

INFORMING DECISION MAKING WITH
INDIGENOUS AND LOCAL KNOWLEDGE AND SCIENCE

Research Article



Enabling coexistence: Navigating predator-induced regime shifts in human-ocean systems

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Abstract

1. Rapid system-wide changes triggered by predators can pose considerable challenges to people. In the Northeast Pacific, the recovery of sea otters *Enhydra lutris* following their extirpation due to the 18th and 19th century fur trade is driving a social-ecological regime shift with profound implications. While the ecological consequences of this shift are well documented, very little research has examined the conditions that enable or constrain people's ability to adapt to the social, economic and cultural changes that transpire.
2. Through a collaborative partnership and workshops with Indigenous knowledge holders spanning Alaska to British Columbia, along with quantitative and qualitative interviews in two Indigenous communities among the first to experience sea otter recovery, we examined people's perceptions of the social-ecological conditions that affect their ability to adapt to these changes.
3. We found that communities differed in their relative rankings of adaptation-enabling conditions; however, the following four broad strategies were perceived as critical to improving coexistence with sea otters: (a) strengthening Indigenous governance and decision-making authority; (b) promoting adaptive co-management; (c) weaving Indigenous knowledge and Western science into management plans and (d) establishing learning platforms. Both communities also identified that increased livelihood options and financial assistance would not compensate for lost food security.
4. Differences in enabling conditions and attitudes towards sea otters within and between communities can be attributed to the social-ecological and political context in which sea otter recovery occurs.
5. Our study suggests that enhancing Indigenous peoples' ability to adapt to predator-induced regime shifts will require a transformation in current resource

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governance systems if we are to navigate towards an ecologically sustainable and socially just operating space. Overall, this work highlights the need for more Indigenous authority, knowledge and leadership in addressing predator-induced regime shifts in coupled human-ocean systems.

KEYWORDS

adaptive governance, collaborative management, Indigenous knowledge, kelp forests, keystone predator, predator-recovery, social-ecological systems, trophic cascade

1 | INTRODUCTION

Human communities and management institutions are greatly challenged by social-ecological regime shifts, when linked systems of people and nature undergo sudden and profound changes that are difficult to reverse (Nayak & Armitage, 2018; Scheffer, Carpenter, Foley, Folke, & Walker, 2001). For example, the recovery of keystone predators can generate cascading effects that fundamentally alter ecosystem processes (Estes et al., 2011), trigger mixed psychosocial responses (Pooley et al., 2017) and deeply challenge traditional systems of governance faced with trade-offs involving the unequal distribution of impacts and benefits (Marshall, Stier, Samhuri, Kelly, & Ward, 2016; Pinkerton, Salomon, & Dragon, 2019). While the ecological changes associated with predator-induced regime shifts are often well documented, less information is available on how human communities are adapting to the interconnected transformations in food systems, livelihoods and resource governance. As such, there is a growing need to better understand what enables people's ability to adapt to new social-ecological system configurations and coexist with predators that trigger profound change (Carter & Linnell, 2016).

In coastal communities around the world, many people rely heavily on marine resources that are highly influenced by predators and susceptible to regime shifts. In a famous example, the collapse of predatory Atlantic cod *Gadus morhua* triggered a regime shift from groundfish-dominated to invertebrate-dominated fisheries that profoundly influenced maritime livelihoods, culture and economies (Hamilton & Butler, 2001). While often overlooked, coastal Indigenous communities are especially impacted by marine regime shifts due to longstanding dependence on ocean resources for food and livelihoods (Lepofsky & Caldwell, 2013), high rates of poverty and food insecurity (Power, 2008), and frequent marginalization in marine resource management and decision-making (Bennett et al., 2018; Carothers, 2010). Fortunately, Indigenous knowledge of marine species and predator management is increasingly being documented (Berkes, 2008; Huntington, 2000; Salomon, Kii'iljuus, Xanius, Tanape, & Happynook, 2015); however, an ongoing need still exists within research and management arenas to work with coastal Indigenous communities to better understand and support their capacities to adapt to rapid environmental change (Berkes & Jolly, 2001; Ford et al., 2009; Reid et al., 2014).

Adaptation in social-ecological systems refers to adjustments that are carried out to reduce damaging impacts, or the ability to take advantage of new opportunities that result from observed or anticipated changes (Smit & Wandel, 2006). But decision-making about adaptation is challenging, particularly at local scales, where people are often divided about what should be done and how it should be implemented. Moreover, people's worldviews and values influence their perceptions of change and determine their desired actions (Reid et al., 2014; Wolf, Alice, & Bell, 2013). More frequently, scholars and practitioners are calling for proactive and tangible community-scale adaptation initiatives to enhance communities' capacity to manage change on the ground (Smit & Wandel, 2006; Whitney et al., 2017). One approach is to elicit perceptions of adaptation strategies from individuals who are experiencing rapid change and prioritize measures tailored to the needs of a community and a particular stressor (Ford et al., 2009; Marshall & Marshall, 2007; Wolf et al., 2013). In Indigenous communities, studies have further shown that if adaptation planning, management and policy are to be perceived as legitimate, adaptation research must include Indigenous knowledge, values and rights (Berkes & Jolly, 2001; Reid et al., 2014; Wolf et al., 2013).

Along the northeastern Pacific coast, one of the most iconic predator-induced regime shifts is occurring in the traditional territories of coastal Indigenous peoples. Sea otters *Enhydra lutris*, once ranging along the entire north Pacific Rim and coexisting with Indigenous communities (Bodkin, 2015; Salomon et al., 2015; Simenstad, Estes, & Kenyon, 1978), were extirpated during the 18th and 19th century commercial fur trade. Due to an international treaty in 1911, federal protection acts and intentional translocations in the 1960s and 1970s, recovering sea otter populations are now expanding their range and triggering rapid ecosystem shifts and considerable social challenges (Lee, Thorley, Watson, Reid, & Salomon, 2018; Salomon et al., 2015; Salomon, Tanape, & Huntington, 2007; Sloan & Dick, 2012). As keystone predators and major architects of marine ecosystems (Estes & Palmisano, 1974), the recovery of sea otters involves significant trade-offs. When otters are absent, sea urchins, crabs, clams, abalone and other shellfish are abundant, supporting commercial and subsistence fisheries (Carswell, Speckman, & Gill, 2015; Larson, Hoyt, Eckert, Gill, & Rochet, 2013; Salomon et al., 2007). In contrast, when sea otters are present, there is a substantial reduction in shellfish density and size

(reviewed in Estes, Heithaus, McCauley, Rasher, & Worm, 2016) reducing human access to these species, which can be further exacerbated when shellfish are commercially harvested (e.g. abalone, Lee et al., 2018). However, sea otter predation on herbivorous urchins promotes kelp forest expansion (Estes & Palmisano, 1974), habitat for some fish (Bertocci, Araújo, Oliveira, & Sousa-Pinto, 2015), recreation and tourism (Loomis, 2006) and carbon sequestration (Wilmers, Estes, Edwards, Laidre, & Konar, 2012). Despite the prevalence of recovering sea otter populations in Indigenous territories, issues of reduced food security, co-management, and traditional use and stewardship of otters have been largely neglected (Levine, Muthukrishna, Chan, & Satterfield, 2016; Pinkerton et al., 2019; Salomon et al., 2015). Furthermore, in Canada, sea otter recovery has implications for Indigenous rights where the federal constitution protects Indigenous access to fisheries for food, social and ceremonial purposes (R. v. Sparrow, 1990). To confront the complex challenges associated with expanding sea otter populations, there is a growing need to identify conditions and strategies that enable coexistence with sea otters, and the types of governance structures that can help communities navigate the shift between alternative social-ecological states.

Here, we examine the conditions that affect people's ability to adapt to the social-ecological regime shift triggered by sea otter recovery. We worked within a collaborative Indigenous partnership led by Hereditary Chiefs representing 19 First Nations and Tribes spanning south central Alaska through British Columbia (B.C.), to ask: (a) What social-ecological conditions are perceived to enable people's ability to adapt to sea otter recovery, and which are most enabling? (b) How do perceptions of these conditions differ between communities? and (c) How variable are people's attitudes towards sea otters and what factors might influence this? We developed these questions and our survey design through one large workshop with Indigenous knowledge holders representing all 19 Nations and Tribes, and then conducted town meetings and survey interviews in two participating Indigenous communities that have the longest experience with sea otter recovery (60 and 45 years). We hypothesized that people's perspectives in these two communities would be influenced by their different exposure times to sea otter recovery. By learning from both the similar and different perspectives held by these two communities, our study aims to identify a suite of possible strategies to improve Indigenous communities' capacity to coexist with sea otters as they continue to expand their range, as well as insights for natural resource agencies seeking to design socially just and environmentally sustainable ecosystem management more broadly.

