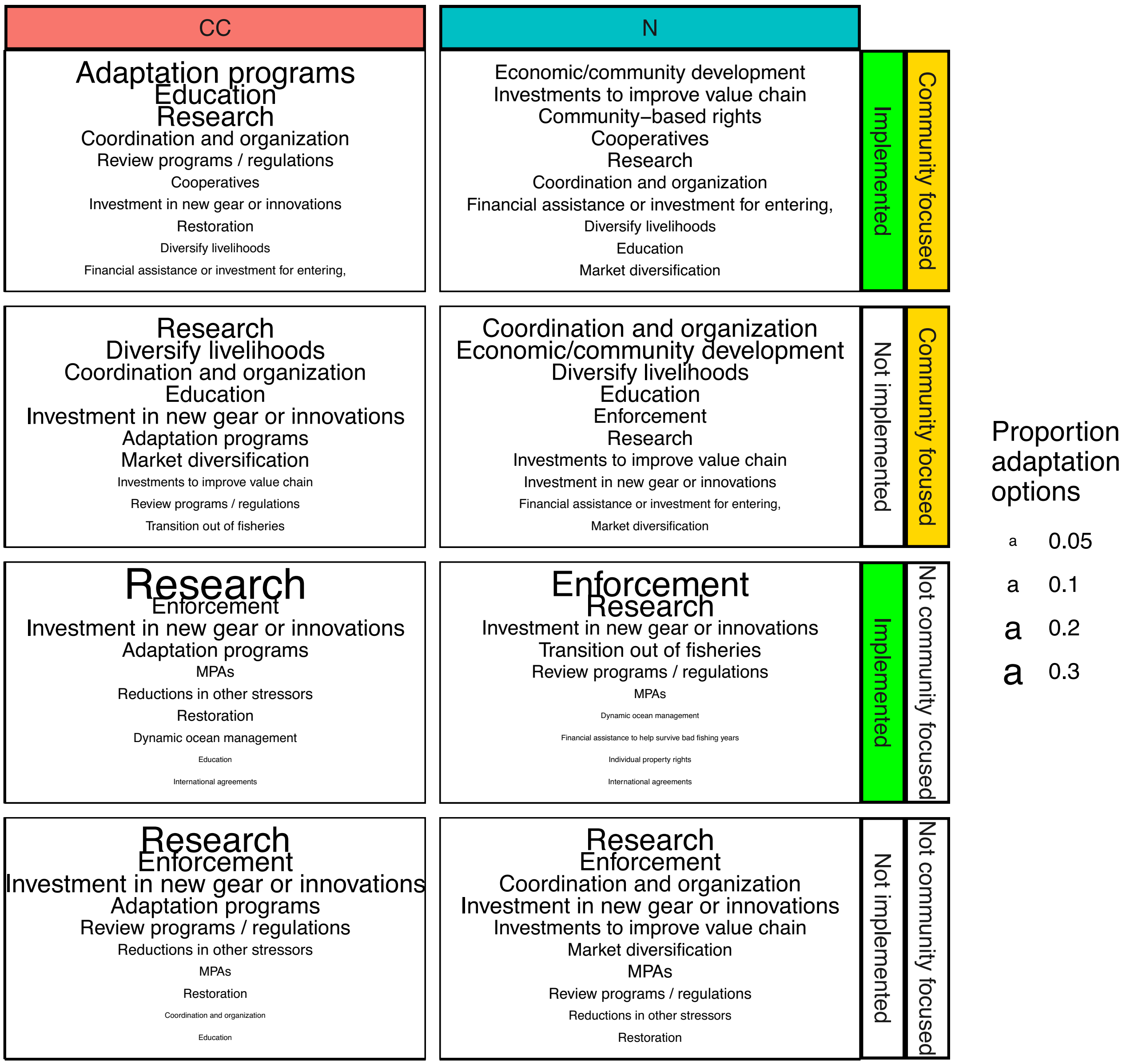

Figure 3. The top ten most frequently cited adaptation options are listed within a CC or N context, and within a subset defined by having a community focus and being implemented or not. Text size reflects the proportion of a given adaptation option found within the subset of records with attributes defined by panel labels at right.

adaptation options support management adaptation, but what will stakeholders do with this information? What direct or secondary effects on social resilience were intended? Were they achieved after implementation? Having a clearer overview of how adaptation options have been used in the past can help structure an approach to answering such questions in individual application.

