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Barriers and opportunities for social-ecological adaptation to climate change in coastal British Columbia

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ABSTRACT

Climate change poses novel and complex challenges to planning, management, and policies for marine and coastal social-ecological systems. Despite ongoing discussion of adopting interventions for improving adaptation and adaptive capacity to climate change, practitioners often continue to carry out conventional management strategies that do not effectively incorporate climate change impacts and projections. Using a web-based survey and semi-structured interviews, we explored the perceptions of practitioners (coastal managers and planners) in British Columbia, Canada relative to climate change risks, adaptation actions for social and ecological systems, and barriers for adaptation within the region. Overall, practitioners shared a concern that climate change is not currently well incorporated in management or policy in this region, and noted significant implementation gaps. Practitioners expressed more support for ecological adaptation actions that are well suited to regional implementation, such as incorporating climate change projections into management and reducing fisheries overexploitation, than for actions such as protecting specific areas. Social adaptation actions were overall perceived as less useful than ecological adaptation actions, and actions that would support local management and monitoring efforts were viewed as more useful than developing alternative livelihoods. The main barriers and associated opportunities for climate change adaptation in marine management included political action, reducing scientific uncertainty, improving communication, and increasing capacity (both funding and staff). Additional opportunities include effective engagement with Indigenous governance, improving policies and funding for adaptation including monitoring, and focusing efforts on communication and education programs specific to practitioners and communities. This study demonstrates the necessity of collaboration across scales of management for effective climate change adaptation.

1. Introduction

Marine and coastal regions are dynamic social-ecological systems (SESs) that are threatened by climate change, among other anthropogenic stressors (Harley et al., 2006; Hoegh-Guldberg and Bruno, 2010; Poloczanska et al., 2016). The direct effects of climate change on the ocean, including increasing ocean temperatures, ocean acidification, rising sea levels, and changing storm cycles, also have indirect effects on coastal social and ecological systems (Connell and Russell, 2010; Turner et al., 2010). Despite international agreements to reduce emissions, which are intended to stabilize atmospheric greenhouse gas (GHG) concentrations and mitigate the impacts of climate change (i.e. the Paris Agreement, 2016), emissions and associated impacts continue to increase (IPCC, 2018). Due to the lag time of GHG concentrations and the warming of the ocean, climate-related changes will continue for the next several centuries no matter what mitigation activities occur (Solomon et al., 2009). This current stasis demands adaptation at all scales. At local and regional scales, adaptation planning can be an effective means of focusing action on climate change (Butler et al., 2015; Hine et al., 2016).

Adaptation actions are those that minimize the negative effects and/or maximize the potential benefits of climate change impacts, ultimately improving the social and/or ecological outcome (Smit and Wandel, 2006; McClanahan et al., 2008; Eisenack and Stecker, 2012; Bennett et al., 2014; Whitney et al., 2017). Adaptation actions are often categorized into 'hard' (e.g. engineering, infrastructure interventions), 'soft' (e.g. policy, governance, institutional changes), and 'ecosystem-based' (e.g. management, conservation, restoration) approaches (Biagini et al., 2014; Jones et al., 2012). To date, implemented adaptation actions have tended to be reactive, and have focused on

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managing ecosystems or social systems separately rather than through a linked social-ecological approach (Berrang-Ford et al., 2011). Theoretical research has aimed to frame and identify indicators of adaptive capacity, or the latent potential for a system or group of individuals to adapt to change or take advantage of the opportunities (Brooks, 2003; Mortreux and Barnett, 2017; Yohe and Tol, 2002). A recent review (Whitney et al., 2017) summarized various ecological, social, and social-ecological actions to proactively increase adaptive capacity through a social-ecological systems lens. Effective ecological adaptation actions included developing larger and more effective protected areas, improving connectivity among protected areas through network planning, and diminishing cumulative effects and non-climate stressors (e.g. resource extraction, pollution, infrastructure development; Hannah et al., 2002; Groves et al., 2012; Hagerman and Satterfield, 2014). Social adaptation actions included developing alternative livelihoods, infrastructure improvements, or supporting programs which develop social capital such as supportive institutions and community organizations (Adger et al., 2009; Adger and Vincent, 2005; Nelson et al., 2007). Since implementing adaptation actions will have impact across social-ecological spheres and scales, iterative monitoring and post-assessment evaluation of such actions is important for realizing benefits and preventing mal-adaptations (Cinner et al., 2018; Owusu-Daaku, 2018).

Many scientists now argue that to manage the 'wicked' problem of climate change, innovative and potentially controversial adaptation actions that aim to support linked social-ecological adaptation are necessary (Araújo et al., 2011; Hobbs et al., 2011; Serrao-Neumann et al., 2013). For example, proactive conservation planning may help both ecological and human communities to adapt to climate change impacts (Roberts et al., 2017). Implementing dynamic protected areas versus traditional static protected areas (Maxwell et al., 2015) may help maintain both ecosystems as well as provide social benefits to adjacent communities as species ranges change. Conservation triage decision-making (e.g. focusing on viable species or ecosystems rather than those which are threatened; Lawler, 2009; Wiens and Hobbs, 2015) has been proposed due to limitations of capacity, funding, and doubts about the long term efficacy of conventional actions including protected areas (Agardy et al., 2011; Bruno et al., 2018; Gill et al., 2017). Examples of proactive and unconventional adaptation strategies include managing for novel ecosystems as species and habitats change (Corlett, 2015; Doney et al., 2012; Hobbs et al., 2009), adaptive co-management, in particular for Indigenous peoples (Armitage et al., 2009; Berkes et al., 2000; Folke et al., 2005), and implementing adaptive fisheries management policies (Creighton et al., 2015; Ogier et al., 2016; Perry et al., 2010; Pinsky and Mantua., 2014).