2 | METHODS

2.1 | Research co-production

To uphold Indigenous rights and governance protocols, before we began our research we acquired free, prior and informed consent (United Nations, 2007) from the Hereditary Chief Councils of three

coastal Indigenous groups in British Columbia—the Nuu-chah-nulth (representing 14 Nations), Haida (Skidegate and Old Massett) and Heiltsuk First Nations. We did the same with Indigenous community leaders in Alaska, representing two Sugpiaq Tribes. We then established a collaborative research partnership with a selected steering committee of Hereditary Chiefs, knowledge holders and cultural advisors to guide our collaborative approach (Salomon, Burt, Herb, et al., 2018: www.CoastalVoices.net). This approach ensured that the co-production of research followed each Nation's protocols, was grounded in Indigenous values and was supported by participating communities. Critically, it gave joint decision-making authority over the specific research questions pursued. Members of the steering committee and cultural advisors participated in all components of the research, including the design and implementation of workshops, community visits and surveys.

2.2 | Survey design

We used a two-step, inductive and deductive process to design a survey that assessed coastal Indigenous peoples' perceptions of the social-ecological conditions that enable their ability to adapt to sea otter recovery. We use the term 'social-ecological conditions' broadly to refer to social, institutional, management, regulatory or ecological circumstances that influence the context in which people experience sea otter recovery. First, we identified social-ecological conditions relevant to sea otter adaptation generated from facilitated dialogue and semi-structured interviews that took place during a 4-day workshop (17–20 June 2014) attended by Indigenous Chiefs, community leaders and knowledge holders representing 19 Indigenous Nations and Tribes across B.C. and Alaska (Salomon, Burt, Kii'iljuus, et al., 2018). We conducted an emergent content analysis (Stemler, 2001) of the workshop transcripts using NVivo11 Qualitative Research software to identify 18 social-ecological conditions that were stated to influence people's ability to adapt to living with sea otters (Table 1). Select key quotes from workshop knowledge holders relating to each social-ecological condition are in Table S1. Next, we grouped these conditions into seven social-ecological themes grounded in adaptation and resilience theory (e.g. Adger, 2003; Armitage et al., 2009; Biggs et al., 2012; Folke, Colding, & Berkes, 2003; details and additional references in Table S2) and predicted a direction of influence. Based on the literature, we added four conditions within the 'Livelihoods' theme that might influence communities' adaptive capacity (Allison & Ellis, 2001; Badjeck, Allison, Halls, & Dulvy, 2010; Blythe, Murray, & Flaherty, 2014; Marschke & Berkes, 2006) for a total of 22 social-ecological conditions (Table 1; Table S2) framed to enable adaptation to sea otters, with negative responses identifying potential constraints.

The survey asked respondents to rank each social-ecological condition on a 9-point Likert scale from 'greatly reduces' (−4) to 'does not influence' (0) to 'greatly improves your ability to adapt to living with sea otters in your territory' (+4). To help interpret our quantitative 'adaptation response scores' we also recorded qualitative comments

TABLE 1 Social-ecological conditions identified by Indigenous knowledge holders and adaptive capacity literature (*) as influencing an individual's or community's ability to adapt to sea otter recovery. Actions illustrate how each condition might enable adaptation, except 'Climate Change', which was considered to reduce (↓) adaptation. Details in Table S2

Theme	Conditions identified to influence adaptation	Actions that enable adaptation to sea otter recovery
Management	Incorporate traditional knowledge Local management plan Experiment with management	<ul style="list-style-type: none"> • Weave traditional knowledge and stewardship with Western management approaches • Design and implement a local management plan for sea otters, shellfish and kelp • Experiment with otter exclusions, spatial harvests, shellfish transplants, aquaculture, kelp harvest, etc.
Governance	More local Indigenous authority Community leadership Trust and respect across governments Federal regulations	<ul style="list-style-type: none"> • Increase decision-making power in local management of otters, shellfish, kelp and all nearshore resources • Support effective leaders that build trust, communicate and play a key role in local resource management • Enhance trust, legitimacy and cooperation between Indigenous and Federal/State governments • Have federal regulations that can enable local hunting/harvesting of sea otters
Knowledge and learning	More traditional knowledge Learning from other communities Monitoring information	<ul style="list-style-type: none"> • Gather traditional knowledge relating to the use, stewardship and governance of sea otters, shellfish, kelp • Exchange information with other communities adapting to sea otter recovery (their experience, advice, etc.) • Monitor information on the abundance/locations of sea otters, shellfish, kelp and harvest activity
Social capital	Within community Between communities	<ul style="list-style-type: none"> • Hold gatherings, groups and social exchanges that are forums for communication or support • Enhance reciprocity and exchange with adjacent communities to enable access to important resources
Perceived resilience	Willingness to embrace change Experience from other changes	<ul style="list-style-type: none"> • Have a positive or accepting attitude towards change • Utilize experience from navigating other shocks/shifts that involved re-organization and learning
Livelihoods and financial security	Novel livelihood opportunities * Employment options * Individual occupational mobility * Household occupational multiplicity * Access to financial support	<ul style="list-style-type: none"> • Create sea otter-focused tourism opportunities • Expand alternative livelihood opportunities in the community to better cope with uncertainty • Expand people's capacity/willingness to engage in alternative livelihoods making them more flexible • Have multiple household incomes to enhance flexibility and income security • Facilitate access to loans from the bank or other community sources to help with financial security
Ecosystem resilience	Redundancy of harvest sites More kelp habitat created Climate change	<ul style="list-style-type: none"> • Have multiple locations where community members can harvest shellfish, urchins, crab, etc. • Become aware of positive trade-offs: More kelp may provide greater fish habitat and other benefits • Warming ocean temperatures and ocean acidification are additional system stressors



from respondents associated with each condition. We then asked participants to rank their attitude towards the presence of sea otters on a 9-point scale ranging from 'very negative' (−4) to 'neutral' (0) to 'very positive' (+4). Covariates such as participants' age, gender, occupation, economic status (monthly cost of living) were collected along with self-assessed ranking of knowledge of sea otters/shellfish/kelp, trust between community and federal marine governing institutions, and level of power in resource decision-making. The final survey, along with workshop focus groups, interviews and community visits were all approved by the project cultural advisors, the project steering committee and Simon Fraser University's office of research ethics. All of

the data and transcripts from the workshop and survey were returned to the participating Nations/Tribes and shared (with permission) with the Nuuchah-nulth, Haida and Heiltsuk Hereditary Chief Councils and Sugpiaq Tribal Councils.

2.3 | Case study communities

Although the list of conditions enabling adaptation came from our initial workshop engaging Indigenous experts representing 19 First Nations and Tribes across the region experiencing different stages

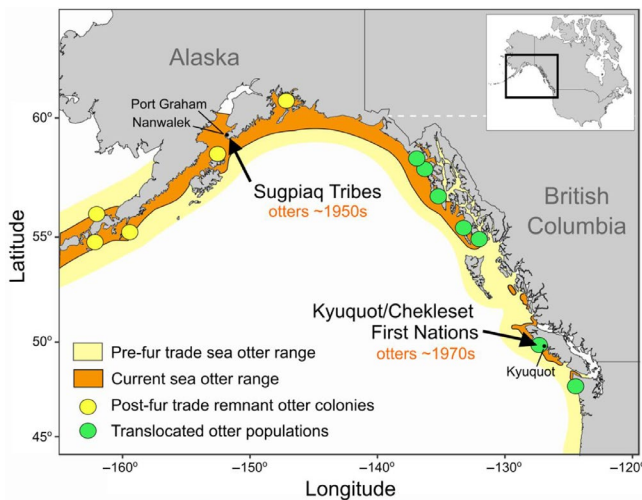


FIGURE 1 Northeast Pacific coast with village locations for the Port Graham/Nanwalek Sugpiaq Tribes and Kyuquot/Chekleset First Nations with the approximate range of sea otter populations (current and pre-fur trade). Locations of post-maritime fur trade remnant sea otter colonies recorded (yellow dots) and translocated otter populations (green dots). Modified from Bodkin (2015)

of sea otter recovery, we used a community-based case study approach to compare the experiences of two participating Indigenous communities. These chosen communities were among the first to experience sea otter recovery in the northeast Pacific (Figure 1). The communities are comparable in population size, geographic isolation (only accessed by boat or small aircraft), socio-economic status (locally based livelihoods, low average incomes and high unemployment) and strong subsistence culture. Yet they differ in the length of time they have experienced sea otter recovery (~60 vs. ~45 years), the manner in which sea otters recovered (natural recolonization vs. intentional re-introduction) and the federal regulations that govern sea otter protection and management. Members of both communities attended our regional workshop and welcomed us to their villages to share the 2014 workshop findings and conduct more in-depth survey interviews.

