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Learning from Indigenous knowledge holders on the state and future of wild Pacific salmon

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Abstract

In response to colonial research paradigms that have subjugated Indigenous Peoples, knowledges, lands, and waters, Indigenous research methodologies have emerged to center Indigenous visions and voices in research practice. Here, we employ such methodologies to improve collective understanding of the state and future of wild Pacific salmon (*Oncorhynchus* spp.) and fish–people–place relationships across British Columbia's three largest salmon-producing rivers: the Fraser, Skeena, and Nass. Through partnerships with 18 communities of "Salmon People" and semi-structured interviews with 48 knowledge holders (i.e., Elders), we learned that, on average, Elders spent more than half of a century actively engaged in salmon fishing and processing. Modern salmon catches are reported to be approximately one-sixth of what they were estimated to be five to seven decades ago, and the top five threats to salmon identified by Elders included (*i*) aquaculture, (*ii*) climate change, (*iii*) contaminants, (*iv*) industrial development, and (*v*) infectious diseases. Threat priorities varied regionally, reflecting distinct lived experiences and regional variation in the prevalence and impact of different threats. Elders perceived threats to salmon equally as threats to aquatic health and human well-being, with evidence that the relationships between people and water, and salmon and people, are being profoundly transformed.

Key words: Elders, First Nations, Indigenous fisheries, Indigenous research methodologies, threats, decolonization

Introduction

Indigenous research methodologies

> "Indigenous methods do not flow from western philosophies; they flow from tribal epistemologies. If tribal knowledges are not referenced as legitimate knowledge systems guiding Indigenous methods and protocols within the research process, there is a congruency problem. Furthermore, by not recognizing Indigenous inquiry for what it is—a distinctive methodology—the political and practical quagmire will persist." (Kovach 2010, p. 37).

In response to colonial research paradigms that have subjugated Indigenous Peoples, knowledges, lands, and waters, Indigenous research methodologies have recently emerged to center Indigenous visions and voices in research practice (Wilson 2008; Kovach 2010; Smith 2012). As Indigenous Peoples around the world reclaim self-determination (see **Table 1** for glossary of key terms; Coulthard 2014), and as interest grows among practitioners of Western science in moving beyond knowledge assimilation or integration (Nadasdy 1999), we are beginning to see a rise in natural and social science research approaches and outcomes that are more respectful and responsive to Indigenous needs and priorities, and this has been through the work of Indigenous and non-Indigenous scholars alike (Arsenault et al. 2019; Thompson et al. 2019; Beveridge et al. 2020; Burt et al. 2020; Chapman and Schott 2020; Latulippe and Klenk 2020; McGregor, Whitaker and Sritharan 2020; Westwood et al. 2020; Steel et al. 2021).

The foundations for Indigenous participatory community-engaged research were laid by Kirkness and Barnhardt (1991), who described four "Rs" of ethical research practices for working in Indigenous contexts: respect, relevance, reciprocity, and responsibility. The application and practice of these core values leads to research that privileges Indigenous voices and respects distinct worldviews, that responds to local contexts and addresses community challenges, that strengthens Indigenous communities through equal benefit sharing and reciprocal learning, and that is conducted in a so-called "good way" where cultural protocols are honoured and power imbalances are recognized and rectified (Castleden et al. 2017; Arsenault et al. 2018). Through trust-based relationships and sustained commitment (Wilson 2008), these choices and actions culminate in research that is with—as opposed to on—Indigenous communities, transforming the nature and purpose of researcher–community interactions and relations.

Indigenous communities globally are increasingly asserting their rights, creating their own ethical guidelines and protocols for permitting research in their territories, and research and policy instruments are being designed to protect Indigenous knowledge systems (including scientific, traditional, and traditional ecological knowledges; refer to **Table 1**). There are perhaps as many approaches to this

Table 1. Glossary of key terms (in order of appearance in the main text).

Key Term	Definition
Self-determination	The right of Indigenous Peoples to freely determine their political status and pursue economic, social, and cultural development[a]
Western science	Scientific knowledge with roots in the philosophy of Ancient Greece and the Renaissance, favouring reductionism and physical law[b]
Indigenous knowledge	Knowledge created and/or mobilized by Indigenous Peoples that may include Traditional Knowledge and scientific knowledge,[c,d,e]
Scientific knowledge	Systematic enterprise that gathers and condenses knowledge into testable laws and principles[b]
Traditional Knowledge	Longstanding knowledge, practice, and belief, developed from experience gained over centuries and adapted to the local culture and environment, handed down through the generations[e]
Traditional ecological knowledge	Relates to the relationship of living beings (including humans) with one another and with their environment[e]
Indigenous science	Scientific knowledge of peoples who, as participants in culture, are affected by the worldview and interests of their home community[f]

Note: Sources: [a]United Nations Human Rights Office of the High Commissioner (1976); [b]Wilson (1999); [c]Arsenault et al. (2018); [d]TallBear (2014a); [e]Berkes (2018); [f]Snively and Corsiglia (2016).

protocol as there are Indigenous Nations, with protocol agreements requiring a range of procedures, from formal application processes with board or departmental reviews (for instance, that of the Heiltsuk Integrated Resource Management Department 2015), to obtaining support from community leadership through presentations and meetings with, for example, Chief and Council (First Nations of Quebec and Labrador Health and Social Services Commission 2014) or hereditary leadership (Beveridge et al. 2020). In terms of data and knowledge protection, the First Nations Information Governance Centre's OCAP® principles (Ownership–Control–Access–Possession; fnigc.ca) provide a roadmap for protecting knowledge holders and systems, reflecting a key principle outlined by the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP; United Nations General Assembly 2007) that explicitly protects Indigenous intellectual rights, stating that "free, prior and informed consent" must always be obtained regarding how such knowledge is collected, treated, and shared. Negotiating what constitutes "good" research protocols in a specific community context is an important first step in challenging existing power imbalances, it emphasizes self-determination and opens up lines of communication between the researcher and the community (Smith 2012; Arsenault et al. 2018).

As we navigate this transition to a point where Indigenous communities and knowledge holders are rightful and full partners in research, there needs to be a commensurate shift away from viewing Indigenous knowledge systems as simply filling in the gaps of a Western scientific understanding, where the latter serves as the default frame of reference to which the former is added on, too often as an afterthought, or for the apparent "utility" of serving as a resource where Western scientific data are lacking. Indigenous knowledge systems and worldviews must instead "become a starting point for new research efforts" (Arsenault et al. 2018), valid in their own right, and through the application of a decolonial research framework, they can be used to determine the values, processes, and methodologies that guide and direct research (Simpson 2004).