Implementing adaptation actions falls on people involved in the 'front lines' of planning and adaptation work, i.e. managers and planners who work for governance and management organizations across scales (hereafter "practitioners"). Incorporating climate change adaptation is now a component of work for practitioners in a wide range of backgrounds and careers (Cohen, 2010; Eisenack and Stecker, 2012). There has been extensive research on the views and perceptions of the average citizen, or 'lay people', on climate change impacts and adaptive strategies (Capstick et al., 2015; Knapp et al., 2014; Lotze et al., 2018; Lowe et al., 2006). The perspectives of academic researchers have also been explored at global and regional scales, specific to marine conservation (Rudd, 2014), biodiversity conservation and protected areas (Rudd, 2011), climate change adaptation and risk (Lowe and Lorenzoni, 2007), and biodiversity conservation considering climate change (Hagerman and Satterfield, 2014, 2013). Since effective responses to climate change impacts will depend on responses at the local scale (Adger, 2001), understanding the perceptions of practitioners within a community of practice about the barriers and opportunities for adaptation can inform and direct better adaptation (Cinner et al., 2018). The perceptions of practitioners has been explored specific to adaptation to sea level rise (in coastal California; Moser and Luers, 2007; Tribbia and Moser, 2008), to terrestrial protected areas (in the Canadian province of Ontario; Lemieux and Scott, 2011), and within a US federal management institution (US Forest Service; Hagerman, 2016). What remains unclear are the actions to support adaptive capacity to climate change that would be most effective across multiple perspectives. Generalized theories of adaptive capacity are unlikely to apply across contexts, as adaptation actions, actors, and barriers to adaptation are diverse and complex (Eisenack and Stecker, 2012). Thus, it is important to develop a broad understanding of adaptation actions that could contribute to implementing adaptation strategies. What are the pragmatic approaches derived from theoretical adaptive capacity research that could support regional adaptation, if any? What are the barriers and opportunities to effecting change in current conservation and fisheries management approaches?

The purpose of this research was to explore the perceptions of a diverse set of practitioners including Indigenous peoples in regard to climate change adaptation within a coastal region, filling an important gap in the literature. We conducted a survey and semi-structured interviews with technical staff, marine planners, and fisheries managers working in British Columbia (BC), Canada, to explore how they perceive (1) climate-related risks to marine social-ecological systems, (2) social and ecological adaptation actions derived from the resilience and adaptive capacity literature, and (3) barriers and opportunities for adaptation in this context.

2. Methods

2.1. Case study and context

Climate change is likely to have negative ecosystem effects in productive and biodiverse coastal and marine areas of BC (Okey et al., 2014), and those impacts are already being observed (e.g. "Warm Blob" event, unusual algae blooms, warm water species arrivals; Chandler et al., 2017). However, many future impacts are poorly understood, especially at local scales and for social systems. Projections indicate that marine species will shift to higher latitudes and decline in abundance as ocean temperatures increase (Morley et al., 2018; Weatherdon et al., 2016). These suggest forthcoming social inequality issues among the diverse Indigenous (known as First Nations in this part of Canada) and non-Indigenous human communities in the region as access to marine resources and associated socio-economic and cultural benefits change and decline (Weatherdon et al., 2016). The coastal region of BC is an ideal place to investigate and describe the perspectives of experts working in planning and management in relation to climate change adaptation and marine planning because the effects of climate change are already being felt, and because there are active marine spatial planning and marine protected area processes underway.

There are several adaptation strategies being implemented in coastal and marine BC that at least partially or potentially relate to climate change. Canada has committed to international agreements under the Convention of Biological Diversity to protect 10% of national marine waters by 2020, and have made strong statements on climate change mitigation and adaptation strategies (Jessen et al., 2017; Lemieux et al., 2019). An ongoing marine protected area planning process is underway in the northern coastal portion of the province (MPANetwork, 2019), which involves practitioners and decision makers across governance scales. Many of those involved are also part of the Marine Plan Partnership (MaPP, 2019), a partnership between First Nations and Provincial governments to develop and support implementation of effective marine planning. Across the BC coast, First Nations are heavily involved in governance, management, and monitoring. The Guardian Watchmen in the traditional territories of 7 First Nations (Haida, Gitga'at, Metlakatla, Kitasoo/Xais Xais, Heiltsuk, Nuxalk, Wuikinuxv) work to monitor and steward their respective lands and waters and carry on traditional stewardship practices. Since 2005, independent Watchmen programs have been coordinated and

supported through a collaboration with the regional Coastal Guardian Watchmen program (Initiative, 2019). Awareness and rhetoric on climate change mitigation and adaptation is increasing both across Canada (Lemmen et al., 2016) and in BC (Nyland and Nodelman, 2017), in that both federal and provincial governments have made statements and set targets on limiting carbon emissions and establishing sector-specific and provincial adaptation pathways (Andrey and Palko, 2017; Vogel et al., 2018). However, the successful consideration of climate change impacts into management, and the development of adaptation actions, will be strongly influenced by practitioners working on applying policy proclamations.

2.2. Survey methodology

We conducted a web-based survey of practitioners working in coastal BC. The survey framing and questions were developed over the preceding months with feedback and discussion with regional First Nations governance organizations (Central Coast Indigenous Resource Alliance, Coastal First Nations/Great Bear Initiative) to ensure that the results would be informative. This collaboration also serves to develop Indigenous perspectives in climate change adaptation planning, which have typically been underrepresented (Ban et al., 2018; Sheremata, 2018; Wolf et al., 2013). Our selection criterion was people working in the coastal BC region with First Nations, Provincial, or Federal government organizations related to coastal and/or marine management and planning.

We obtained a regional sample of experts within this tight-knit community in two main ways: by email through existing relationships with First Nations organizations, and through emails to regional fisheries managers and marine planners accessed through the provincial government and federal Fisheries and Oceans Canada (Department of Fisheries and Oceans, hereafter DFO) website. Several participants also sent it on to others (snowball sampling). Invitation emails included a description of the project, information about planned follow-up work, and a link to the survey. Initial invitations were sent in early August 2017, and two reminder emails were sent prior to closing the survey in early November 2017 (following a modified Dillman schedule; Dillman, 2000). While there is no one directory or listing of relevant practitioners, we estimate that there are ~40 people working in relevant jobs that met our selection criteria of managers and planners working on the coastal system of BC.