2.3.1 | The Sugpiaq Tribes

In south central Alaska, on the tip of the Kenai Peninsula, the Sugpiaq people in the adjacent villages of Port Graham (population ~178) and Nanwalek (population ~300) have experienced sea otter recovery since the late 1950s when otters naturally expanded their range into the area (Figure 1; Salomon, Huntington, & Tanape, 2011; Salomon et al., 2007). Due to their close proximity (1 km apart) and shared history, family relations and experience of sea otter recovery, we considered these villages to represent a single Sugpiaq community in our analyses. Subsistence activities have always been and remain an essential part of these village economies; most households exchange and rely on subsistence harvest of salmon, halibut, seal, sea lion, intertidal invertebrates and algae. Following the return of sea

otters, the Sugpiaq people observed a serial decline of highly valued shellfish species, which they attributed to both to sea otter predation and intensified subsistence and commercial harvests (Salomon et al., 2007, 2011). As Alaska Natives, Sugpiaq are legally permitted to hunt sea otters through a waiver to the federal *Marine Mammal Protection Act* (MMPA, 1972), which places a moratorium on the take of all marine mammals. Locally hunted otters must be processed, tagged and tanned, then 'significantly altered' into an authentic Native handicraft before sea otter products can be traded and sold (USFWS, 2014).

2.3.2 | The Kyuquot/Chekleset First Nations

The people of the Ka'yu:k't'h'/Che:k'tles7et'h' First Nations, in English the Kyuquot/Chekleset (used hereafter), are members of the broader Nuuchah-nulth First Nations that live along the west coast of Vancouver Island, British Columbia. The Kyuquot/Chekleset people have experienced sea otter recovery since the early 1970s when the federal government translocated 89 otters into their traditional territory north of the village of Kyuquot (population ~172; Bigg & MacAskie, 1978; Figure 1). The sea otter population on the west coast of Vancouver Island grew at a rate of 19.0% per year between 1977 and 1995 (Nichol, Watson, Abernethy, Rechsteiner, & Towers, 2015), corresponding to a sharp decline in sea urchins (Watson & Estes, 2011) and other shellfish that residents harvested and relied on for food, social and ceremonial purposes. Kelp beds also expanded in areas where urchins declined (Watson & Estes, 2011). Sea otters were first listed as 'Endangered' in 1978 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and later legally listed in 2003 as 'Threatened' under the *Species at Risk Act* (SARA, 2002), which protected sea otters from being captured, killed or disturbed and prohibited anyone from possessing an otter pelt. As the annual population growth rate slowed to 8.4% from 1996 to 2008 and 7.1% from 2009 to 2013 (Nichol et al., 2015), sea otters were down-listed in 2009 to a species of 'Special Concern' under SARA. This designation enables First Nations to apply for a license under the *Aboriginal Communal Fishing License Regulations*, in turn under the *Fisheries Act*, to hunt otters for food, social or ceremonial purposes. However, to date, such a licence has yet to be applied for (R. Dunlop, Uu-a-thluk, Nuuchah-nulth Fisheries Program, pers. comm., Jan. 2019).

2.4 | Data collection

Surveys were carried out in spring 2016 by way of convenience sampling of as many adult residents (≥ 19 years old) as possible. Effort was made to capture a representative sample of ages (19–96), occupations and gender. Before the survey we gave a preamble describing the research context and all survey participants gave informed written consent before proceeding. All the recorded responses were verified with the participant to ensure the qualitative statements and intended interpretations were accurately captured. Within the Kyuquot/

Chekleset and Sugpiaq communities, we conducted 39 and 35 survey interviews, representing ~34% and ~15% of the resident adult population respectively. In advance of conducting the survey interviews, the project team (including Hereditary Chiefs on the steering committee) and community leaders co-hosted town meetings where community members were informed of the broader research project and regional workshop findings, participated in dialogue and were encouraged to participate in the surveys.

2.5 | Data analyses

To examine which social-ecological conditions most enabled people's ability to adapt to sea otter recovery and how they differed between communities, we used a nested ordinal logistic mixed-effect model with a cumulative link function (details in Appendix A1). We used likelihood ratio tests to evaluate the influence of the main fixed effects ('Social-ecological condition' and 'Community') and their interaction, and we conducted pairwise contrasts to evaluate whether 'Condition' differed in mean response score by 'Community' (p -values adjusted via Tukey method). We plotted the response distributions for each social-ecological condition within the two communities along with the median response score and 25th or 75th percentiles. We then delineated the most influential (enabling or constraining) conditions for each community as those with median response scores ≥ 3 or ≤ -2 , because the highest median score for Kyuquot/Chekleset rankings was 3, and -2 was the lowest negative median score observed.

Second, we reviewed and summarized the qualitative information from the survey responses to contextualize the quantitative results. We selected key statements relating to each of the 22 social-ecological conditions to illustrate the range of responses (Table S1).

Finally, we examined if respondents' attitude towards sea otters differed between communities and could be explained by socio-demographic covariates. Covariates were selected a priori based on hypotheses derived from the literature and a posteriori based on informative univariate relationships with sea otter attitude (Appendix A2). We fit ordinal regression models of 'Otter Attitude' including two-way interactions of independent covariates and compared their relative strength of evidence using small sample adjusted Akaike's information criterion (AICc) and likelihood ratio tests (Appendix A3). We also examined the relative proportions of positive, neutral and negative qualitative statements in response to 'Otter Attitude'. Analyses were conducted in R (R Core Team, 2017) using the ordinal and lsmeans packages (Christensen, 2018; Lenth, 2016).

2.6 | Limitations

While our survey is limited to synthesizing the perspectives and attitudes of only two communities (Sugpiaq and Kyuquot/Chekleset), our ability to generalize coexistence-enabling conditions that are important to coastal Indigenous communities more broadly is supported by the extensive qualitative data that we collected during our

2014 regional workshop which represented perspectives from 19 First Nations and Tribes (see www.coastalvoices.net and Salomon, Burt, Kii'iljuus, et al., 2018). Nevertheless, every Indigenous Nation/Tribe is unique and there are likely different ecological, social and political circumstances (e.g. the severity of sea otter impacts, the availability and preference for shellfish and seafoods, community livelihood profiles, different relationships with marine governance authorities, etc.) that would cause local people to weigh important conditions for sea otter coexistence differently.

3 | RESULTS

3.1 | Social-ecological conditions that enable adaptation differed between communities

The relative ranking of social-ecological conditions perceived to enable adaptation to sea otters varied between communities (Figure 2; $\chi^2 = 182.83$, $df = 21$, $p < 0.001$). Overall, the adaptation response scores of respondents from Kyuquot/Chekleset in B.C. were lower than those of the Sugpiaq in Alaska, suggesting that the former community perceived fewer conditions would enable their ability to adapt to sea otter recovery in their territory. Specifically, the Kyuquot/Chekleset had only six conditions with a median response score ≥ 3 , whereas the Sugpiaq had 14 (yellow points, Figure 2).

The federal regulations governing Indigenous hunting or possession of sea otter pelts were viewed as 'reducing' Kyuquot/Chekleset respondents' ability to adapt (62%), whereas the majority of Sugpiaq respondents perceived them as 'improving' or 'greatly improving' (71%) their ability to adapt (Figure 2). Qualitative responses reveal this is tied to the Canadian federal regulations that restrict the Kyuquot/Chekleset from hunting otters, whereas the Sugpiaq value their ability to harvest sea otters under US federal legislation (Table 2; Table S1). Kyuquot/Chekleset respondents expressed that their ability to adapt was constrained by restrictions on their traditional use of sea otters, not being able to play an active role in sea otter management, and the general disregard for traditional systems of natural resource governance (Table 2; Table S1).

We also detected differences between Sugpiaq and Kyuquot/Chekleset respondents in their perceptions of 'social capital' and its role in adaptation *within* their community (i.e. the value of community events, forums, meetings) and *between* communities (i.e. the value of exchanging seafood with adjacent communities). The Sugpiaq viewed both social capital conditions as 'improving adaptation', whereas the Kyuquot/Chekleset perceived them as 'not' or only 'slightly' improving adaptation (Figure 2). The Sugpiaq expressed that social exchanges and community meetings helped reduce internal conflict, provide critical information and bring people onto the same page. In contrast, the Kyuquot/Chekleset commented that exchanges and meetings about sea otters were dominated by negative voices and opinions, repetitive, and did not offer solutions or lead to actions (Table S1).