Indigenous knowledge systems of Pacific salmon

> "We need the salmon for our survival as a distinct people. It is so connected into our lives that if the salmon disappear, so will we. We use the salmon for our rituals, food and trade, and in return we pay homage to the salmon" (Alfred 2010, p. 2).

Pacific salmon—fish known by a host of Indigenous names throughout their vast geographic range (genus *Oncorhynchus*)—have been in a state of decline in British Columbia (BC), Canada for several decades (Price et al. 2017) such that a growing number of wild salmon populations have been assessed as "at risk"' (from Special Concern (n = 5 populations) to Threatened (n = 3) to Endangered (n = 10)) by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC; Government of Canada 2018). As both ecological and cultural keystone species, without the continued existence of salmon, ecosystems and societies alike would be entirely transformed (Willson and Halupka 1995; Garibaldi and Turner 2004). For the Nisg̲a'a Nation, which sits on the BC–Alaska border (and to which the lead author belongs), salmon are vital. They shape *ayuukhl* (code of law) and *adaawak̲* (oral histories), they figure centrally in *yukw* (feasts, known externally as "potlatches"), and they are a focal point of the Nisga'a Treaty (2000) that defines Nisg̲a'a rights tied specifically to salmon. As Nisg̲a'a and indeed many Indigenous nations identify as "Salmon People" (Columbia River Inter-Tribal Fish Commission 2020; Earth Economics 2021), there is serious concern about what will become of salmon-linked cultures, economies, knowledges, languages, laws, well-being, and worldviews as the annual return of these anadromous fish to rivers across the Pacific Northwest become increasingly unpredictable and, in many systems, Indigenous fisheries for wild salmon become a shadow of their former selves (Jacob, McDaniels and Hinch 2010; Atlas et al. 2021). Decolonial research strategies that respect Indigenous intellectual traditions and affirm Indigenous control over Indigenous knowledge

are critical to the maintenance and recovery of salmon-based knowledge systems and salmon populations (Simpson 2004; Bingham et al. 2021).

Indigenous knowledge systems of Pacific salmon are notably absent from the Western-based fisheries management systems that currently dominate due to a range of institutional, cultural, philosophical, and methodological challenges (see Murray et al. 2011). Across Northwestern North America, Indigenous knowledge is said to be "drowned out, marginalized, and at times, worse, forgotten" in many contexts (Walsey and Brewer 2018, p. 1170). Similar to fishers' knowledge (Johannes, Freeman and Hamilton 2000), which has gained traction in the literature at multiple points in time (see Hind 2015), the acceptance of experiential, place-based knowledges into fisheries management and policy has been largely precluded by Western scientific perceptions of such knowledge (and its study) being unquantifiable/unreliable, nonsystematic, and idealized (Davis and Ruddle 2010)[1].

This article addresses these two separate but connected challenges (i.e., the decline in salmon, and the historical and contemporary exclusion of Indigenous knowledge systems). We employ Indigenous research methodologies to document and mobilize Indigenous knowledge systems of Pacific salmon on Indigenous terms. We also detail the systematic approaches undertaken herein to address three management-relevant questions based on our awareness that Indigenous knowledge systems are not uniform, and given their place-based nature, they will reflect localized contexts. Our three main lines of inquiry included:

> Research query (RQ)1 – Have Pacific salmon populations and fisheries catches changed over time and, if so, how?
>
> RQ2 – What are perceived as leading aquatic threats to Pacific salmon survival now and in future?
>
> RQ3 – How do RQ1 and RQ2 vary by region and across BC's largest salmon-bearing river systems?

Methods

Developing research partnerships and protocols

This research (see **Fig. 1** for methodological workflow) emanates from a long-term research program (with leadership and involvement from all co-authors) centered on Pacific salmon ecology and conservation, using tools and understandings primarily from the natural and social sciences, with only more recent contributions from Indigenous science (by way of the lead author). Through this program, our team has built a network of collaborators (~80 representatives from other research groups, First Nations, environmental nongovernmental organizations, governmental agencies, and stakeholders) who convene each year at The University of British Columbia for an Annual Research Symposium on salmon migrations, ecology, and management (entering its 16th consecutive year; Cooke et al. 2020). This symposium provides an opportunity for collaborators to offer feedback on research and recommend directions for future work, helping also to maintain research relationships in between field seasons. The need for and interest in the present study was identified through discussions here in February 2017 and February 2018 (stemming also from previous research by our team: Jacob et al. 2010; Nguyen et al. 2016), and the annual symposium has since served as a platform for sharing preliminary results from this work and addressing interim questions and ideas.

[1]This predates the mainstreaming of responsive natural and social science research noted above (but, remains overshadowed by a large majority of studies that lack Indigenous acknowledgement or consideration; e.g., Schang et al. 2020; Bingham et al. 2021).