The survey questions focused on perceptions of observed climate impacts, actions on climate change adaptation so far, and opinions of a set of proposed adaptation actions. The proposed adaptation actions were drawn from the literature within the field of applied conservation planning and social-ecological adaptation (Whitney et al., 2017, Table 1; for the complete survey, see Appendix B). As part of the survey, we included open-ended questions and opportunities for respondents to include context and commentary to enliven their quantitative responses and to allow for responses that we had not anticipated. We also provided the opportunity for individuals to express their willingness to participate in a follow-up telephone interview, which included questions related to adaptation actions, barriers and opportunities for adaptation within the experience of the participants and their work (Appendix C). Interviews were on average 30 min long (20–45 min).

2.3. Analysis and thematic coding

The survey used both Likert and open-ended questions throughout. We synthesized the relevance of each of the adaptation options by summing positive and negative responses along a five-point Likert scale using the 'likert' package in R (www.r-project.org). We coded open-ended survey and semi-structured interview responses to develop initial codes followed by focused coding to categorize common responses to specific questions (Charmaz, 2006). In this method, categories of responses emerged from dominant or frequently observed themes rather than through preassigned categories (Thomas, 2006). Participant responses to a single question often contained multiple themes. We calculated proportions of responses rather than respondents, and we reported sample sizes for individual questions as not all respondents replied to all questions. For example, if 6 respondents mentioned 10 themes, and 3 of the themes were about A, then the response proportion was 30%. We also identified additional codes relating to common issues that arose throughout the survey and interviews that were not specific to our initial questions. Given the small target population and hence sample size, the diversity of nuanced responses, and the limitations of our non-random sampling design (i.e. a focused target group, and snowball sampling), we did not use inferential statistics to generalize trends and results.

3. Results

3.1. Professional characteristics of respondents

A total of twenty-six individuals (65% estimated response rate) participated in the survey between August and November 2017 (Table 2; Appendix A). Sample sizes for different questions varied because not all respondents answered all questions (while 26 participated, 21 completed the entire survey). The high proportion of participants who self-reported as employed by First Nations governance we think reflects the current governance system and status of marine network planning on the northern BC coast, as well as interest in the topic. Eight survey participants also agreed to a semi-structured interview to elaborate on specific issues of interest and identify points of special concern (participant numbers are standardized to the survey participants; interviewed participants gave their consent and contact information to be interviewed).

3.2. Climate risks to marine social-ecological systems

Most participants (96%, 25 of 26 responses) noted direct or indirect observations of change that they attributed to climate change, including changing species and species' ranges (19%), warmer ocean temperatures (12%), changes in seasonality and other weather patterns (19%), and decreases in culturally important food resources (33%. e.g. *Porphyra* seaweed, salmon; Table 3). A few commented that they had observed increasing instances of warm water species, which they associated with the 'Warm Blob' phenomena of 2014–2016 (Bond et al., 2015).

3.3. Importance and scale of adaptation actions

Almost all (96%, 23 of 24 responses) participants agreed that climate change adaptation is very important for regional planning (scored ≥8, 10-point scale). Most respondents identified national governance as the more effective scale of governance to implement adaptation actions (67% of responses, n = 21), followed by provincial (58% of responses) and First Nations governance (42% of responses). The least effective scale for interventions were individual (75% of responses were negative) and community-based adaptation (62% of responses were negative). Participants shared a range of concerns about consequences of failing to adapt to climate change, from impacts to social systems (43% of 23 responses), economic impacts (27%), and others (Table 4). We also described the most common responses by respondents working with First Nations, Provincial, and Federal governments (Appendix A, Fig. 1).

3.4. Social and ecological adaptation actions

Most of the adaptation actions we asked about had more positive than negative responses, which may reflect the scarcity of climate change action in this region. Ecological actions were seen as more

Table 1
Focal adaptation actions under either social or ecological themes covered in the survey. See Appendix B for the full survey.

Adaptation action	Social, ecological, or social-ecological (SE)
Develop alternative livelihoods	Social
Support local adaptive governance	Social
Infrastructure improvements	Social
Create supportive institutions (e.g. community organizations)	Social
Strengthen social networks and community groups	Social
Support intergenerational knowledge sharing	Social
Consider adaptive policies for economic diversity and occupational mobility (help people to change careers)	Social
Encourage increased participation and engagement in management and decision making	Social/SE
Invest in monitoring and early warning systems	Social/SE
Prioritize conservation: develop better networks of marine protected areas	Ecological
Incorporate climate modelling into management and resource allocation decisions	Ecological
Manage for ecological resilience where possible	Ecological
Identify less degraded areas for 'hot spots' of ecological integrity, and protect them	Ecological
Identify more degraded areas as critically important, and protect them	Ecological
Improve connectivity among habitats	Ecological
Avoid over-exploitation in fisheries	Ecological/SE
Take an ecosystem-based approach to fisheries management: manage for population, species, and ecosystem diversity	Ecological/SE
Develop regional forums to support ecological knowledge and sound management practices	Ecological/SE
Develop education and training opportunities for maintaining ecological integrity	Ecological/SE

Table 2
Participant professional characteristics: Years working in the field, roles in their organizations, and primary employer (First Nations, state government, other).

Professional characteristics	Total sample (n = 21 complete surveys)
Years working in this field	38% 1–5 years
	29% 5–10 years
	24% 11–15 years
	10% 16–20 years
Professional role	43% Planning
	33% Management
	14% Policy or Research
	10% Other/multiple roles
Primary employer	62% First Nations
	19% Federal
	14% Provincial
	4% other/no response

beneficial overall than social actions (Fig. 1), and social actions had higher levels of uncertainty attributed to them (neutral or unsure responses). Some specific social adaptation actions arose as more important: for instance, participants indicated that investing in monitoring and early warning systems, and supporting local governance was most likely to be effective to support social adaptation (91% perceived a positive influence of these actions, of 21 responses), while avoiding fisheries overexploitation was the most important ecological adaptation action (91% of 21 responses). Incorporating climate change modelling into management was also perceived as important, perhaps reflecting the comment of one fisheries manager who noted: *"Climate change has not really played a big role in our [marine] planning to date. Primarily, I think it is because we don't have easy to understand or explain projections or models of the effect or future state to inform our discussions or longer term thinking" (Participant # 22, First Nations)*.