Last, the magnitude by which human-induced climate impacts were perceived to affect respondent's ability to coexist with sea

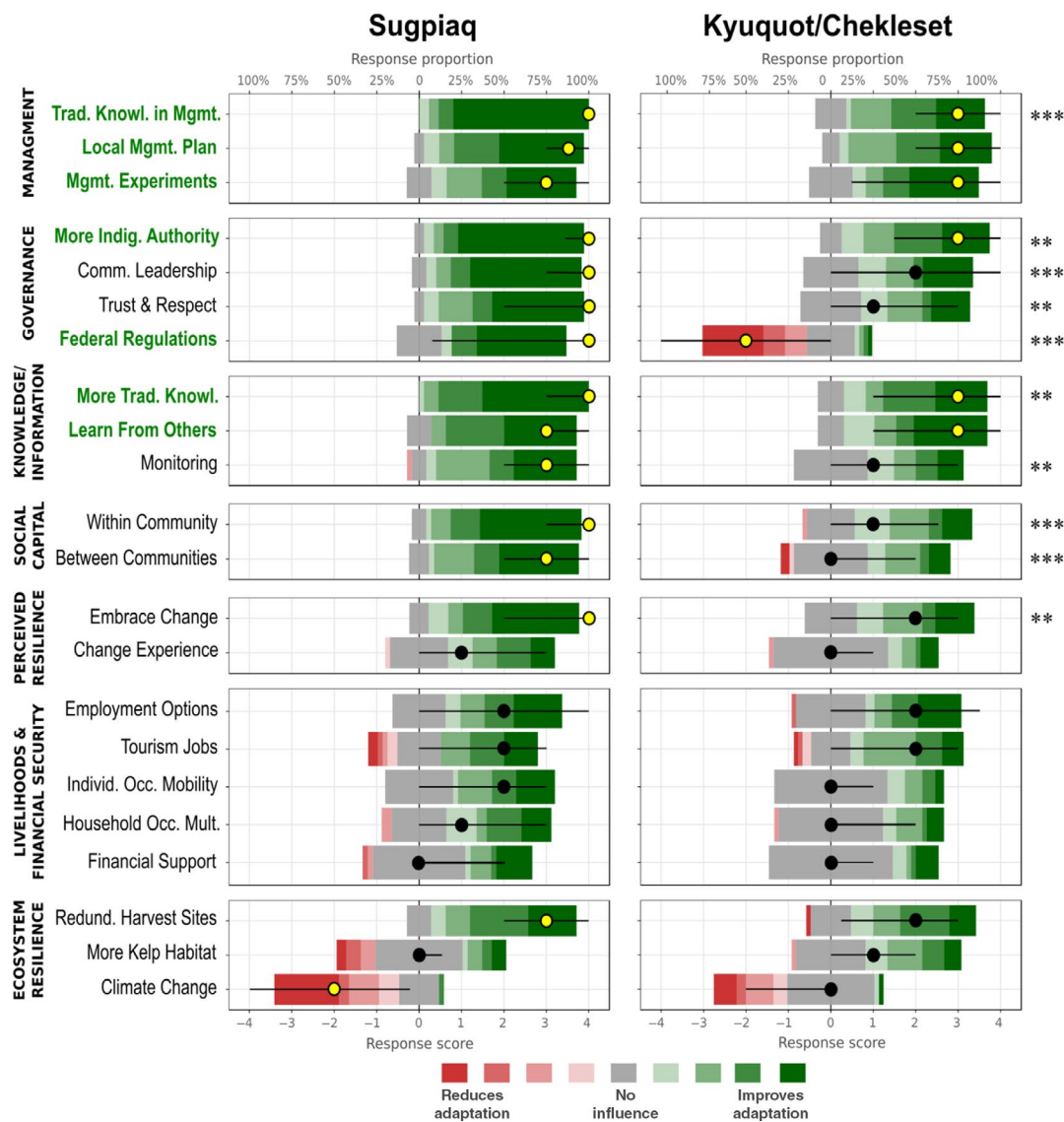


FIGURE 2 Relative rankings of 22 social-ecological conditions nested within seven themes that are perceived to influence the Sugpiaq and Kyuquot/Chekleset peoples' ability to adapt to sea otters. Coloured bars show response proportions (top axis); black points show median response score (bottom axis) with 25th/75th quantiles; yellow points are the most influential conditions perceived to improve or reduce adaptation (median ≥ 3 or ≤ -2 respectively). Conditions in bold green text have the greatest influence on adaptation across both communities. Stars represent a significant difference ($* < 0.05$, $** < 0.005$, $*** < 0.001$) between communities

otters differed between communities. In general, the Sugpiaq perceived climate change to greatly reduce their ability to coexist with sea otters (median = -2) whereas the Kyuquot/Chekleset perceived no influence (median = 0 ; Figure 2). Above 69% of Sugpiaq respondents gave specific comments about the negative effects of climate change on the local ecosystem and subsistence harvest, compared to only 28% of Kyuquot/Chekleset (Table S1).

3.2 | Conditions that most enable coexistence with sea otters

Seven social-ecological conditions were perceived by both communities as most enabling adaptation to sea otters (Figure 2; Table 2).

Respondents in both communities perceived that 'incorporating traditional knowledge into sea otter management' (#1), and 'greater traditional knowledge' (#2) of the use, stewardship and management of sea otters, shellfish and kelp would greatly improve people's ability to coexist with otters. Survey respondents and Indigenous knowledge holders from the initial workshop expressed their perception that traditional knowledge provided important information about when to hunt otters, how to hunt otters, how to prepare to hunt otters, how otters and shellfish were used and managed in the past, and how stewardship values of respectful, non-wasteful harvest are important to emphasize and teach the younger generations (Table 2; Table S1). Similarly, it was expressed that place-based traditional knowledge provides important local-scale system understanding, that traditional stewardship values should be the foundation

TABLE 2 Select quotes illustrating the highest ranked social-ecological conditions perceived to enable adaptation to sea otter recovery. Additional quotes and attributions in Table S1

Key social-ecological conditions	Perspectives from indigenous leaders & community members
(1) Incorporate traditional knowledge into management	<ul style="list-style-type: none"> 'The traditional knowledge has to be the basis of the (sea otter management) plan'. 'I think it's important that we combine traditional knowledge and scientific knowledge. It gives us a better understanding of what we can prepare for'. 'It is important that our ancient management knowledge come forth in current practice because our people live there. Connection to place is needed to effectively manage'.
(2) Gather more traditional knowledge	<ul style="list-style-type: none"> 'The greater knowledge we have of traditional values and cultural roles helps us be able to adapt to change. Traditional values focus on balance- and harvesting in a responsible, non-wasteful manner'. 'We have a cultural responsibility to the sea otter. There are specific rules ... for example, when to hunt otters, how to hunt otters, how to prepare to hunt otters'. 'My traditional knowledge gives me the information about what we had before. It can guide us in making policies and decisions on what needs to be done'.
(3) Implement a local management plan for sea otters, shellfish, & kelp	<ul style="list-style-type: none"> 'Having a plan helps to keep the traditions alive but ensure that we don't overharvest'. 'The management plan triggered us getting involved—having our people go out and harvest (otters) and utilize the furs. It wasn't until we started to devise an otter management plan that the villages got a seat at the table'. '(A management plan for sea otter) has got to be co-created, not created for us'.
(4) Experiment with different management approaches	<ul style="list-style-type: none"> '(Management experiments) might be useful to know if any methods have worked or not. Shellfish transplants, clam gardens, kelp harvests are some of the things that would be so good to have done'. 'There needs to be an experimental approach to human control of sea otters on a small spatial scale. The objective would be manage for local resources—certain clam beaches/bays-site specific management'! 'You can apply the knowledge you gain in one experiment to another system that might not even be linked to sea otters. You'll expect one thing, but there will be other surprises and things you learn'.
(5) Federal regulations on traditional hunting of otters	<ul style="list-style-type: none"> 'It's hard to live with the (Federal) restrictions. We used to play a more active role in management'. 'They (Federal Government) have taken away our people's ability to manage this resource. Our Hereditary Chiefs had a management plan in their governing system'. '(Being allowed to harvest otters) is keeping our hunting and our traditions alive—that's what we survived on, it's how we adapted'.
(6) Indigenous authority in marine resource decision making	<ul style="list-style-type: none"> 'It doesn't really work very well when outside people come in and impose their values on a system they don't understand'. 'We need to have authority so we can manage this situation to benefit all, including the sea otter, our resources, and us as a people'. 'You have to get a seat at the table. We had to fight for that. I would say to other communities that it's important to sit at the table, so you have a voice'.
(7) Learn from communities who have experienced sea otter recovery	<ul style="list-style-type: none"> '(Learning from others) is necessary in these adapting times. The best is to communicate what is working and not working with each other'. '(Sharing information) gives us a better understanding of what we can prepare for... We're looking at other communities that have management plans for otters and apply it to here'. 'I would like to see the Alaskan people come share information about sea otter management'.

of any active sea otter management, and that the ideal scenario is 'traditional, local and current knowledge all combined in one pot' (Table S1).