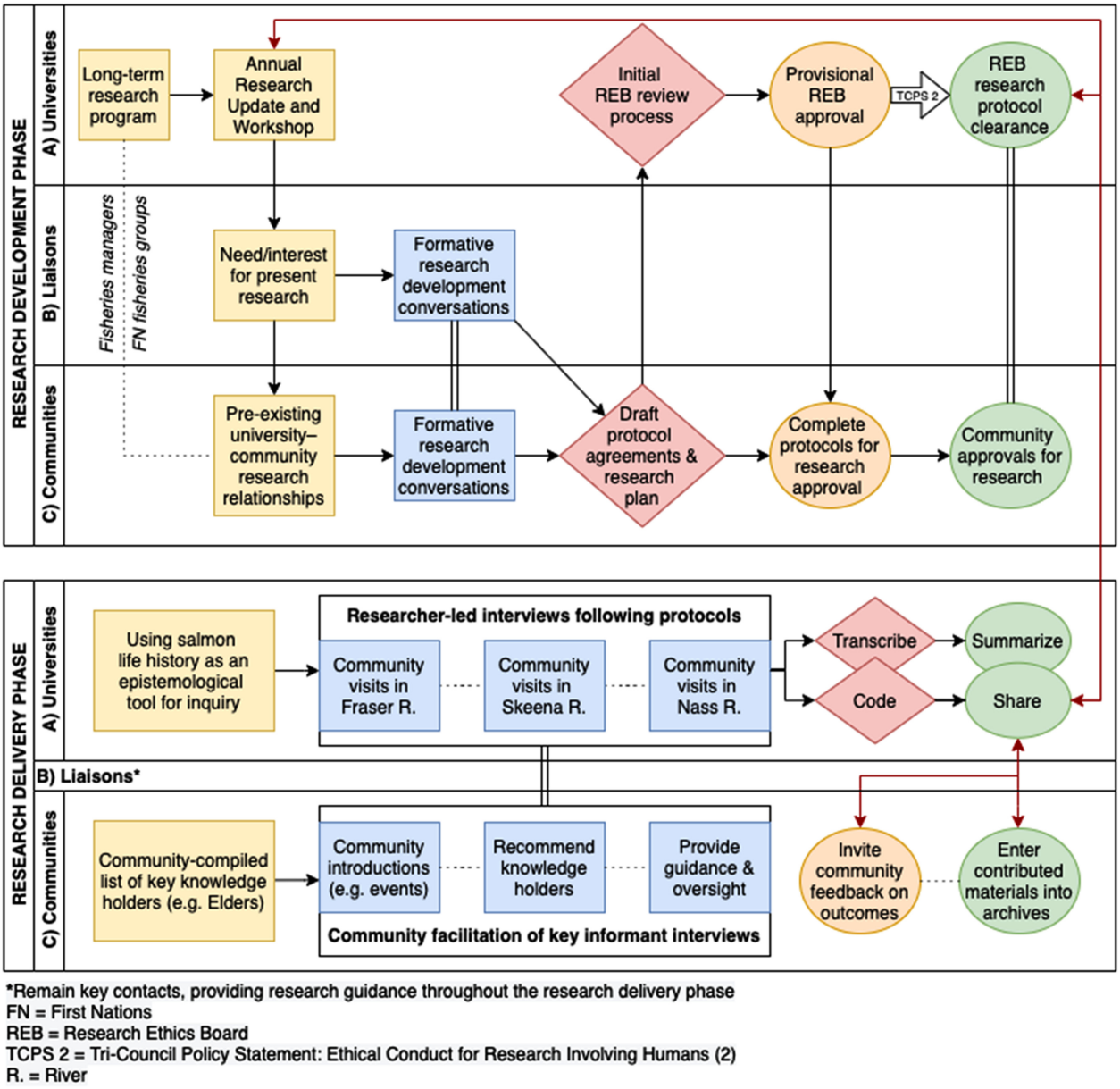

Fig. 1. Swimlane diagram detailing the methodological workflow for the research development phase (top) and delivery phase (bottom) for a research team involving university scholars, community liaisons, and Indigenous community partners. Black arrows show the directional, stepwise flow of research development and delivery activities; dashed lines indicate interconnections; double bars show where activities are working in necessary parallel; and red arrows show the flow of research outcomes.

From this large network and based on existing research relationships with Indigenous communities across BC's three largest salmon producing river systems—the Fraser, Skeena, and Nass Rivers—we initiated conversations with various First Nations (often starting with their fisheries managers with whom we have worked extensively in many cases) as well as our primary contacts with various First Nations fisheries groups (including but not limited to: First Nations Fisheries Council, Lower Fraser Fisheries Alliance, Upper Fraser Fisheries Conservation Alliance, Secwépemc & Skeena Fisheries

Commissions, Nisga'a Fisheries & Wildlife Department). These formative conversations identified potential community interest in this work (or occasional suggestions for additional communities to contact), they specified community needs and expectations around reciprocity and mutual responsibility in research, and they also clarified what local research protocols entailed.

These initial conversations informed how the research team prepared protocol agreements and the research proposal for community review, which in turn informed the ethics review process with affiliated universities. Communities were invited to begin compiling lists of key knowledge holders with respect to Pacific salmon (to be shared once permissions and approvals were in place). Records were maintained to detail when community conversations took place, and at which stage of the process we were with each community. Because the Research Ethics Board (REB) process can be lengthy, it was initiated as soon as we had received and addressed feedback from potential community partners, but because no approvals had yet been sought from community partners (as in many cases, university REB approval was a prerequisite), we detailed our research practice, process, and plan for the university without providing specific community partner names for the initial review. Once provisional REB approval was granted, we then completed individual community research approval processes by May 2018. These ranged from formal application processes and proposal reviews by community board members, to remote participation in community leadership meetings where objectives were explained and questions answered, to communities simply indicating no such protocols were (yet) in place and proceeding with this work would simply require individual consent from knowledge holders. Following this, we finalized our research protocol and received REB clearance in June 2018 (Carleton University Ethics Clearance ID: Project # 108478; University of Ottawa Ethics File Number: S-06-18-853) and completed required associated training (e.g., Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2) – Course on Research Ethics).

Indigenous knowledge holder interviews

Following the migratory path of adult Pacific salmon, from the coast upstream to spawning grounds, and during the time of sockeye runs in BC (July–November of 2018), the lead author visited communities belonging to First Nations spread across the Fraser, Skeena, and Nass Rivers (**Fig. 2**) at which time communities of salmon practice were flourishing in places where runs were healthy and abundant that year, and notably absent in others where, for example, salmon wind-drying racks stood bare (**Fig. 3**). By using the salmon lifecycle as an epistemological tool (as with Ingersoll's (2016) "seascape epistemology"), the migratory path provided an insightful means of connecting with cultures and communities, observing variations as well as points of convergence among them. Given the research objectives and key lines of inquiry described above, this research aimed to be community-engaged (sensu Adams et al. 2014), but not community-based which is widely understood as a cyclical and iterative process in one or few locales over long time scales (Castleden et al. 2012). To examine variation across different geographies and contexts, this "migratory" method of research was essential.

In each partnering community, introductions were often made with a presentation at a community meeting, or in some cases at a community feast or culture camp. Between one and five community-identified knowledge holders were identified as potential "key informants" in each community, all of which were Elders or young Elders (also referred to as Elders-in-training), recognized by their community as keepers and teachers of knowledge, not simply individuals above a certain age threshold or belonging to any specific gender identity or career path. Additional inquiries were made within each community (outside of leadership) about recommended knowledge holders to speak with, but this practice did not yield additional names not previously identified, instead it provided a secondary (and often a tertiary) confirmation of who the community considers to be key knowledge keepers. Carleton University's "Guidelines for Working with First Nation, Métis and Inuit Elders and