Investing in community programs and supportive institutions was the social action most ambiguous or perceived to be less likely to affect change (52% perceived either action to be of benefit; Fig. 1). Some of these potential actions are limited at this stage by uncertainty, as illustrated by this quote: *"Other than food security, infrastructure needs gaps are unknown. How do coastal communities prepare their infrastructure for climate change?" (Participant #12, First Nations)*. Interestingly, 35% of respondents did not support the idea of developing alternative livelihoods as an adaptation strategy. The least supported ecological action was about regional forums that could support sound management practices or protecting more degraded habitats as critically important through marine planning (59%, n = 21) (Fig. 1).

In an open-ended question to generate other adaptation ideas, nine participants suggested actions ranging from economic investment in local value-added industries, improvements in housing infrastructure, improvements in forestry and resource management (linked to concerns over increasing forest fires), and regional level communications and education related to climate change impacts. Three responses were actually mitigation actions related to consumer behavior (reducing transportation emissions and reducing carbon-intensive behaviors more generally, and improving water efficiency practices in communities). One participant suggested transplanting threatened species to better

Table 3
Observed climate impacts as shared by participants, in response to the question, "What type of climate related impacts have you seen or heard about?"

Change	Percentage of noted observations (total = 52)	Illustrative quote
Decreasing food resources	33%	*"Last year the seaweed (Pryopia) we harvest for food failed to grow in the normal abundance we were accustomed to. In living memory of our folks, the seaweed had never failed to grow like this before and I attribute this to the acidity associated with the [Warm] Blob."*
Changing species ranges	19%	*"More fish species moving north associated with the south like Mackerel and Hake"*
Changes in weather patterns	19%	*"Warmer and drier summers, warmer and lower rivers affecting salmon's health and ability to travel up river to spawn."*
Warmer ocean temperatures	12%	*"Warm water species that have never been seen here before, including pelagic tunicates and snails. Unprecedented die-off of canopy kelps."*
Diminishing glaciers and freshwater levels	10%	*"I have noted that the glacier fields on top of the mountains in the Valley are disappearing at an alarming rate. Smaller creeks and rivers too."*
Increasing storms and erosion	8%	*"Erosion to cultural and archaeological sites from storm events could be related to climate change as well."*

Table 4
Responses to the question, "What do you see as the consequence(s) of failing to adapt?"

Change	% (67 comments, from 23 participants)	Illustrative quote
Social impacts (food security, culture, conflict, property)	43	*"The places most at risk to erosion and storm surge are the cultural sites, such as ancient village sites and petroglyph sites. For the First Nations on the coast, climate change can destroy thousands of years' worth of culturally significant resources and areas."*
Economic impacts (jobs, infrastructure)	27	*"Costs to coastal infrastructure, increased uncertainty and disruption to coastal economic activities with resultant impacts on jobs and livelihoods, conflict among different interests …"*
Ecological impacts	13	*"Loss of ecological functions, loss of economic opportunities for coastal communities, community instability"*
Social-ecological effects	10	*"Declines in biodiversity, ecosystem services and other values (e.g., loss of fisheries, impacts to cultural and spiritual values)"*
Management challenges	7	*"Poor choices with respect to locations of any new area-based conservation measures"*

habitats (assisted migration).

3.5. Marine planning and adaptation

Most participants (77%, n = 22) thought that climate change was an important part of comprehensive marine planning (scored ≥8, 10-point scale), and that climate change projections should be included in the design of marine protected areas (MPAs) (68%, n = 22, scored ≥8, 10-point scale). Participants had diverse opinions about how MPA planning and management should respond to projected changes in species ranges (Weatherdon et al., 2016; Appendix A, Fig. 2). Practitioners thought that MPA networks that protect both current and future habitats would be most effective to support adaptation to climate change (91% positive responses) and some respondents noted that current MPA networks (which are in the design phase, but not yet implemented) would be insufficient to protect species as climate change continues to affect species distributions (44% of responses). As one respondent noted: *"A combination of static and dynamic MPAs seems like a good approach but is a somewhat new concept for management and policy makers" (Participant #24, First Nations).*

Two additional themes emerged as important elements of incorporating climate change into marine planning. First, practitioners noted the need for further work at the community level to understand the support for different management actions across scales. As one respondent stated,

"Understanding the potential outcomes from different management actions and finding community support would help to implement climate change into MPA planning." (Participant #19)

Second, the importance of co-management between provincial, federal, and First Nations governments as a component of regional management and conservation planning initiatives was reflected in some responses. As one participant noted:

"If MPAs were well designed to ensure habitat connectivity and collaboratively and adaptively managed with coastal Nations to support various types of uses rather than being no-go or no-take areas, they will have a better chance of supporting long-term climate adaptation." (Participant #1, Federal)

3.6. Community adaptation planning

In the context of shifting species ranges (Weatherdon et al., 2016), we asked about strategies and policies that could contribute to community adaptation. Participants indicated that communities will need further support from governance and management to prepare for new fisheries as species shift north (95% positive responses, n = 21). Responses to whether communities should shift away from fisheries as an adaptive response were less positive (only 59% positive responses, n = 21), a result mirrored in the negative perception of alternative livelihood development in the previous social adaptation actions question (Fig. 1).