Respondents in both communities felt that 'implementing a local management plan' (#3) for sea otters, shellfish and kelp would greatly improve people's ability to live with otters in their territory. Among the Sugpiaq in Alaska, respondents expressed that the draft management plan helps keep hunting and crafting alive and reduced the possibility of overharvesting. Moreover, community members familiar with the plan expressed that it 'triggered us getting involved' in sea otter management and 'pay more attention to our role as managers' alongside federal and state management

agencies (Table 2; Table S1). Respondents also emphasized that the management plan has to be co-created with the active participation of local people and would only be helpful if it was properly implemented with adequate capacity to be maintained. Both communities also identified the need to 'experiment with different active management approaches' (#4), for example, trying to spatially manage sea otters (e.g. keeping them out of key shellfish areas by hunting them and using a variety of deterrents), rebuilding shellfish populations (e.g. transplants, aquaculture, rebuilding ancient clam gardens) and initiating kelp harvesting (Table 2; Table S1). While many respondents commented that different 'experiments' their community had tried resulted in improved system understanding

and learning, some respondents were more sceptical because they felt the community had spent valuable time and resources on trying things that did not work.

Having 'federal regulations that support Indigenous hunting of sea otters' (#5) was perceived to improve coastal communities' ability to coexist with otters. Sugpiaq respondents expressed that they valued being able to 'control local otter populations', 'keep hunting/crafting traditions alive', and use and sell otter pelts, as was done prior to colonization (Table 2, Table S1). In 14 of the 26 comments, Sugpiaq mentioned that a very limited number of otters were hunted in their community because: few community members actively hunt; sea otters are not hunted for food; pelt processing and tanning costs are prohibitive; rules constrain commercialization of pelts; severe consequences exist for overharvest; and community members feel that hunting large numbers of otters is unnecessary and inappropriate.

Respondents in both communities felt that having 'increased local Indigenous authority in resource decision-making' (#6) would improve people's ability to coexist with otters. Both communities ranked their current authority as being just above 'low', with an average rank (from 0 to 8) of 3.3 ± 2.5 SD and 2.5 ± 2.5 SD among Sugpiaq and Kyuquot/Chekleset respectively. Similarly, mean perceived levels of trust between the communities and federal marine governing institutions were 'low' (Sugpiaq = 2.5 ± 1.6 SD and Kyuquot/Chekleset = 2.2 ± 2.0 SD). Respondents in both communities felt that resource decisions were being made by governments that had little understanding of the local context ('how we actually live', 'our way of life'), and suggested that having increased power in decision-making would help people become more aware of Indigenous people's commitment to conservation, encourage more young people to join advisory committees, legitimize local enforcement and 'give communities a voice' (Table 2; Table S1).

Finally, both communities perceived that adaption to sea otter-induced changes would improve if they could 'learn from other communities experiencing sea otter recovery' (#7). They suggested this would help them better understand anticipated changes and be better prepared, and that sharing information (i.e. what has worked, what has not) would be useful to inform ongoing management strategies and plans (Table 2; Table S1).

3.3 | Conditions that least enable coexistence with sea otters

Household occupational multiplicity, individual occupational mobility and access to financial support were among the least influential conditions influencing both Sugpiaq and Kyuquot/Chekleset respondents' ability to adapt to sea otter recovery (Figure 2). While having alternative employment options in the community was recognized by some people in both communities as being beneficial, many comments indicated that employment, additional incomes and bank loans are not a substitute for the loss of local shellfish subsistence resources: 'Having jobs does not bring fresh seafood' (Table 3).

TABLE 3 Select comments from the survey pertaining to 'livelihoods and financial security' in Sugpiaq and Kyuquot/Chekleset communities. Additional quotes and attributions in Table S1

Community perspectives: Food security in the context of livelihoods and financial security

Sugpiaq

- 'Any community needs jobs to help the economy, but jobs don't help people deal with otters'.
- 'Your body will lead you back to trying to find food. Jobs are not as important'.
- 'If people have a part-time job or full-time job, they still need subsistence harvest. And the otters affect subsistence harvest'.
- 'Having access (to loans or financial support) in certain situations may be helpful, but the subsistence is more important'.

Kyuquot/Chekleset

- '(If we had a variety of employment opportunities), we would still miss our seafood'.
- 'Having more (income) sources would not help because there is still no seafood'.
- 'I don't think (access to financial support) makes a difference, because it's the food we want back'.
- 'The otter has depleted valuable traditional foods that we have been able to trade like abalone, sea cucumber, clams, etc'.

3.4 | Diverse attitudes towards otters exist between and within communities

The majority (68%) of Sugpiaq respondents felt either positive (31%) or neutral (37%) towards the presence of sea otters in their territory (Figure 3a). In contrast, there was a larger proportion (51%) of Kyuquot/Chekleset respondents with a negative attitude towards sea otters (Figure 3a). This pattern was also reflected in the qualitative data whereby the Sugpiaq had more positive (39%) or neutral (29%) comments, expressing a general acceptance of sea otters and appreciation for being able to hunt them, with fewer comments (32%) raising negative otter sentiments (Figure 3b). In contrast, just over half of Kyuquot/Chekleset comments were negative (57%), expressing their frustration with the 'forced' re-introduction of otters, having witnessed the loss of shellfish resources within one's lifetime, the younger generation having no access to traditional shellfish foods and the lack of Indigenous involvement in sea otter management (Figure 3b; Table S1).

Although a wide range of perspectives on sea otters was expressed in both communities (Figure 3), there was no evidence in our data that this variability could be attributed to respondent age, economic status, occupation or level of knowledge associated with the use/stewardship of sea otters, shellfish and kelp (Appendix A2). However, we did detect a small effect of gender on Kyuquot/Chekleset attitudes towards sea otters, but not among the Sugpiaq ($\chi^2 = 6.33$, $df = 1$, $p < 0.01$; Appendix A3). Among the Kyuquot/Chekleset, female respondents had a more negative attitude towards sea otters than males ($p < 0.01$). However, models including 'Community' and 'Gender' only explained 16% of the variation in 'otter attitude'.