Recent studies regarding adaptation options in fisheries have been mainly written within a CC context (Comte and Pendleton, 2018; Poulain *et al.*, 2018; Whitney and Ban, 2019; Pecl *et al.*, 2019; Bell *et al.*, 2020; Ojea *et al.* 2020). Comte and Pendleton (2018) compiled "adaptations", categorized into the four types addressing the goals of mitigation, protection, reparation, and adaptation to support resilience in coral reef ecosystems. The first three types focused mostly on addressing ecological hazards or resilience; the fourth centered around social adaptation (e.g. livelihood adaptation and relocation). Other studies have centered on adaptation to climate, among other changes, by certain resource users or individuals (e.g. Himes-Cornell and Hoelting, 2015; Pecl *et al.*, 2019; Jara *et al.*, 2020). Bell *et al.* (2020) and Ojea *et al.* (2020) present reviews of actions potentially employed, mainly by centralized government, to reduce impacts of climate change in fisheries, listing both a variety of technical improvements to assessments or harvest- and conservation-related management strategies, as well as social interventions (e.g. permit banking, co-management, gear innovation, increasing product value, and community/stakeholder initiatives). Poulain *et al.* (2018) summarized climate adaptation actions taken in relation to fisheries and aquaculture globally by focusing on case studies. Adaptation activities were categorized into