The communities within the remote coastal region of BC are small,

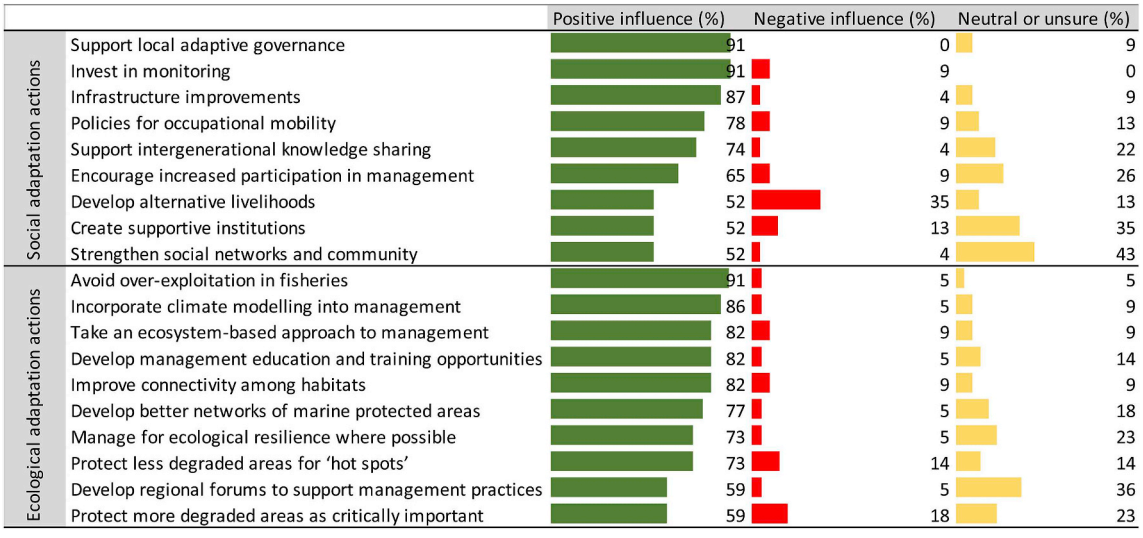

Fig. 1. Practitioner perceptions of social (n = 23, top half) and ecological (n = 22, lower half) actions that may support adaptation to climate change. Responses are ranked by the percentage of perceived positive influence within social and ecological actions, respectively.

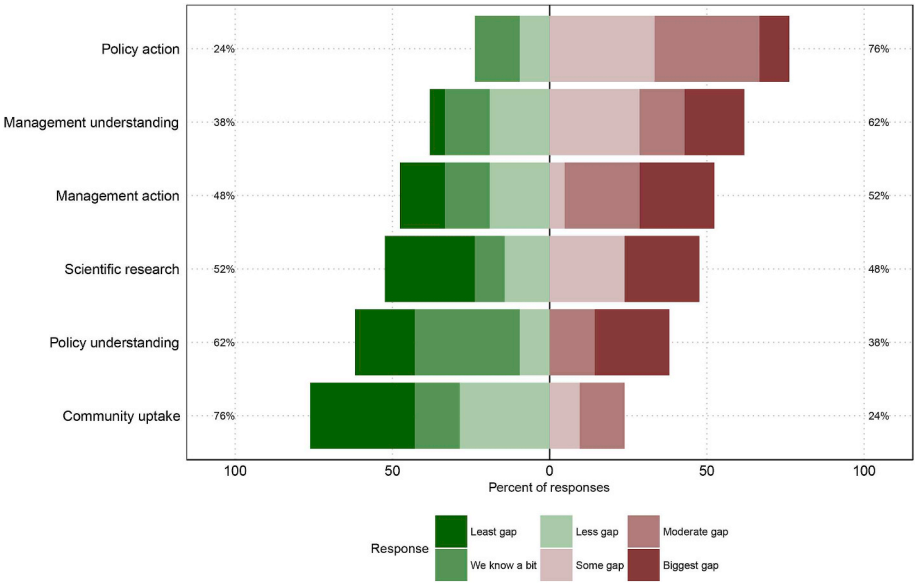

Fig. 2. Perceived barriers to incorporating climate change into marine protected areas planning.

isolated, and little is known about the impacts and strategies that may be useful in those contexts (but see Reid et al., 2014 for a description of a community-based adaptation planning process for the Gitga'at Nation). Participants commented on the importance of the issue of food security throughout the open-ended component of the survey. In a follow-up interview, one participant noted how these changes are already an issue along the coast:

> "[The] food security piece is so important in this context. It's really hard. Last year … So much less pyropia [edible seaweed] … this year, it's been much better … What is the driver? What can we do to nurture the communities when they rely on certain food sources from year to year?' (Participant #12, First Nations).

3.7. Barriers and opportunities for adaptation

Most (81%, n = 21) practitioners acknowledged major knowledge gaps in their ability to incorporate climate change adaptation into marine planning. Over three-quarters (76%) identified gaps in policy action as a leading barrier to climate change adaptation, followed by gaps in management understanding, and then management action (Fig. 2). Incorporating climate projections in marine planning also demands high-quality data and management understanding. As one respondent noted; *"We have a poor understanding of the conditions species require or prefer in the current environment, let alone under future scenarios. We have little baseline data for most species as to where they occur now." (Participant #17, Federal*).

In the survey, most respondents (81%, n = 21) indicated that there were knowledge gaps that could be addressed to better incorporate climate change into their work. Many participants reported that they simply lack the resources to incorporate climate change adaptation in their current work plans (76% reported 5 or less on a 10-point scale, in response to "Do you feel that you have the resources available to successfully incorporate climate change into your work").

Four overarching implementation and knowledge gaps that emerged from the open-ended survey responses included a lack of government action (35% of 34 statements), uncertainty in scientific understanding and data availability (29%), communication and misinformation (26%), and capacity, including education and training (9%) (Table 5). Little is known about the vulnerabilities or adaptive capacity of communities along the coast of BC, the infrastructure needs, and preferences of communities as to social adaptation actions. Participants noted that ecological uncertainty arises from both a disconnect between scales of data collection and data sharing, and around science communication. Concerns were also raised about the lack of clear objectives on climate change adaptation planning, the lack of coordination on outreach and education among communities along the BC coast, and uncertainty about how to progress considering the lack of capacity. Several participants expressed frustration in regard to the current jurisdictional context, including the limited ability of First Nations to enforce fisheries closures or other major rules. The challenge of implementing adaptation planning also relates to funding, as one respondent noted: "*Province or country-wide adaptation will be very expensive and neither the provincial or federal governments are likely to be interested in footing the bill" (Participant #21, First Nations)*.