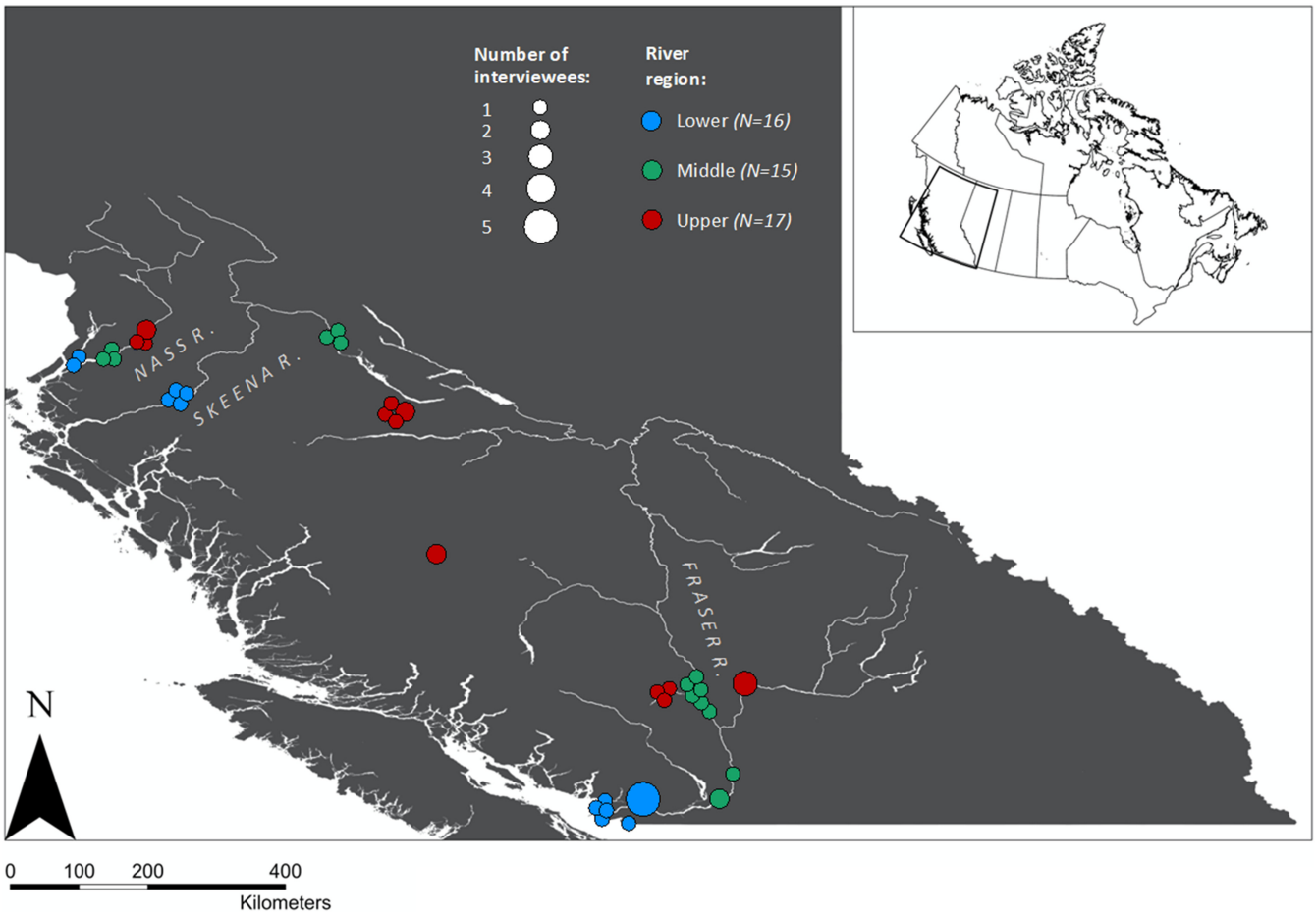

Fig. 2. Map of British Columbia's three largest Pacific salmon producing river systems (Fraser, Skeena, and Nass Rivers), showing the locations where semi-structured interviews with 48 Indigenous knowledge holders took place in June–November 2018. River regions were categorized as "Lower" (the first communities in the study to encounter return-migrating salmon), "Middle" (the second), and "Upper" (the third)––these are not true positionings within the watershed, but rather the order by which salmon (and the lead author) came into contact with communities in 2018. Geospatial data used to create this map are from the British Columbia Freshwater Atlas (Ministry of Forests, Lands, and Natural Resource Operations 2011). Base map created by J.F. Lane.

Knowledge Keepers" were followed throughout the research process (Centre for Indigenous Initiatives 2018).

Community-identified individuals were invited to participate in semi-structured interviews on the state and future of Pacific salmon. Interviews were voluntary, and written or oral consent were equally allowed. Each interview was initiated by the researcher reading aloud the key consent form elements: research purpose, data security and confidentiality measures, right to withdraw, compensation plan, permissions to be audio-recorded and (or) photographed, and copyright sharing agreement details. For this latter element and in line with OCAP® guidelines, individuals retained control of their knowledge and could opt to require being contacted before any future direct uses of their knowledge for details and approvals, and they could also agree or decline to having their interview materials contributed to their First Nations' archives (once transcribed and finalized). Interviews took place in locations of their choosing, primarily in their homes, on occasion in public spaces such as the band office or community hall, and infrequently in "atypical" locations (e.g., riverside, smokehouse,