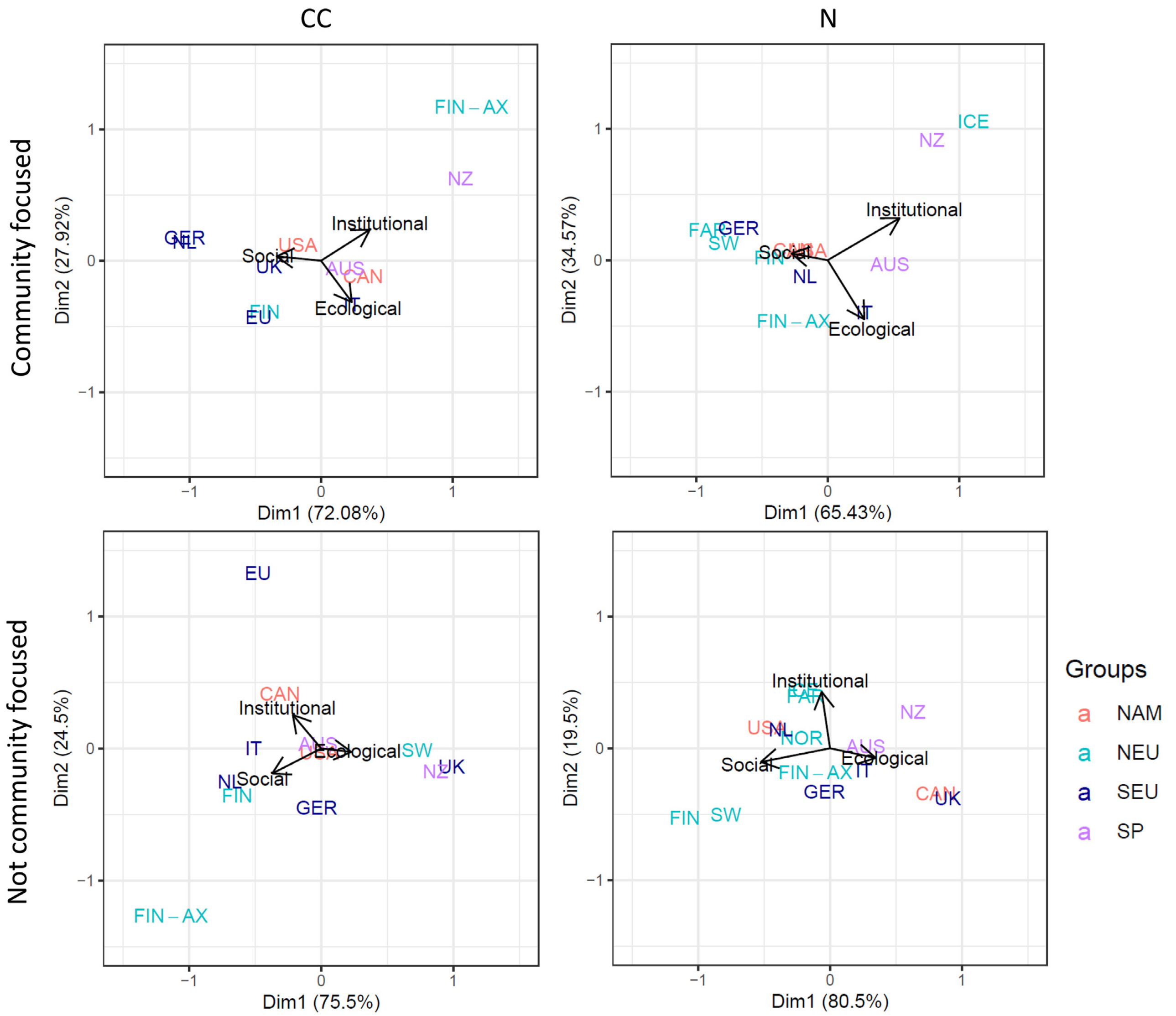

Figure 4. Ordinations from correspondence analyses of the frequency of using different adaptation banners (ecological, social, and institutional) in literature pertaining to the nations labelled: AUS, Australia; CAN, Canada; EU, European Union (not country-specific); FAR, Faroe Islands; FIN, Finland; FIN-AX, Åland Islands; GER, Germany; ICE, Iceland; IT, Italy; NL, Netherlands; NZ, New Zealand; SW, Sweden; NOR, Norway; UK, United Kingdom; USA, United States of America (and regions within). Nations were colored by larger geographical areas (NAM, North America; NEU, northern Europe; SEU, southern and continental Europe; and SP, south Pacific). Correspondence analyses were conducted within the four subsets of adaptation records with a CC or N, and with a community focus or not.

three types: institutional adaptation, livelihood adaptation, and risk reduction and management for resilience. Many of these reviews include examples of social interventions and often had management scales stretching to include private/non-governmental influences. This study joins these by conducting an unconventional review of adaptation options recorded by a wide variety of fisheries researchers, emphasizing their utility beyond a CC context. Such studies are not only useful for revealing broad trends in how adaptation options have been used in the past, but also barriers to conceptualizing and/or implementing adaptation options under uncertain and undefined conditions. They provide a foundation for analyses of what adaptation processes are or are not supported within a certain EBM implementation, allowing for clearer judgement and targeting of assessment needs (Woods, 2021).

Emphasis and stressors

The task of discretizing observed adaptation options is inherently problematic: adaptation options and stressors can be interpreted slightly differently among individuals depending on the context. For example, enforcement or further research (for example, into stock dynamics) was often prioritized by fisheries systems facing declining stocks in the literature without a climate change focus (N, Figure 1). However, many of these records relate to enforcement of harvest limits set by stock assessment research, a process that reduces the stressor (i.e. overharvesting). Reducing the stressor would be more akin to "mitigation" within a CC (i.e. reducing carbon emissions), rather than adaptation. As "mitigation" in the field of climate change research has its own meaning that is distinct from adaptation (e.g. Füssel, 2007a; VijayaVenkataRaman *et al.*, 2012), it did not feature strongly in our CC search results, and cannot be compared between CC and N contexts. That is, preventing stock decline due to overharvesting via research, forecasting, and enforcement is the main mitigative function of fisheries management and cannot be considered an adaptation option, except within the CC context where it could be considered an "other stressor" to be reduced (i.e. thereby reducing negative impacts of interactions between fishing and effects of carbon emissions). Caution should therefore be taken when comparing multiple records of the same adaptation option, as its actual usage depends directly on the stressor and context involved.