In terms of opportunities, participants suggested a diversity of ways to better incorporate climate change adaptation into marine planning and management. Opportunities ranged from improving capacity (35%) and funding (26%), to better research (17%), policy action (13%), and education (9%) (Table 5). Determining how to support remote coastal communities through this time of change is a critical next step and opportunity for future research. As one respondent noted, *"The uncertainty around the impacts of climate change will persist. (We need) tools and policy guidance that prepare management agencies, communities, and users to adjust in the face of that uncertainty" (Participant #4, Federal)*.

Several participants also took the opportunity to suggest other tools or ideas, such as incorporating more traditional ecological knowledge (TEK): *"First Nations have adjusted in the past by transplanting species such as salmon, seaweed, clams to enhance and protect them, we need to consider how this could work under these situations." (Participant #2, First Nations*).

4. Discussion

This research is one of very few studies that we know of (e.g. Picketts et al., 2012a, 2012b) to survey practitioners' perceptions of climate change adaptation actions, particularly in the context of a coastal region. Focusing on British Columbia's coast, we described practitioners' perceptions of climate-related risks to the coastal social-ecological system, social and adaptation actions, and barriers and opportunities for adaptation. Most adaptation actions that we included were thought to be helpful, though practitioners particularly highlighted improving sustainable fisheries and supporting local governance and monitoring as most useful. Barriers to climate change adaptation are perceived obstacles that can be overcome, either through shifts in

Table 5
Barriers and opportunities: Responses to survey questions regarding the existing and perceived knowledge gaps in incorporating climate change adaptation into existing work on management and planning in BC's coastal region (top section), and opportunities for incorporating climate change adaptation in marine planning and management (lower section), in response to a question asking how practitioners suggest improving their ability to incorporate climate change adaptation into their work.

Implementation or knowledge gap (Barriers)	Total statements (34)	% of responses	Illustrative quote
Lack of action	12	35	
Climate change is not incorporated in management/planning	8	67	*"Fisheries work does not currently subscribe to any climate change related policy or decision-making mandates" – Participant 23, First Nations*
Lack of action related to government and policy	4	33	*"Government doesn't have to change, so they don't." Participant #12, First Nations* *"We're reacting to outside events and crises instead of proactively planning for climate change." – Participant #21, First Nations*
Scientific uncertainty	10	29	*"Over the region, there are big gaps on climate change indicators data. Who is analyzing the data? Who can communicate the results effectively? This is the gap … Regional data for climate indicators is missing." – Participant #12, First Nations*
Data sharing and communication challenges	9	26	*"Science needs [are relevant], but communication and coordination needs are more important. [We need to] increase public awareness – these are the changes, these are how we are going to adapt." –Participant #3, Province* *"… we could be developing policy guidance on how to account for trade-offs between management decisions for different fisheries in an ecosystem context. These would both be useful precursors to more explicitly considering climate change in fisheries management." – Participant 4, Federal* *"(The) gap in communication is the issue. Often, people know things are changing, but they don't know what to do, or how things might change … There's a real gap between knowledge and communities so that the knowledge is accessible." – Participant #12, First Nations*
Capacity	3	9	*"Incorporating climate change adaptation requires more capacity" - Participant #8, First Nations* *"Capacity is a huge problem, especially in First Nations communities … especially long-term capacity. Training and people need to stay involved. People get training and capacity in a moment in time, or people from outside the community come in, and then they move on. [This is a] Major challenge in implementing anything." – Participant #19, Province* *"Guardian Watchmen don't have the capacity to enforce major rules or closures … There's not a lot of government support, [they] don't shift power to the Watchmen program but just apologize after the fact. Along the coast there's 11,*000 km *with Watchmen monitoring, while DFO made it up there twice. [We need to] shift power to the local community." – Participant #5, First Nations.*
Suggested solutions (Opportunities)	**Total mentions (23)**	**% of responses**	**Illustrative quote**
Capacity	8	35	*"Increased capacity to develop and assess the application of 'dynamic' MPAs within a network" – Participant #24, First Nations*
Funding	6	26	*"Breaking through rigid practices and protocols that do not yet acknowledge climate change impacts as an important aspect in future scenario planning, for example." – Participant #1, no named affiliation* *"There is significant misinformation on behalf of many stakeholders - fishers, First Nations, marine shipping, regional districts and local governments … Federal and Provincial governments need more funding to be able to get the word out and execute their messaging and science efficiently." – Participant #13, Province*
Research	4	17	*"It would be helpful to be able to describe potential impacts to biodiversity, species, and people and how different management actions would influence the outcomes of climate change. Also, it would be good to understand how people perceive impacts and willingness to accept policies/management actions that may impact them today, especially given the uncertainty of how climate change will impact them in the future." – Participant 19, Province*
Policy action and leadership	3	13	*"Currently we lobby our leadership for the mandate to either a) just do it at our expense or b) to search out partners or funders" – Participant #11, First Nations*
Education	2	9	*"Educate ourselves on the effect climate change has on all concerned." – Participant #2, First Nations* *"It is tough to scientifically attribute climate change to observations we make on the ground. Training or guidance in gathering information on the ground would help me in my job." – Participant #11, First Nations*

perspective, organization, institutions, resources, or creativity (Adger et al., 2009; Gifford, 2011; Moser and Ekstrom, 2010). The four key barriers and opportunities for climate change adaptation that emerged through both quantitative and qualitative results are comparable to those that others have noted when examining conservation and fisheries issues in the context of climate change adaptation: policies and political action for incorporating adaptation strategies (Miller et al., 2017; Mills et al., 2015), uncertainty (Cvitanovic et al., 2014; Picketts et al., 2012a), capacity and funding (Picketts et al., 2012a; Vogel et al., 2018), and lack of effective communication and knowledge of adaptation strategies (Cvitanovic et al., 2015b, 2015a; Kettle and Dow, 2014). These barriers fall within what Moser and Ekstrom (2010) categorize as the understanding and planning phases of the adaptation process. Adaptive capacity can be developed at multiple scales, but strategies for building adaptive capacity are likely to interact with other social and ecological dynamics in unpredictable ways. This is particularly important when considering the mechanisms that might enable opportunities for innovative adaptation actions (Sieber et al., 2018). Here we unpack the perceptions of adaptation actions, those key challenges, and discuss potential opportunities.