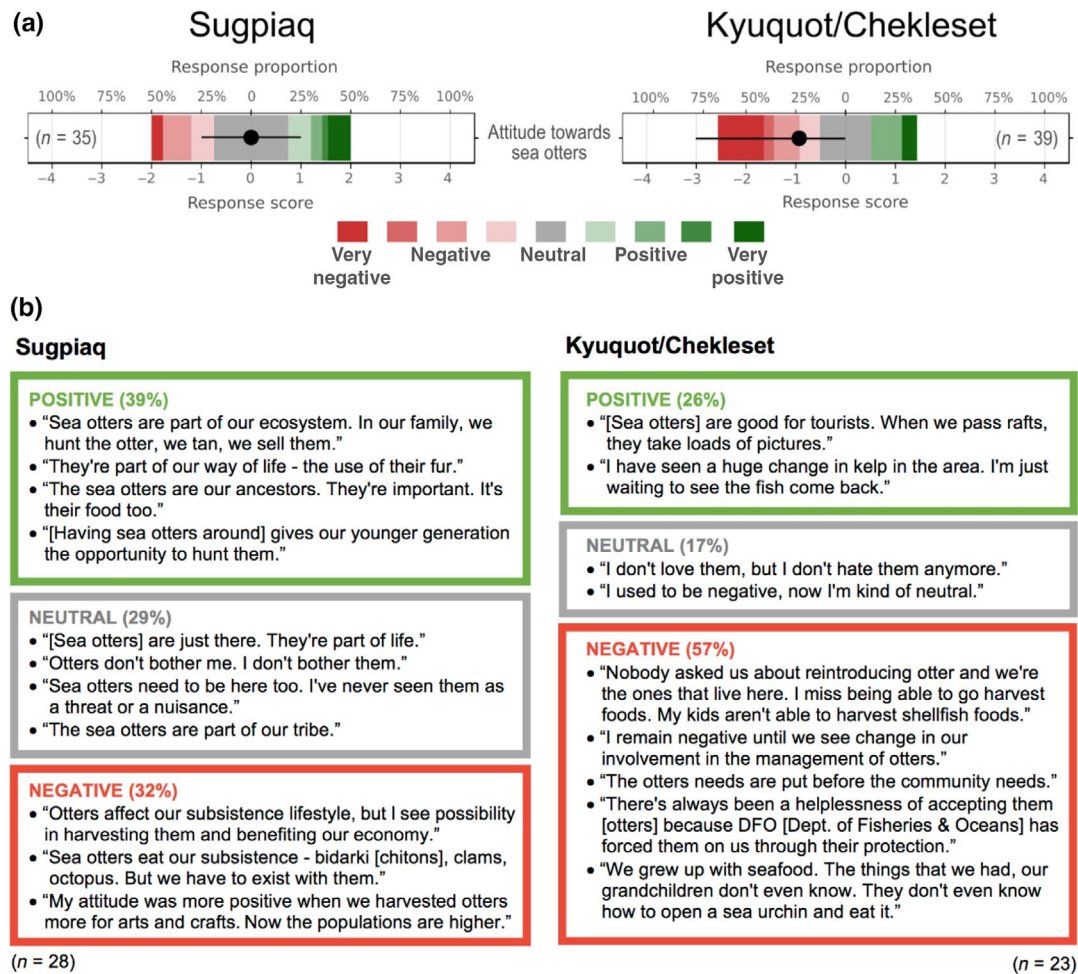


FIGURE 3 Quantitative and qualitative responses to the question: 'How would you rank your general attitude towards the presence of sea otters in your territory?' (a) Bars show response proportions and points show the median response score with 25th/75th quantiles, with n = community sample size. (b) The relative proportions (% and reflected in box size) of qualitative comments with select illustrative quotes, n = number of respondents who provided commentary

3.5 | Trade-offs elicit polarized perspectives

Conditions commonly cited as being positive gains that accompany sea otter-induced regime shifts—sea otter tourism and increased kelp habitat—elicited polarized responses within both communities (Figure 2). Some respondents in both communities felt that the opportunity for sea otter tourism would be 'a boost to the economy', 'a sustainable source of income', 'an ecotourism asset' and a way to 'create jobs' (Table S1). In contrast, some Sugpiaq respondents expressed that tourist values might clash with their traditional hunting values: 'Tourists wanting to see the otters would make it harder to hunt them. Most people who want to see them are the 'save the whales' type people' (Table S1). Similarly, some Kyuquot/Chekleset respondents felt tourism would only benefit the mostly non-Indigenous lodges in the area. Other Kyuquot/Chekleset respondents expressed that while tourism could be beneficial, there was no sufficient information, resources or training within the community to develop such ventures (Table S1). Perspectives about kelp were also mixed. There were positive comments from Kyuquot/Chekleset

respondents who felt more kelp was 'good for herring' or 'good for rockfish', but there were also comments that too much kelp made it difficult for navigation, or that having more kelp did not matter because 'the fish are being fished out'. Sugpiaq respondents were more negative about kelp, expressing that 'having more kelp makes it harder to get around using small outboard motors' and that kelp is 'not good for salmon' because they observe adult salmon avoid swimming in kelp beds and kelp fouls their salmon gill nets.

4 | DISCUSSION

Our study identifies key social-ecological conditions that influence the ability of Indigenous communities to coexist with sea otters and the profound social-ecological changes they elicit. First, through focus group discussions with Indigenous leaders and knowledge holders representing 19 B.C. First Nations and Alaska Tribes, we documented 18 conditions that would enable people to adapt to sea otter recovery. Next, through survey interviews in two communities

with long sea otter occupations, we revealed that despite differences in the relative rankings of adaptation-enhancing conditions, seven social-ecological conditions were commonly identified to have the greatest importance in improving coexistence with sea otters. These conditions can be summarized in four broad themes: (a) strengthening Indigenous governance and decision-making authority, (b) promoting active and adaptive sea otter co-management, (c) acquiring and incorporating Indigenous knowledge in management and (d) learning from other Indigenous communities. Our survey results also highlight that local food security is the primary concern and is not compensated for by greater livelihood opportunities or financial stability. Finally, we reveal that diverse attitudes towards sea otters exist within and between communities, suggesting that people's perceptions of predator-induced regime shifts are highly context dependent. Overall, our findings suggest that a collaborative and adaptive management approach would improve the adaptive capacity of coastal Indigenous communities that are currently, or will soon be navigating the transformations triggered by recovering sea otters.

4.1 | Social-ecological context

Our findings echo other studies that show that people's perceptions of environmental change and their ability to adapt are influenced by their individual experiences within a broader social-ecological context (Cinner & McClanahan, 2014; Coulthard, 2012; Marshall & Marshall, 2007; Wolf et al., 2013). In our study, the Sugpiaq Tribes tended to have a more 'positive' overall perception of sea otter recovery and their ability to adapt to it, compared to the Kyuquot/Chekleset First Nations' (Figures 2 and 3). One explanation for this may be due to the different lengths of time each community has been exposed to sea otter-induced regime shifts and the legacy effects of 'shifting baselines' (sensu Pauly, 1995), whereby human perceptions of ecological systems change due to loss of knowledge about past conditions. Given that sea otters recovered in Sugpiaq territory in the late 1950s, most of the participants we surveyed have grown up in the presence of this predator with only a few remaining Elders having memories of a 'pre-otter' ecosystem. In contrast, many adult Kyuquot/Chekleset respondents can recall harvesting abundant shellfish before sea otters were re-introduced in their territory in the 1970s, and stated that younger generations 'do not know what we are missing'. Others from Kyuquot/Chekleset commented that 'a lot of people do not eat our traditional foods, so they do not care (about sea otters)' which indicates changing social and cultural norms may also influence how people perceive ecological change (Adger, 2003; Turner & Turner, 2008). In contrast to the often negative implication of shifting baselines for measuring species or biodiversity loss (Papworth, Rist, Coad, & Milner-Gulland, 2009), our findings suggest that human perceptions of predator recovery can improve with time.

While the temporal context is important, our data suggest that a more influential element relates to the level of agency and power that communities have during their experience with sea otter recovery. Since 1969 when sea otters were translocated to Kyuquot/

Chekleset territory without prior consultation and subsequently protected under federal and provincial laws, residents have lost their access to local shellfish resources due primarily to sea otter predation, and been given little opportunity to participate in decision-making around sea otter management (Pinkerton et al., 2019). By comparison, the Sugpiaq Tribes have federally granted access rights to hunt marine mammals, and Indigenous-led institutions such as *The Alaska Sea Otter and Steller Sea Lion Commission* which have promoted Tribal involvement in policy decisions, research and sea otter stewardship (TASSC, 2018). That these different social contexts of agency and power influence people's attitudes and ability to adapt reflect the findings from Nayak, Armitage, and Andrachuk (2016) who showed that social-ecological regime shifts in two coastal lagoons in India and Vietnam had a disproportionately negative impact on disempowered and marginalized communities. Social structures of power are shown to shape adaptation actions, such that 'powerlessness' reduces adaptive capacity (Marshall & Marshall, 2007; McLaughlin & Dietz, 2008), and having 'agency'—the ability of people to have free choice in actively shaping their future—is essential for building adaptive capacity (Cinner et al., 2018) and resilience (Coulthard, 2012). Our work highlights that it is critical to consider how agency and power shape adaptive capacity, determine the perceptions of impacts and influence the ability for resource-dependent communities to navigate difficult environmental change (Brown, Adger, & Cinner, 2019; McLaughlin & Dietz, 2008; Nayak et al., 2016).

4.2 | Access to local seafood and social justice

While sea otter recovery is an acknowledged threat to commercial shellfish-based fishery livelihoods (Carswell et al., 2015; Larson et al., 2013), our work with Indigenous communities highlights a foundational concern less frequently discussed in the adaptation literature: subsistence harvest and local food security. In contrast to a focus on livelihoods, Indigenous workshop participants and survey respondents strongly emphasized how sea otter recovery affected their access to locally obtained shellfish food sources that are critical to people's diets and health, to social bonding and cultural continuity, and to local food sovereignty given their remote locations (Table S1). These strong values around place-based food access and complex ties to well-being are acknowledged in other studies with coastal First Nations people (Turner & Turner, 2008), and are echoed in the 'cultural consequences' described by Māori communities in New Zealand who feel they have lost access to valued food species (Dick, Stephenson, Kirikiri, Moller, & Turner, 2012). These strong cultural ties to food help explain why having more livelihood options and greater financial security were not considered very influential in improving coexistence with otters (Figure 2; Table 3). Another reason why livelihoods may have been less of a priority is that very few people in either community are actually employed in commercial fisheries. This is largely due to the legacy of federal fleet rationalization and privatization policies that have resulted in reduced Indigenous access rights to most commercial fisheries along the coast (Bennett et al., 2018; Carothers, 2010).