Confusion may be added by a lack of distinction among possible stressors: stock decline, species distributional changes, and ecological uncertainty were not consistently categorized. Causes of stock decline within the CC context could be traced back to species distributional and other shifts due to warming oceans (Perry *et al.*, 2005; Cheung *et al.*, 2009; Astthorsson *et al.*, 2012; Champion *et al.*, 2018) or indirect linkages to anthropogenic carbon emissions (see Gattuso *et al.*, 2015). Stressors are also especially difficult to distinguish when they are yet unobserved or with an unknown ecological cause, and hence with less clear pathways for adaptation. Between the CC and N contexts, differences in classification tendencies appeared to be related to (i) the concrete observance of stock declines outside the CC context vs. potential nature within the CC context, and (ii) the certainty of the ecological cause (i.e. it is more frequently known outside the CC context). For example, Garnacho and Pinnegar (2013; record IDs: 1091–1201 in Supplementary Material spreadsheets) discuss within the CC context a need for setting harvest limitations more conservatively for species considered more vulnerable to effects of climate change (1175) and modifying stock assessment and quota-setting practices for new species commercial opportunities (1174). Here, they were considered to address ecological uncertainty as a stressor, but if they were instead related to an actualized case study (i.e. one that has already come to pass), they might have been considered standard activities of fisheries management in relation to stock decline or a species distributional change. Growing recognition of complex interactive effects of climate and fishing on species' distributions (Poloczanska *et al.*, 2016), spatial structure (Kerr *et al.*, 2017), abundances (Bonanomi *et al.*, 2015), and phenotypic diversity, growth, and adaptive capacity (Morrongiello *et al.*, 2019; 2021) can further complicate adaptation planning efforts (Gaines *et al.*, 2018, Free *et al.*, 2020).

This dependency on context, stressor, stressor uncertainty, and actualization can make it difficult for an average fisheries researcher to conceive of or interpret adaptation options. Therefore, adaptation option occurrences presented here should be thought of as a theme, rather than repeated observances of the same method. Certain related adaptation options were also sometimes confused and should be interpreted as a common theme (e.g. research, enforcement, MPAs, and reductions in other stressors). However, distinctions between social and ecological adaptation options were more easily made. Frequencies of each differed considerably between the two contexts, and contrary to our hypothesis, the top adaptation options considered in the CC context focused heavily on ecological adaptation options, whereas those emphasized within the N context were under social banners. Comte and Pendleton (2018) found a similar ecological emphasis in their review of climate change adaptation options related to tropical reefs, rather than a focus on human adaptation. A survey of fishery practitioners regarding barriers and opportunities for climate change adaptation also found similar trends: preferences were placed on ecological rather than social options. The authors attributed barriers to the use of social options to "…trust in established, better understood actions, an ecologically-minded bias in adaptation planning, and a perception that conventional ecological management actions are less risky" (Whitney and Ban, 2019, p. 8). Similar barriers could be interpreted from this study, as any of our literature sources with the term "ecosystem" in the title was almost entirely dominated by ecological and institutional records (IDs: 252–257, 305–310, 593–594, 595–596, 1027, and 1217–1218 in the Supplementary Material spreadsheets). The two exceptions were from Finland (IDs: 881–882 and 883), a nation well-known for its broad-reaching system of social services. Furthermore, institutional adaptation options were found to be easily confused with both ecological and social adaptation options, depending on the case, possibly signaling vagueness in how to approach institutional change in the literature, and for what purpose.

Management scales

When analyzing management scales, ecological and institutional adaptation options were mainly recorded as top-down processes; however, some of these options were implemented through bottom-up processes as well, by non-profit organizations, or by individuals (e.g. dynamic ocean management, reductions in other stressors, research, and restoration). Some of the records with "ecosystem" in the source title were government-sponsored sources (IDs: 593–594, 595–596), and the literature broadly appeared focused on methods focused on reducing ecological risks, thereby mainly supporting management adaptation.

In contrast, social adaptation options were particularly prominent when there was a community focus (Figure 3), particularly in the European literature searches (less so in Australian and Italian, Figure 4), and often managed "bottom-up". Cooperative and economic or community development options were characterized by bottom-up and top-down management with similar frequency, as were community-based rights. In contrast, diversification of livelihoods, insurance, investment in new gear or innovation, investments to improve the value chain, and transition out of fisheries were all frequently associated with individual or business actions and decisions. Records were often based on research articles on the subject (e.g. several examples from records 23–327 in the Supplementary Material spreadsheets) and indicate that bottom-up processes (e.g. business/community associations), and in some cases non-profit entities, have had an important role in governance through the formation of organized social groups with greater rights, decision-making power, or coordination to reduce risk threats (except through insurance). Individual choice and actions, on the other hand, appeared vital to effect livelihood/business modification (diversification, innovation, streamlining, or transition).