4.1. Adaptation actions and marine planning responses to climate risks

Our findings suggested that while protected areas and other conventional fisheries management actions are still promoted, practitioners are aware that they are not a panacea for effective adaptation to climate change in coastal marine systems. This shifting perspective to innovative and less conventional management strategies (e.g. assisted migration, conservation triage, dynamic protected areas) mirrors previous work at the global scale by Hagerman and Satterfield (2014) who found that previously novel conservation actions are sometimes becoming more acceptable, perhaps as the risks from climate change increase. Certainly, the practitioners in our study region consistently reported observing diverse impacts and risks from climate change; these observations are also reflected in previous work on perceptions of climate changes along the BC coast (e.g. Reid et al., 2014; Turner and Clifton, 2009).

While we found support for most adaptation actions, there was stronger support for ecological than social adaptation actions, and more uncertainty around social adaptation actions. This may be due 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 (Hagerman and Satterfield, 2013). While there is research on what investments can improve peoples' capacity to adapt (Cinner et al., 2018; Pelling, 2011; Whitney et al., 2017), there are very few examples of implemented social or social-ecological adaptations to changing ocean conditions (yet many examples of ecological adaptation projects) (Miller et al., 2017).

All of the adaptation actions that we considered in the survey would address climate change challenges, with various implications. Conventional management strategies were highly ranked by these participants, namely reducing fisheries over-exploitation and investing in monitoring efforts. In this region, fisheries abundance has declined precipitously in recent decades (Healey, 2009; Walters et al., 2019) Projections of the impacts of shifting species ranges due to warming ocean temperatures suggest that this area will be further affected by declining abundance and access to commercially and culturally important species (Weatherdon et al., 2016). Knowing this, it follows that addressing fisheries over-exploitation and implementing more precautionary fisheries policy would help to support social-ecological resilience to climate change. Similarly, developing monitoring efforts, in particular, which incorporate early warning systems for climate impacts, would inform practitioners' choices for both fisheries and marine conservation management (Brown et al., 2018; Haasnoot et al., 2018). To enable better monitoring for changing environmental conditions at local and regional scales would require First Nations involvement; the framework for this is already in place through the Coastal Guardian Watchmen program and Coastal First Nations' Regional Monitoring System (Lagasse et al., 2014). Incorporating more community perspectives for monitoring environmental change (e.g. in Gitga'at territory; Thompson, 2018) and specific climate indicators (both social and ecological) through Indigenous perspectives should be encouraged (Leclerc et al., 2013; Tribal Adaptation Menu Team, 2019).

Unconventional management actions, such as dynamic protected areas or assisted species migration, could also support social-ecological adaptation to climate change. While the political feasibility of unconventional actions such remains a question (Cvitanovic et al., 2014; Maxwell et al., 2014), our research highlights practitioners are interested in unconventional planning tools such as dynamic protected areas and improving co-management processes to better support adaptation to climate change impacts. Considering that an MPA network planning process is currently underway in BC, it may be timely to incorporate adaptation actions into such plans. Many of the respondents to this survey also communicated a lack of integration of climate change impacts or adaptation strategies in conventional fisheries management. Similar to Ogier et al. (2016) in Australia, ecosystem-based management (EBM) and co-management arrangements were identified by practitioners to be an effective adaptation action. In the study region, co-management arrangements such as the Guardian Watchmen program and Marine Plan Partnership are intended to facilitate Indigenous voices in place-based management. By supporting leadership and control over the planning process (Moser and Ekstrom, 2010), such co-management structures may enable greater flexibility in fisheries and resource management than larger governance structures (Armitage et al., 2009; Cvitanovic et al., 2015b; Ogier et al., 2016). Ownership over the planning process can thus enable adaptive policy making for the uncertain dynamic impacts of climate change (Nagy et al., 2014).

The need for more flexible management actions was certainly reflected in this study, and should be developed further as the indirect effects of climate change on human communities are likely to appear more rapidly than expected (Mills et al., 2013). Other adaptive or flexible management structures that may facilitate fisheries adaptation includes quota transfer mechanisms that may allow fishers to target different species as species ranges shift, capacity adjustment schemes, and programs to help fishers transition or develop alternative livelihoods (Lindegren and Brander, 2018; McIlgorm et al., 2010; Pinsky and Mantua., 2014). Surprisingly, developing alternative livelihoods as an adaptation strategy was not positively perceived by many respondents in this study, which could be due to the numerous other values associated with fishery livelihoods beyond monetary value (social, cultural values) (Young et al., 2016).

4.2. Barriers and opportunities: capacity, uncertainty, and co-management

Broadly, the themes that emerged through this research highlight a need for a transformative change in governance in order to effectively tackle the diverse challenges of climate change (Pelling, 2011). The barriers and opportunities that emerged from this work are systemic and persistent in the literature, and stem from governance paradigms that undermine the capacity of other actors and institutions to implement adaptations (Moser and Ekstrom, 2010). Similar to previous work on community-level adaptation in BC (Picketts et al., 2012a), our results suggest that the main barriers to climate change adaptation are political will and action, followed by management capacity and understanding. Policy action would mean leadership and support for the development of effective adaptation plans that incorporate information on climate impacts from multiple scales and lead to proactive management responses. This mirrors the findings of Miller et al. (2017), who found that the most common barriers to implementing climate change adaptations in marine systems worldwide have related to institutions, governance, and capacity. Many people in our study highlighted the lack of capacity, both in terms of people and funding, which limits the ability to conduct research and inform the public. Funding cuts that affect government scientist capacity to anticipate and evaluate environmental change have been a challenge in Canada in recent years (Barnett and Wiber, 2018), and a lack of funding for climate change adaptation, in particular, has been a problem in British Columbia (Picketts et al., 2012a). When climate change projects have focused on adaptation, they have tended to explore specific climate impacts at the scale of communities, such as sea level rise (Abeysirigunawardena and Walker, 2008; Dolan and Walker, 2006), stormwater management (Flood and Land, 2011; Withey et al., 2016), or changes in forest composition (Aitken et al., 2008; Spittlehouse, 2008). Down-scaling adaptation planning to the local and regional scale has been shown to reduce government costs of adaptation as well as result in higher acceptance of adaptation strategies (Pinkerton, 1989). Recent Canadian federal funding awarded to expand the Indigenous Guardians Pilot Program (Canada, 2019) is an opportunity to develop adaptation planning in collaboration with existing co-management and planning processes.