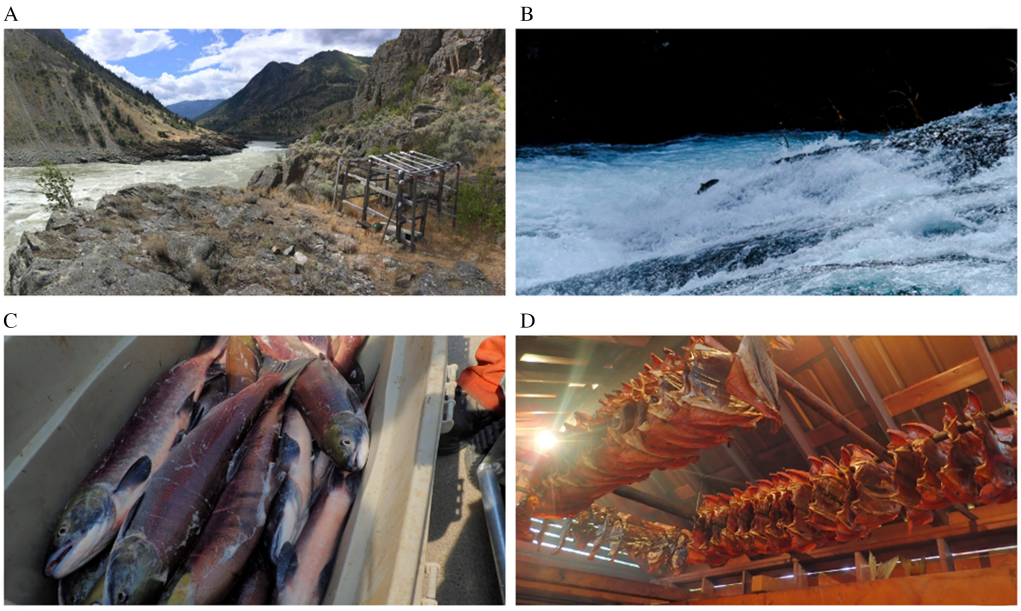

Fig. 3. Images taken during the 2018 field season, where the life cycle of Pacific salmon was employed as an epistemological tool. With permission, all photos were taken by the lead author from the territories of the: (A) St'át'imc Nation, Xwísten fishing grounds along the Fraser River, where a salmon wind-drying rack stands bare; (B) Nisga'a Nation along the Meziadin River, a tributary of the Nass, where a salmon attempts jumping waterfalls near spawning grounds; and (C) and (D) Lake Babine Nation, where plentiful Skeena River sockeye salmon (*Oncorhynchus nerka*) have been caught for a local Elder and stripped and hung to dry in a smokehouse, respectively.

four-wheeler, canoe). Participants were presented with a small gift (a jar of homemade raspberry jam and (or) bear grease salve) at the start of each interview and were offered an honorarium to recognize time taken away from other roles and responsibilities at interview end (as outlined in each research agreement).

Semi-structured interviews lasted 0.5–2.5 h, as determined by the knowledge holders. All interviews took place in English (although the research team was prepared to hire translators if knowledge holders preferred to speak in their native language). We approximately followed the interview guide, pivoting where necessary in response to what knowledge holders wished to share, and given their role(s) in their community (i.e., a former commercial fisher could provide insight on various changes in salmon catch over time, whereas those engaged in food processing could do the same for changes in fish condition and health). Conversations were free-flowing, with only a portion focused on the above-listed research questions (specific details follow). Much of the knowledge shared was recorded for the purpose of community access in the long term.

RQ1- and RQ2-related questions were qualitative and quantitative in nature (see template questions in **Table 2**). The approach for RQ1 involved sub-questions posed in reverse-chronological order, starting with the present state and gradually progressing backwards in time. To gauge perspectives on changes in the state of Pacific salmon, knowledge holders were simply asked whether or not they had witnessed changes in salmon abundance over their lifetimes, and to describe those changes if applicable. Similar to Eckert et al. (2018), knowledge holders felt comfortable contrasting their catches from when they began fishing (hereafter "historical") to now or when they stopped fishing (hereafter "modern"). Historical values were associated with years spanning the 1950s to 1970s (thus ~50–70 years ago), and modern values were all in reference to within the last decade. To examine

Table 2. Template questions pertaining to RQ1 and RQ2 for semi-structured interviews.

RQ	Template questions	
1	Were (or are) you active in Pacific salmon fishing and/or processing?	
	Have salmon changed in abundance over your lifetime? Please describe.	
	How long has it been since you last were out salmon fishing?	
	How many salmon did you catch then? (as a unit of fish/time, e.g., 10 fish per day)	
	How old were you when you first went salmon fishing?	
	Who taught you how to salmon fish?	
	What is the main gear type you used for salmon fishing?	
	When did you start fishing on your own?	
	How many salmon would you catch then? (as a unit of fish/time, e.g., 10 fish per day)	
2	What is a key threat endangering Pacific salmon populations?	
	From these 12 potential threats, select your five top concerns. Next, rank them 1-5.	
	• Aquaculture (salmon farms)	• Illegal harvest
	• Climate change	• Indigenous fisheries
	• Commercial fisheries	• Industrial development
	• Contaminants	• Infectious diseases
	• Fisheries bycatch	• Other (specify; can select up to 5x)
	• Hydroelectric projects	• Recreational fisheries

change in salmon catch during subsequent analysis, historical values were set as a benchmark of "1" against which the modern state could be compared as a relative proportion per individual.

For RQ2, the first sub-question was posed as an opportunity to identify leading threats before being influenced by the prelisted threats in the second sub-question (a free listing elicitation exercise; Weller and Romney 1988). For the second sub-question, knowledge holders were presented with each pre-identified threat listed on a cue card, laid out in a randomized order. They were first asked to identify their top five concerns (including an "other" category which, if selected, they needed to specify; "other" could be selected up to five times, if desired). Once top selections were made, knowledge holders were invited to organize threats in order of relative importance. The threats presented reflected an amalgam of global leading freshwater threats (from Reid et al. 2019) and major stressors identified through the *Cohen Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River—Final Report* (Cohen 2012), which included testimony by diverse knowledge holders. A weighted score was produced for each threat, accounting for the number of times each threat was selected among the top five priorities and in which priority position it was placed (scored 0–1; **Supplementary Table S1**).

At the end of each interview, knowledge holders were asked whether they had questions pertaining to the state and future of Pacific salmon (particularly from a Western scientific standpoint). Their responses were recorded, and answers were researched and returned to them where possible. Most interviews were conducted individually, four interviews were in pairs, and two took place in small Elders' groups; for the latter two cases, responses could be given individually or through consensus (responses were recorded on a per individual basis given they could vary even within group contexts).

Interviews were transcribed with help from three university undergraduate students, and responses were coded according to main themes. Using Microsoft Excel, responses were categorized and tallied for qualitative analysis and to inspect for variation with respect to RQ3. R statistical software was used to visualize quantitative results (version 3.6.3 R Core Team 2017).

Results

Community and knowledge holder engagement

Across the research visits in 18 First Nations communities, 48 knowledge holders took part in semi-structured interviews between June and September 2018, with one phone interview in November 2018 (Fig. 2). This included 31 men and 17 women, ages 56–93. Individuals self-identified as belonging to the Nations of the Katzie, Nat'oot'ten (Lake Babine), Nisg̲a'a, Peters, Stó:lō, Secwépemc (Shuswap), St'át'imc, Tŝilhqot'in, Ts'msyen (Tsimshian), and xʷməθkʷəy̓em (Musqueam; English spellings provided where still commonly used). Communities were spread across the Fraser, Skeena, and Nass Rivers, encompassing regions categorized as "Lower" (the first communities in the study to encounter return-migrating salmon), "Middle" (the second) and "Upper" (the third) in each river. These are not true positionings within the watershed, but rather the order by which salmon (and thus the lead author) came into contact with communities in 2018. While we worked towards geographical breadth in this research, where interviews took place is reflective of where our partnerships were situated. This was not considered a comprehensive or exhaustive approach given the existence of ~200 BC First Nations—most (if not all) of which are touched by salmon. No community that we engaged with declined interest in this work; although one potential partner community along the Skeena River experienced the loss of a community member during the time of the study, making it unsuitable for our research to proceed there at the time of this work.