A diversity of governance processes in addition to top-down resource management therefore appear critical to adaptation, mirroring results of other reviews on the subject (Poulain *et al.*, 2018; Wilson *et al.*, 2018; Lomonico *et al.* 2021). Some of these processes extend beyond what is institutionally considered the jurisdiction of what centrally governed, top-down fisheries management is responsible for implementing (Gutiérrez *et al.*, 2011). Conceptual models of social-ecological systems (Berkes *et al.*, 2000, Kooiman and Bavinck, 2005; Ostrom, 2007), suggest that top-down and bottom-up processes cannot be viewed in isolation: components of governance interact and can cause positive or negative feedbacks, requiring a social-ecological approach for understanding (Yletyinen *et al.*, 2018). As a result, influencing cross-scale management interactions can be important in practice by using them to enhance positive or diminish negative impacts on resilience (Niiranen *et al.*, 2018). For example, resilience could be enhanced through science–industry collaborations and outreach that use centralized government funds to support innovative and co-creative interactions with stakeholders (Lomonico *et al.*, 2021). Likewise, interventions may be used to decrease negative impacts of government policies, for example, those that decrease livelihood diversification (i.e. quota systems or licensing restrictions; Holland and Kasperski, 2013; Holland *et al.*, 2017) or market opportunities (e.g. direct marketing or distribution patterns; Stoll *et al.*, 2015a; Stoll *et al.*, 2015b). Such interventions can be especially important when considering that most records related to livelihood modification rely on individual choice. Without incentives created for individuals/businesses to modify their livelihoods in a manner that can lead to positive outcomes for the whole system, maladaptation can occur (see, for example, Hamilton *et al.*, 2004; Criddle, 2012; Kates *et al.*, 2012).

Planning and implementation

Ecological adaptations were more dominant under the CC context, and were more anticipatory when related to climate change, or when not yet implemented (Figure 2). Social adaptation options were more prevalent in the N context (Figure 2) and often classified as responsive, particularly when already implemented (e.g. several records within IDs: 23–327). This prevalence of social adaptation literature outside the CC context is not what one would expect given that methods used to effect adaptation in management and stakeholders within CC are designed to generate social adaptation options [see Woods (2021) for a fuller analysis]. Current methodology for climate change adaptation gathers information, where relevant, regarding socially constructed vulnerability to generate adaptation options that span social strategies, among others, using vulnerability-based assessments (Burton *et al.*, 2004; Füssel, 2007b; Brugère and De Young, 2015; and see Ekstrom *et al.*, 2015 for an example). In contrast, vulnerability assessments of natural resources tend to yield information regarding secondary effects on social resilience or adaptation and are not designed to invoke social strategies to maintain social resilience directly (Chin *et al.*, 2010; Stortini *et al.*, 2015; Hare *et al.*, 2016). This pattern suggests that most literature reviewed in the CC context likely does not use methodology developed for supporting planned adaptation of social groups, or a related social-ecological approach (Allison and Ellis, 2001; Folke, 2006; Cinner *et al.*, 2011).

As a result, the greater tendency of social adaptation options to be responsive when implemented outside the context of climate change, along with a general lack of them within a CC, likely indicates a lack of planning and therefore a continuation of the status quo into the climate-changed horizon. Following this path, future uncertainty will be minimized via improved forecasting to sustain ecological resilience using natural extensions of top-down, natural resource management tools (i.e. those mainly focused on achieving positive ecological outcomes, with secondary social effects). However, addressing social impacts appears *ad hoc* and rarely planned, which if extended into the future, will result in a patchwork of social damage mitigation measures used responsively where stakeholders experience extreme negative impacts from unexpected changes to the system, and perhaps from those that were expected as well.