We noted the issue of uncertainty, both in scientific understanding (i.e. data and projections, or epistemic uncertainty) and practitioner understanding (i.e. linguistic uncertainty; Regan et al., 2002) as a

barrier to climate change adaptation action. A lack of understanding of how adaptation actions would work has been cited as a barrier to implementing adaptive management of MPAs in both California (Hopkins et al., 2016) and Australia (Cvitanovic et al., 2014). Another communication challenge that emerged was 'misinformation,' and ineffective communication of existing scientific knowledge on climate change. Similarly to Picketts et al. (2012a), we also noted several instances of confusion between mitigation activities and adaptation actions in the responses. While anecdotal, this supports the message from practitioners that adaptation planning is still in its infancy, or nonexistent in some cases, within the study region. Indeed, a recent analysis of 39 BC communities found that while 25/39 Official Community Plans do explicitly address climate change, their strengths lay in policies and goal-setting rather than implementation, and mitigation goals far outweigh adaptation goals or policies (Baynham and Stevens, 2014). Burch (2010) noted that adaptation planning has rarely translated into effective action at the municipal scale, related to issues of uncertainty. In Australia, a study of planners' knowledge of climate change adaptation found that planners have limited and often questionable information sources, and no professional support for learning more (Lyth et al., 2007). Communicating future climate scenarios and adaptation actions in a simple matter for practitioners to understand and utilize can be a challenge (Picketts et al., 2012a). In Canada, national studies of climate impacts and adaptation have increased in recent years (e.g. Lemmen et al., 2016), but the commentary in our study suggests that those improvements are not yet having an effect at the regional scale.

Practitioners shared a perception that climate change adaptation actions would be most effectively implemented by national government. Yet, we noted many participants indicated a lack of trust, a lack of action, and a lack of support from national government agencies. This is a problematic conflict, considering that management actions require the social acceptance and buy-in of those affected in order to be successful (Mascia et al., 2003; Watson et al., 2015, 2018). This could be attributed to the study population (i.e. just 4 participants were employed by the federal government while 13 represented First Nations), and the issues of communication that arose throughout our survey. Engaging First Nations communities in adaptation planning and adaptive co-management would be an opportunity to develop diverse and effective adaptation actions that reflect local voices and needs, particularly as Indigenous well-being is intimately linked with ecological health (Donatuto et al., 2014). For example, for the St'at'imc people in central British Columbia, the impacts of climate change on the availability of sockeye salmon will have dramatic effects on their culture, traditions, and sense of community (Jacob et al., 2010). As some of the practitioners in our study commented, traditional knowledge and Indigenous-led management tools could, and should, be engaged and supported in adaptation planning and decision making (Turner and Spalding, 2013). Participatory values-based approaches to involve Indigenous communities, as exemplified by adaptation planning with the Gitga'at Nation in Hartley Bay (Reid et al., 2014), are particularly effective in this context.

4.3. Conclusions

Our findings suggest some future research directions in order to identify the most effective and socially relevant planning and management actions given a certain context. Climate change adaptation planning is more likely to be implemented if it is incorporated into existing management plans and processes, rather than developed as separate strategic documents (Füssel, 2007; Smit and Wandel, 2006). Much better integration of climate change adaptation research with fisheries management and conservation planning processes would be useful to develop the dialogue among fisheries managers, conservation planners, and adaptation practitioners. However, we hypothesize that as climate change impacts continue apace (IPCC, 2018), and given that practitioners in our study noted the lack of climate change strategy in, for example, fisheries management, it may be important to also develop stand-alone adaptation plans at least at regional levels (Kates et al., 2012). In this region and more broadly, research is needed at the community level in regard to local perceptions of climate impacts, risks, and opportunities, as well as support for various adaptation approaches (e.g. Reid et al., 2014). Framing climate change impacts and adaptations in the values of local peoples, for example in the context of Inuit communities of Labrador (Wolf et al., 2013), can reduce the uncertainty of the impacts of adaptation actions, and increase the likelihood of implementing effective adaptation actions. In cases where Inuit views and values have not been explicitly addressed, adaptation efforts risk perpetuating inequality and effectively increasing the vulnerability of local peoples (Cameron, 2012; Reid, 2019). Additional research on the social implications of climate change impacts and adaptation actions would improve our ability to understand how adaptation planning might support and incorporate Indigenous ways of knowing and ways of life (Artelle et al., 2018; Turner and Spalding, 2013; Turner and Clifton, 2009).

Supporting the capacity of Indigenous governance and management is likely to have multiple benefits that reflect effective adaptation actions, including avoiding over-exploitation, achieving effective ecosystem-based management, and enabling local monitoring for climate impacts. Since bottom-up approaches to management can be more affordable, supporting a governance transformation to enable Indigenous management is likely to reduce funding needs as well, enabling the ability to act. We propose that one solution to this is reframing the focus on proactive adaptation actions at multiple scales given what we *do* know, rather than merely developing a better consensus on scientific uncertainty and knowledge gaps. While the ongoing and future realities of climate change on social and ecological systems may be unclear, the necessities of developing more conscientious and perhaps, more contentious proactive responses are evident.

4.4. Limitations

Our research had several limitations. The format of an electronic survey, even with the addition of semi-structured interviews with some recipients, may have limited our ability to capture nuance and details in the perspectives of practitioners. We simplified the descriptions of the adaptation actions and management responses as much as possible based on multiple iterations and comments through reviews of the survey and pilot testing. However, we acknowledge that due to the complexity of the topic, the description of some of the strategies may have been challenging or difficult to understand, even given the focused sample for this survey. Finally, while the community of practitioners who we targeted is relatively small in this area and we were able to hear the perspectives of many working across the region, our sample size was nonetheless limited to those who had the time and capacity to respond.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ocecoaman.2019.05.010.

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