Also notable, no individual knowledge holders declined participating in this research, and none abstained from having their interviews audio-recorded or a profile photograph taken (for the purposes of inclusion in community archive packages and (or) to be printed and returned to them alongside interview materials). There was widespread interest in contributing interview materials in both written and oral formats to community archives. Excluding the four community instances where no such archives exist (or are soon to be developed; n = 12 interviews), 86% of participants (n = 31) consented to this arrangement and 14% declined (n = 5; exclusively in two regions where hereditary leadership remains strong, but community archives reside with elected band councils). Where consent was given, recordings and transcriptions were compiled in printed and digital formats (e.g., CDs/mp3s, printouts/PDFs) and have already been or are in the process of being shared with all community partners as prescribed by protocol agreements (note: delays in this process have been introduced by the COVID-19 pandemic). All knowledge holders opted to retain control of their knowledge, as described above.

Change and threat evaluation

In response to RQ1 sub-questions, we confirmed that all knowledge holders were active participants (past and (or) present) in salmon fishing and (or) processing. All began fishing from a very young age (mean = 6 years old), with "since I could walk" (or an equivalent variant) being the most common response. On average, women had fished for 52 years and men 57 years of their lives. Seventy-one percent recounted learning to fish from their parents, 23% from their grandparents, and 6% from older siblings. Set and drift gillnets were the most common fishing gear type used (64%), followed by dipnets (22%), hook and line (8%), and lastly seine nets (by former commercial fishers, 6%). With one exception—a knowledge holder from the Upper Skeena who reported no change in the state of salmon in their region—all other knowledge holders reported witnessing negative changes in salmon

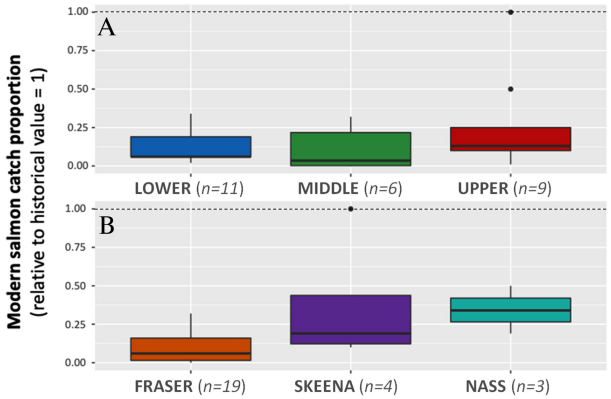

Fig. 4. Relative proportion of Pacific salmon catch by river region, A, and system, B, as perceived by Indigenous knowledge holders. Historical values of catch (from the 1950s-1970s, reported in the form of number of fish per unit of time) were used as benchmark (set to '1', demarcated by horizontal dashed line) against which modern values (also reported as fish per unit of time) could be compared as a relative proportion per individual (n = 26). For example, a transition from catching 200 salmon per week historically, to catching 50 salmon per week contemporarily, is described as having a relative catch proportion of 25% (or, equivalently, a 75% decrease).

abundance over their lifetimes of fishing and living in their territories. Based on estimates of historical and modern salmon catch sizes from 26 respondents who felt confident providing such values, an average 83% decline was reported. Comparing, on a relative basis, modern catch sizes against historical ones revealed consistently low values across Lower, Middle, and Upper river regions (except for two outliers in Upper regions; **Fig. 4A**), and when examined by river, this revealed slightly lower values for the Fraser, greater variation across the Skeena, and slightly but consistently higher values for the Nass (**Fig. 4B**).

All knowledge holders contributed to RQ2. In 81% of cases, threats that were free listed were also found within the threat list developed for the second sub-question, with most responses centering on aquaculture (specifically salmon farms; 29%), climate change (17%), commercial fisheries (15%), and industrial development (11%). Contaminants, hydropower projects, illegal harvest, and infectious diseases accounted for another 10% of free-listed responses. The other threats put forward included multiple variants that can be grouped as "mismanagement" (8%; bad fisheries management decisions, Indigenous exclusion, and weak governance structures), "predators" (6%; primarily marine mammal predation), and "capitalism" (4%; where greed or financial ends are prioritized above all else).

Selecting top concerns from the predetermined list yielded slightly different outcomes. Based on weighted scores, the five main concerns across the study were: (*i*) aquaculture (hereafter salmon farms), (*ii*) climate change, (*iii*) contaminants, (*iv*) industrial development, followed by (*v*) infectious diseases (**Supplementary Table S1**). When partitioned by river region, different top priorities emerged. Salmon farms carried the most weight among knowledge holders in Lower regions, contaminants were the leading concern in the Middle, while climate change and industrial development tied for first in the Upper (**Fig. 5A**). Climate change and commercial fisheries were the two threats common to all top five threat lists across regions. A few notable distinctions include heightened concern for predators in the Lower river, hydropower in the Middle, and capitalism in the Upper. By river, knowledge holders placed the most weight on contaminants in the Fraser, on industrial development in the Skeena, and on salmon farms in the Nass (**Fig. 5B**). Salmon farms and climate change were common to the top five threat lists for each river. Finally, a few notable distinctions here included concern for commercial fisheries in the Fraser, as well as for recreational fisheries and