The argument has been made often in climate change adaptation literature that planning ahead for adaptation can more effectively reduce negative impacts than waiting to respond once impacts have been felt (Füssel, 2007a). Do the patterns found here then suggest that fisheries-dependent stakeholders rely on adaptive management cycles that are only designed to create responsive solutions to problems after they are actualized? Can anticipatory preparation be incorporated to minimize negative impacts of future changes, whether known or not (as is done in climate adaptation planning)? Do planned ecological/social interventions work (i.e. are they monitored and modified through adaptive management)? Posing such questions with regards to a certain system highlights that the type of planning involved (e.g. readiness to respond and cope vs. avoidance) is an important distinction made within climate change adaptation assessment literature (Füssel, 2007a; Füssel, 2007b) that is not featured as strongly within fisheries literature related to climate change. These patterns instead suggest a widely held belief in fisheries that to prepare for climate change, more research and management adaptation (using standard tools of EBM) are necessary. This belief also echoes common views that EBM could be better implemented through greater scientific knowledge and institutional change, and it agrees with the opinion of surveyed fisheries practitioners that EBM is the most appropriate framework for implementing climate change adaptation (Ogier *et al.*, 2016). Nonetheless, the current lack of a social-ecological approach in EBM (Ogier *et al.*, 2016) that has been helpful in effecting planned adaptation of stakeholders in response to climate change (e.g. Allison and Ellis, 2001; Folke, 2006; Cinner *et al.*, 2011) also indicates a disregard for using anticipatory adaptation options to support positive outcomes of stakeholder adaptation. This pattern therefore does not support the idea that management adaptation, as depicted from the literature, will yield greater systematic propensity towards avoiding negative future impacts to stakeholders than currently experienced, as there is little regard for using anticipatory tools and methods as done in climate change adaptation assessment (Füssel, 2007a).

Conclusions

Our findings suggest that the current broad approach to climate change adaptation within fisheries entails management adaptation to become more climate-informed so that core functions of ecological resilience are maintained. Adaptation of stakeholders and maintaining social resilience are not as strongly focused upon, which is especially surprising given the theoretical emphasis of EBM on social-ecological systems (Grafton, 2010; Long *et al.*, 2015; Bahri *et al.*, 2021) and its appropriateness for effecting adaptation within a management framework (Ogier *et al.*, 2016). The judgement of whether planned adaptation of stakeholders should be included within a particular EBM implementation can be determined on a case-by-case basis, but there is no theoretical boundary for not doing so (Ogier *et al.*, 2016), especially given the emphasis in EBM on analyzing the full social-ecological system (Grafton, 2010; Long *et al.*, 2015; Bahri *et al.*, 2021). Adaptation is also most likely to occur if incorporated into current infrastructure rather than stand-alone programmes (Füssel, 2007a). Making the distinction clear between what management vs. stakeholder adaptation is meant to achieve will help to underline whether and how each adaptation process is supported in a given system (Woods, 2021).

However, we also recognize that the conclusions drawn from this study may be more applicable to some regions than others. Several nations appear to be better positioned to focus on social resilience, perhaps as a result of being historically more focused on providing social services and welfare (e.g. Nordic and Germanic nations, Canada, and New Zealand), although there was little consistency in the context in which social adaptations were used (Figure 4). Patterns among regions must also be taken with caution, however, as they can differ in the type and frequency of information available in web searches, and individualistic differences among researchers comprising regional teams may bias regional patterns. In addition, although this study is limited to only a series of global North nations that can be broadly categorized as Western-style (Kooiman and Bavinck, 2005), government policies, the strength of centralized government, and the social structure of any nation (e.g. in the need or availability of certain social services) can indirectly affect what is considered an important or necessary adaptation option. For example, this study suggests an importance of managers beyond those in centralized government for supporting social resilience, in agreeance with other studies of adaptation options in fisheries (Himes-Cornell and Hoelting, 2015; Poulain *et al.*, 2018; Pecl *et al.*, 2019; Jara *et al.*, 2020). It also indicates a need for considering anticipatory approaches as suggested by climate change adaptation literature (Burton *et al.*, 2004; Füssel, 2007a; Füssel, 2007b). Overall, by contributing to an understanding of how adaptation to change is currently viewed and approached within a diverse set of fisheries literature, more effective pathways for incorporating adaptation options into future policy and management can be identified, either within or external to EBM, on a case-by-case basis (Burton *et al.*, 2004; Grafton, 2010).

Work statement

PJW, HB, and JM contributed to project oversight and writing, and along with all others contributed to searching and reviewing literature and/or editing of the manuscript.

Supplementary Data

Supplementary material is available at the *ICESJMS* online version of the manuscript.

Data availability statement

The data underlying this article are available in the article and in its online supplementary material.

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