The recovery of sea otters in Indigenous traditional territories raises issues of social justice (Pinkerton et al., 2019). This is because the return of this predator exposes power inequities in sea otter management specifically, and fisheries more broadly, and highlights the inequities in who benefits and who bears the cost from the ecosystem changes that transpire. Furthermore in Canada, the erosion of First Nations' access to shellfish and their inability to spatially manage sea otter populations to improve shellfish access challenges federally recognized Indigenous rights to fisheries for food, social and ceremonial purposes in Canada (Pinkerton et al., 2019; R. v. Sparrow, 1990). These issues are challenging because they involve navigating trade-offs between species/ecosystem conservation and community food security in a context where the socio-economic and governance systems have shifted dramatically since the arrival of colonial people and laws (Lee et al., 2019). While there is increasing research in the integration of law and social-ecological resilience (e.g. Green et al., 2015), there remains limited empirical work that focuses on regime shifts in relation to social-environmental injustices (Nayak et al., 2016). Based on the information shared by our respondents, forward-thinking strategies and interventions that might improve people's ability to coexist with sea otters will involve directly addressing power imbalances and social injustices through redistributions of governance authority, establishing collaborative management arrangements and finding new ways to add Indigenous knowledge and traditional stewardship objectives into management plans (Plagányi et al., 2013).

4.3 | Enabling coexistence

4.3.1 | Strengthen Indigenous governance authority

Power sharing and the devolution of management rights to promote increased local-level participation and agency are key components of adaptive governance (Folke, Hahn, Olsson, & Norberg, 2005). In a broader international movement towards recognizing Indigenous rights (United Nations, 2007), resource management has entered a new era in which Indigenous peoples are increasingly playing a central role in the governance of marine resources in their traditional territories, for example, in Indigenous-owned marine protected areas in Australia (Butterly, 2013), state-recognized customary tenure or management areas in Vanuatu, Solomon Islands, Fiji, Papua New Guinea and New Zealand (Cinner & Aswani, 2007; Hale & Rude, 2017), and through power sharing on fishery co-management boards in Arctic Canada (Armitage, 2005; Snook, Cunsolo, & Morris, 2018). In our study, both communities perceived their current authority in marine resource management to be 'low' and felt that adapting to sea otter recovery would be improved if they had increased participation and agency in marine resource decision-making—'a voice and seat at the table'.

Several multilevel collaborative governance arrangements illustrate that power sharing in marine mammal management is possible at

a variety of scales. In northern Alaska, the Inupiat are part of a cooperative management agreement between the Alaska Eskimo Whaling Commission and the US National Oceanic and Atmospheric Association that uses customary laws and contemporary science to manage subsistence take of endangered bowhead whales (Chiropoulos, 1994; Huntington, 2000). In the Canadian Beaufort Sea, the federal government supports community-based management of beluga whales by the Inuvialuit people, which was enabled by establishing their harvest and management rights in the Inuvialuit Final Agreement in 1984 (Fisheries Joint Management Committee, 2013). While no such power-sharing governance arrangements exist for sea otters in Canada, Alaska Tribes have benefited from active participation in *The Alaska Sea Otter and Steller Sea Lion Commission*, which has operated through a Memorandum of Agreement (1994) with the US Fish and Wildlife Service, enabling Tribal involvement in sea otter management planning, policy decisions, research and population monitoring (TASSC, 2018). These examples are highly relevant to adapting to regime shifts, given their polycentric arrangements of shared power help provide institutional structures for cross-cultural communication, managing conflict, and enhancing self-organization and learning—conditions which in turn enhance adaptive capacity and social-ecological resilience (Armitage, 2005; Biggs et al., 2012; Folke et al., 2003).

Information from our study supports the finding that decentralizing resource governance and establishing Indigenous co-management present both challenges and opportunities (Armitage, 2005; Spaeder & Feit, 2005). One major barrier we identified is a deep lack of trust between Indigenous communities and state/federal management agencies, whereby respondents felt that their communities were undermined in negotiations, that traditional knowledge was not always used or respected, and that there remained a general lack of consultation, information sharing and open communication (Table S1). This is a core issue that will need addressing as studies have shown that relationships of trust and respect help promote the cooperation, cross-scale linkages and perceived legitimacy of management actions that become key when resolving conflict and adapting to changing environmental conditions (Adger, 2003; Cinner, Fuentes, & Randriamahazo, 2009; Young et al., 2016). In Canada, there is an opportunity for continued progress to build better 'Nation to Nation' relationships through federal government commitments to reconciliation (Truth and Reconciliation Commission of Canada, 2015). In other First Nations communities along the B.C. coast, fisheries with long histories of mistrust and conflict are beginning to move towards new relationships of negotiation and co-management (Jones, Rigg, & Pinkerton, 2017; Salomon, Quinlan, Pang, Okamoto, & Vazquez-Vera, 2019).

4.3.2 | Establish community-based and adaptive management

Nested multilevel structures of resource co-management that include strong local-level engagement benefit from place-based system understanding and can have higher levels of monitoring and compliance

due to perceived legitimacy (Armitage et al., 2009; Pinkerton & John, 2008). Our study suggests that the ability of Indigenous peoples' in the northeast Pacific to coexist with sea otters can be improved when they are able to actively hunt and adaptively manage their use of otters in their traditional territories, as evidence suggests they have done for millennia (Salomon et al., 2015; Simenstad et al., 1978). In a contemporary context, this pertains to having the legal authority to hunt sea otters, the ability to implement a locally designed ecosystem-based management plan for sea otters, shellfish and kelp, and the ability to experiment with different management approaches that could help sustain local shellfish resources or provide economic opportunities. The Sugpiaq already implement several aspects of their Tribal management plan as community members engage in the non-wasteful hunting of otters (mostly adult males), tag and monitor their harvest, do hunter-implemented bio-sampling and use otter pelts for cultural handicrafts that provide economic benefit to the community. In contrast, the Canadian federal government maintains exclusive responsibility over sea otter management planning and monitoring in B.C. (DFO, 2014), largely ignoring the cultural, economic and ecological sea otter relationships that First Nations people wish to revitalize (Pinkerton et al., 2019; Salomon et al., 2015). However, in 2012 the Nuuchah-nulth Tribal Council Fisheries Department drafted a comprehensive management plan for Kwakwaka'wakw (sea otters), with the desire to provide ceremonial use of sea otters for First Nation communities (NCN Tribal Council, 2012). This draft management plan contains quantitative estimates for an annual allowable harvest rate in addition to details on the spatial boundaries, harvest permitting and protocols, bio-sampling, population and compliance monitoring, joint federal-First Nation enforcement, and a commitment to work collaboratively with all levels of government and relevant agencies. Although this draft has remained internal to the Nuuchah-nulth Tribal Council while other major fisheries court cases are underway, its future implementation would represent a paradigm shift towards recognizing Indigenous rights and authority in ecosystem-based management in B.C. and improving First Nations coexistence with sea otters.

Developing the capacity for communities to learn from their own experiences is an important part of building adaptive management institutions that are beneficial to dealing with complex social-ecological change and conflict (Armitage et al., 2009; Cinner et al., 2018; Folke et al., 2005). In our study, there was strong support in both communities for experimenting with different sea otter, shellfish and kelp management strategies and general acknowledgement of the benefits of experiential learning. This may be an important element in the development of Indigenous participation in sea otter management, as natural and social scientists emphasize the importance of treating new policies and management arrangements as 'learning experiments' that need to be monitored, evaluated and adapted over time (Armitage, 2005; Walters & Holling, 1990). For example, following the Nunavut Final Agreement that transferred decision-making power to Inuit communities in northern Canada, a new community-based narwhal management plan was first treated as a 3-year experiment and reviewed by a multiparty committee

who made recommendations that were endorsed by the Nunavut Wildlife Management Board and Canadian federal fisheries minister (Armitage, 2005). Importantly, respondents in our study also highlighted that thoughtful planning must inform new 'experiments' in ecosystem management (e.g. spatial exclusion of otters, shellfish seeding or transplants, restoring ancient clam gardens, small-scale kelp harvest, etc.), to maximize time and resource allocation and produce the desired outcomes.

Overall, it is acknowledged that many challenges can arise in implementing community-based resource management, raising caution that the success of such arrangements hinges on providing significant and sustained local capacity building, efficient administration, effective monitoring and enforcement of new rules, and successfully bridging different knowledge systems (Armitage et al., 2009; Marschke & Berkes, 2006; Tengo, Brondizio, Elmqvist, Malmer, & Spierenburg, 2014). For example in Alaska, many of the successful programs for sea otter management planning, monitoring and research implemented by the Tribal-led *Alaska Sea Otter and Steller Sea Lion Commission* and the US Fish and Wildlife Service have ceased to run since 2007–2008 due to insufficient funding and unreconcilable political conflict (P. Norman, Vice-Chair TASSC, Chief of Port Graham, pers. comm., Dec. 2018).