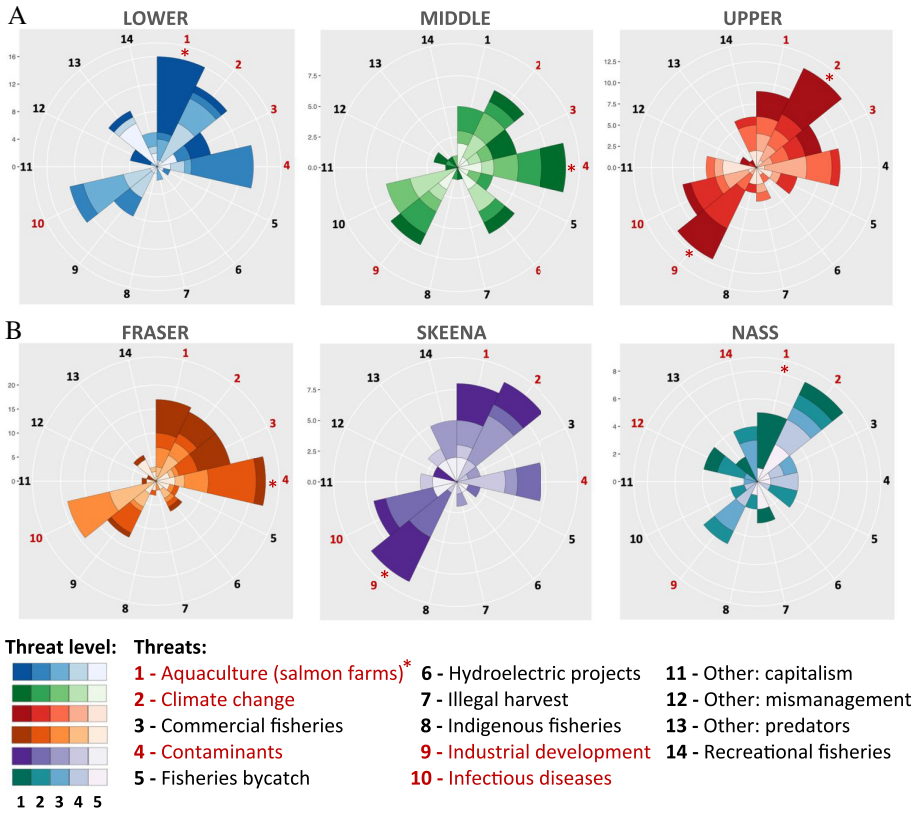

Fig. 5. Rose plots displaying the frequency distributions of leading threats to Pacific salmon survival, as perceived by Indigenous knowledge holders, by river region (A: Lower; Middle; Upper) and system (B: Fraser; Skeena; Nass). Hue, from darkest to lightest, indicates listing in the first position (number one priority) to last position (number five priority), respectively. Based on weighted scores (presented in Supplementary Table S1), the top five priorities per grouping are identified in red font (and for the study as a whole, within the legend), and red asterisks indicate the top scoring threat per grouping (with two tied for first in the Upper region).

mismanagement in the Nass. The top five priorities selected by Skeena-based knowledge holders matched those threats identified as carrying greater weight across the study.

While these lines of inquiry were specific to changes in Pacific salmon populations, associated responses frequently grew well beyond this specified scope. A number of themes emerged, and a few examples are described in Table 3 (see Discussion for further details). One additional theme raised by respondents that is an extension of RQ1- and RQ2-related questions was perceived change in aquatic health more generally. Thirty-five percent of knowledge holders stated that "we used to be able to drink the river" (or similar variants) and how now they never could. One Elder in the Upper Nass, while reflecting on the state of a lake they grew up on, said "That lake is not even a shadow of what it was when I first looked at it in the 1950s." The salmon and the state of the water were, for them, a connected memory:

> "If the north wind was blowing down river and we were coming up, we could smell the salmon in the air. We could smell the salmon. You drink the river water, and you can taste the salmon in the river. Wow!"

Table 3. Example emerging themes arising from semi-structured interviews with Indigenous knowledge holders across the Fraser, Skeena, and Nass Rivers in 2018.

No.	Emerging theme (ET)	Brief description
1	Concern for next generation	Apparent loss of language and limited knowledge of traditional salmon fishing practices among youth; concern for knowledge maintenance
2	Waste avoidance principles	Not wasting any part of salmon, showing reverence by returning bones to the river, keeping what one catches and taking only what one needs
3	Customary tenure systems	Families hold stewardship responsibilities for a delineated area, passed down across generations, often matrilineally
4	Fishing annual cycle	The chronological return of salmon and other anadromous fishes was used to describe the annual cycle of fishing practices and traditions
5	Use of indicator species	Identifying other organisms as signaling the return of the salmon each year, or ideal conditions for processing salmon

Another Elder in a coastal community remarked, "I remember the day that I used to look in the Fraser River and see the fish going up. It was clear. We used to be able to drink the water out of the Fraser." They continued, "We used to go down there and get a fill—a fill of the Fraser River water… Now when you look in the river, you can't even see two inches down." Another Fraser Elder remarked "I wouldn't even touch it now." The story was much the same among knowledge holders in the Skeena, where one Elder said, "We can't drink the water because of the mine," while another confirmed in a separate interview, "Now we can't drink Babine Lake because of the mining. We have to buy our water and it's getting costly." For many knowledge holders, if not all, the health of the water, the health of the salmon, and indeed the health of the people are all one and the same. This was also clearly reflected among the questions posed by knowledge holders at the end of interviews, where the most common questions raised pertained to specific infectious diseases in salmon in their area, the extent and severity of these diseases, and whether they pose a threat to people. Likewise, there was much concern expressed for how specific environmental practices such as mining are affecting local fish, the water, and themselves.

Discussion

What and how we learned

Our study shows that the nature of salmon–people relationships is shifting. The knowledge holders interviewed through this research have lived lives profoundly marked by salmon, spending on average more than half of a century actively engaged in salmon fishing and processing. Modern salmon catches in the Elders' waterways in British Columbia were perceived to be just a fraction—approximately one-sixth—of what they were estimated to be historically, when knowledge holders were just starting out fishing between five and seven decades ago. Through a threat perception and evaluation exercise, we revealed differences in the relative rankings of various stressors in the aquatic environment. The top five threats in order of scored weightings included: (*i*) aquaculture (salmon farms), (*ii*) climate change, (*iii*) contaminants, (*iv*) industrial development, and (*v*) infectious diseases. When partitioned by river region and system, climate change was the only stressor common to all top five threat lists. Our results also show that the single top weighted threat varied by both river region (Lower = salmon farms, Middle = contaminants, Upper = climate change and industrial development) and system (Fraser = contaminants, Skeena = industrial development, Nass = salmon farms), suggesting that people's perceptions and knowledge of key threats are highly context dependent and localized. Finally, through this work, knowledge holders had the space to speak to more than strictly

salmon, and it was made clear that holistic aquatic health is a leading concern, with evidence that relationships between people and place—namely with lake and river systems—is transforming from a state where they once could be consumed without question to a present circumstance where the water can neither be drank nor touched in particular regions. Knowledge holders in many areas must now participate instead in a transactional relationship with water where it must be purchased for safe consumption due to a lack of potable drinking water in their First Nations communities (a state of affairs not uncommon across Indigenous communities in Canada where ~30% of community water systems are classified as "high risk" and water-borne infection rates are 26 times higher than the national average; Patrick 2011).