4.3.3 | Acquire and incorporate Indigenous knowledge in management

Interactions between Indigenous peoples and their environments since time immemorial have resulted in detailed knowledge and place-based stewardship practices that enable adaptation to social-ecological changes (Berkes, 2008; Turner & Berkes, 2006). As such, communities adapting to regime shifts can benefit from mobilizing, making use of and connecting Indigenous knowledge to other knowledge systems in ways that can generate new insights, understandings and innovations to manage complex adaptive systems (Berkes, Colding, & Folke, 2000; Folke et al., 2003; Tengo et al., 2014). In the context of sea otter recovery, there is an opportunity for contemporary management to be informed through a better understanding of how sea otters and shellfish were managed by Indigenous people in the past—for example, through territorial harvest rights, protocols that specified when/where/how to respectfully hunt otters to maintain their populations in some places, and practices like building and tending clam gardens (Groesbeck, Rowell, Lepofsky, & Salomon, 2014; Salomon et al., 2015; Salomon, Burt, Herb, et al., 2018). Moreover, because monitoring regime shifts is acknowledged as being key to increasing communities' ability to anticipate and respond to rapid change (Selkoe et al., 2015), there is great potential to enhance the use of Indigenous knowledge and participation in community-based marine mammal monitoring (e.g. Berkes & Jolly, 2001; Fisheries Joint Management Committee, 2013; Huntington, 2000). Finally, Indigenous knowledge is underpinned by cultural values, principles and protocols, which are highly important in guiding resource governance and 'value-led management' (Artelle et al., 2018) and reflect responsibilities, relationships and

the resurgence of Indigenous worldviews and stewardship practices (Corntassel, 2012; Lee et al., 2019). As an example, the Nuu-chah-nulth concepts of 'Hishuk'ish Ts'awalk' (everything is one) and 'Isaak' (respect with caring) are core principles that frame the overarching vision and objectives of the Nuu-chah-nulth draft sea otter management plan (NCN Tribal Council, 2012). Finding ways to uphold these Indigenous values and mobilize Indigenous knowledge alongside western science has great potential to generate new insights, build respectful cross-cultural relationships and reinforce the legitimacy of each contributing knowledge system (Armitage, Berkes, Dale, Kocho-Schellenberg, & Patton, 2011; Huntington, 2000; Salomon et al., 2007).

4.3.4 | Build learning platforms and knowledge co-production

Learning from other's experiences of navigating ecosystem change can reduce social uncertainties and enable communities to better plan and prepare for shocks and disturbances (Armitage et al., 2011; Berkes, 2009; Cinner & McClanahan, 2014; Folke et al., 2003). Fortunately, there is great potential for information exchange as multiple Indigenous communities are in different stages of sea otter recovery across B.C. and Alaska. The opportunity for these communities to share experiences, knowledge, as well as successful and unsuccessful management strategies could provide important understanding and insight, in addition to providing a broad network of support, communication and potential resources. As an example, the successful proliferation of community-based marine reserves in Kenya was attributed in part to the development of 'learning platforms'—regular visits to neighbouring communities and annual forums to share information about management outcomes (Cinner & McClanahan, 2014).

Many elements of this research also demonstrate the potential benefits for sea otter recovery learning platforms. Both Indigenous knowledge holders and scientists who attended our initial workshop expressed that the gathering (and subsequent film and website: www.CoastalVoices.net) had expanded their understanding and preconceived notions of sea otter recovery. Similarly, through their active participation in the research, Hereditary Chiefs on the project steering committee are now transmitting their learnings within their respective communities. The project team continues to advance this research with its Hereditary Chief steering committee who connect the work back to their councils, who in turn are continuously engaging with the federal government around issues of resource governance and management. Just as social learning has become a recognized catalyst in climate change adaptation (Cinner et al., 2018), our research and associated outreach suggest that ongoing efforts to support information exchange about sea otter recovery have the potential to transform how different actors (general public, coastal communities, managers, policymakers and scientists) perceive predator-induced regime shifts and the types of governance and management systems required to enhance communities' adaptive capacity.

4.4 | Plurality of perspectives

People's perceptions of predators and environmental change are ultimately shaped by individual values and experiences (Marshall & Marshall, 2007; Pooley et al., 2017; Wolf et al., 2013). In both communities there was a high degree of individual variation in people's ranking of enabling conditions (Figure 2) and their attitudes towards otters (Figure 3). This plurality of sea otter attitudes within communities is common in situations of predator recovery globally, where research shows people's differing core values, perceptions of risk, personal experiences and social-cultural norms all contribute to the way they view coexisting with predators (Pooley et al., 2017). Moreover, our study revealed that this plurality of attitudes is not always visible; while negative 'otter attitudes' dominated in Kyuquot/Chekleset community meetings, one-on-one interviews revealed several individuals with neutral or positive perspectives. This is common in regime shift scenarios, and in public debate more broadly, where discourse becomes focused on an extreme position and creates significant social inertia that makes it harder to explore options for policy and management action (Lynham et al., 2017). Another interesting result was that female Kyuquot/Chekleset respondents tended to have more 'negative' attitudes towards otters than males. This aligns with evidence that women are the predominant harvesters of shellfish and attribute higher value to shellfish relative to other ecosystem components (Levine et al., 2016). Additionally, both Indigenous communities were highly polarized in their perspectives about sea otter-based tourism. While many different reasons for supporting/opposing otter tourism were cited, several Sugpiaq respondents were concerned that the values of tourists would not align with the Sugpiaq value of hunting otters. These disparities in values are common in situations of predator recovery, and it has been argued that the failure to directly address differences in human attitudes, worldviews and knowledge about predators undermines coexistence (Carter & Linnell, 2016).

5 | CONCLUSION

Navigating predator-induced regime shifts that profoundly affect both ecological and human communities is a substantial challenge globally. Our study illustrates how regime shifts can disproportionately impact remote Indigenous communities that are reliant on subsistence food sources, constrained in economic opportunities and frequently marginalized in natural resource decision-making. Based on our empirical data combined with adaptation and social resilience theory, it is evident that enhancing Indigenous coexistence with sea otters will require a transformation in current environmental governance systems that increases local Indigenous authority and enables community-based management grounded in traditional knowledge and practice. Successful examples of where such transformations have produced multilevel, adaptive governance and Indigenous co-management of marine mammals provide evidence that it is possible (Armitage, 2005; Chiropoulos, 1994; Fisheries Joint Management Committee, 2013).

On the Pacific coast of Canada, while there are significant barriers to more collaborative sea otter governance and management, there are also growing opportunities to support change. There has been a resurgence of First Nations successfully asserting of their inherent rights to manage marine resources in their territories (e.g. herring—Jones et al., 2017; West Coast Commercial Fisheries—Ahousaht, 2018). Furthermore, government commitments to reconciliation with Indigenous peoples have opened the door to new federal agreements for collaborative fisheries (DFO, 2019a, 2019b) and marine management (DFO, 2018), and the formal adoption of UNDRIP in B.C. provincial legislation (BC, 2019). In Alaska, although Alaska Natives enjoy access rights to harvest sea otters, there remains a need for strengthened authority through formalized co-management agreements and a renewal of sustained federal engagement and funding. More broadly, our work suggests that a greater awareness of the diversity in values tied to apex predators could help promote relationship building, enhance cross-cultural understanding and facilitate people learning together more collaboratively. Overall, this work highlights the need for more Indigenous voice, authority and leadership in generating socially just and ecologically sustainable management options to address predator-induced regime shifts within complex and tightly coupled human-ocean systems.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTIONS

J.M.B., A.K.S. and K.B.J.W. conceived the ideas and all authors designed the methodology; J.M.B. and A.K.S. led and all other authors assisted in workshops and data collection; J.M.B. analysed the data, led the writing of the manuscript with assistance from A.K.S. All authors contributed critically to the drafts and gave final approval for publication.

DATA AVAILABILITY STATEMENT

Video compilations from interviews at the sea otter workshop and during community visits are available on www.CoastalVoices.net. Given the sensitive nature of our data, permission from the Coastal Voices steering committee and the Kyuquot/Chekleset First Nations or Sugpiaq Tribe communities is required to access the quantitative and qualitative data from our survey (contact Anne.Salomon@sfu.ca or Jenn.Burt@gmail.com).

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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