As many Indigenous teachings tell us that how you learn is just as important (if not more important than) as what you learn (Simpson 2004), it is crucial to have placed dual emphasis in this study on (*i*) the insights emanating from this research as well as (*ii*) the deliberate methodological approach undertaken herein to arrive at these outcomes. The high degree of community and knowledge holder participation in this research reflects a focus—the state and future of Pacific salmon—that is a shared concern by all involved. Unanimous interest in retaining control over how one's knowledge is collected, treated, and shared is for us an unambiguous sign of appetite for culturally responsive and ethical research practices. The widespread, albeit context-dependent, willingness to have recorded interview materials returned to community archives (in both oral and written formats) is likely reflective of knowledge holders' recognition that additional methods are needed to help maintain and recover salmon-based knowledge systems. For many of the main and emerging themes in this research, knowledge holders repeatedly expressed concern for the next generation who from their view are increasingly disengaged from traditional salmon fishing practices, related languages, and associated knowledges (Emerging Theme 1 (ET1); **Table 3**). As one Elder put it, "That's very, very, very bad business for the whole community… Nobody is learning how to do the fish." Safeguarding Indigenous knowledges in this way is one means of ensuring that at least aspects of these intricate, fluid, and multidimensional knowledge systems remain accessible to community members now and in future generations.

State and future of Pacific salmon

Our findings are similar to other studies that report declining Indigenous access to safe, healthy, and culturally appropriate food fish. For instance, in the Nuxalk Nation, there was a reported decrease of 82% in the consumption of sockeye salmon from 1981 to 2009 (*O. nerka*; from 27 to 5 kg of fish/family/year) and 66% over that same timeframe for Chinook salmon (a.k.a. spring salmon; *O. tshawytscha*; from 38 to 13 kg/family/year; Kuhnlein et al. 2013). Sockeye and Chinook, respectively, have been found to be the first and third top-consumed seafood species by coastal First Nations in BC, with both accordingly being the first and third most important sources of protein as well as other essential nutrients (e.g., vitamin A, niacin, selenium) in both Indigenous men and women (Marushka et al. 2019). Projecting climate change scenarios forward, the outlook for salmon and associated fisheries continues to appear grim. Catch potentials are expected to decline by another 17%–29% by 2050, with more severe cumulative declines in catch potential for First Nations at lower latitudes (e.g., Coast Salish communities) than those further north (e.g., Ts'msyen; Weatherdon et al. 2016). This is consistent with our finding of lower modern catch proportions in the Fraser in comparison with the more northern Skeena and Nass Rivers. From the observations and experiences shared by diverse knowledge holders here, and in light of these parallels with previous other works, it is likely that similarly staggering declines in salmon catches pervade across BC First Nations.

As noted in the Cohen Commission Inquiry Final Report (Cohen 2012), here we find no single "smoking gun"—no isolated cause to which these precipitous declines in salmon abundance can be attributed. Instead, a range of concerns surface through this work that share near-equal weight as

perceived culprits in the matter (namely, salmon farms (weight = 0.15), climate change (0.14), contaminants (0.13), industrial development (0.12) and infectious diseases (0.11); **Supplementary Table S1**). Where novel insight emerges is from the partitioning of perceived threats by river regions and systems, which reveals a context-specific nature of key concerns. Proximity and novelty could be key explanatory variables in interpreting this variation. For instance, hydroelectric projects emerge as a top concern only among the Middle grouping, and this reflects exclusively the experiences of knowledge holders whose lives and fisheries have been irreversibly transformed by the Bridge River hydroelectric complex in St'át'imc territory (within the Fraser watershed). Knowledge holders here detail histories of forced relocations, salmon run extinctions, and the disappearance of a fishery and a way of life, leaving little guesswork as to why hydropower ranks highly as a threat in this area (as found and postulated in Hallwass et al. 2013, and Baird et al. 2021, respectively). In contrast, hydropower was not identified once by respondents in the undammed Nass River, where instead recreational fisheries (in both marine and fresh waters) as well as mismanagement (specified as being on a federal level) arose as novel top concerns in this system where poor salmon returns in only more recent years have made both topics current hot button issues (Taylor 2017). Interestingly, salmon farms (which are not present in Nisga'a territory) and climate change were identified as major risks in the Nass, suggesting that perhaps risk perception is elevated for threats with potentially far-reaching implications across Nation boundaries or that are perceived as not being effectively addressed. It is worth noting here that this work took place before the Canadian federal government's 2021 decision to phase out—or at least partially close—salmon farms in BC.

The pre-identified threats presented to knowledge holders in the threat perception and evaluation exercise were focused on potential proximate causes of declining salmon stocks; however, through the inclusion of an "other" option, knowledge holders also identified structural drivers such as capitalism and mismanagement that they perceive as problematic for salmon conservation. The two were often viewed as intertwined and standing in stark contrast to Indigenous ethics and waste avoidance principles where one takes only what one needs and no more (ET2). "You can't eat gold" were words commonly spoken, sometimes in explicit reference to Alanis Obomsawin's famous quotation, "When the last tree is cut, the last fish is caught, and the last river is polluted; when to breathe the air is sickening, you will realize, too late, that wealth is not in bank accounts and that you can't eat money" (Osborne 1972, p. 43). One Nass Elder reflected on teachings they received from their Elders, stating they

> "never ever waste any food, any. They respect the land we're in, eh? The waters, the Earth. They respect the food too. They always tell you; you never get more than what you need. Only get what you can use and share with others."

Elders' teachings from generations past are being carried as a living, not past tense, memory. On how Skeena salmon are being managed, or mismanaged, one knowledge holder remarked, "I was told that money talks. It's screaming now." They added,

> "I was brought up just to take what I need, and I still do that today. When I go food fishing, once my family has their share, the rest goes to whoever wants it. I still have it in me. I want to give it to them. So, we are always careful on how much we take. I remember my grandmothers told me that there was so much fish in the Nass, in the Skeena, that you can almost walk on it. It was so much, and now…"

Pre-colonization, Indigenous salmon management revolved around customary tenure systems (ET3) and ceremonial and stewardship practices that relied on deep knowledge of annual fishing cycles (ET4) and an ability to read the land by way of indicator species (ET5)—practices now largely replaced by colonial and corporate systems of salmon management that many knowledge holders feel are putting the state of salmon in jeopardy. Mismanagement was often also described as overlooking

Indigenous knowledge systems or systematically excluding Indigenous Peoples from decision-making spaces that would give occasion for the ethics just described to inform contemporary management practices.

Knowledge keepers and researchers

Important questions have been previously raised about who are considered "local knowledge experts" (Davis and Wagner 2003) and how one goes about engaging with Indigenous knowledge holders (Battiste 2005). This study has taken careful measures to be transparent in our research choices and methodologies for these very reasons, while reserving the space required for communities to self-determine who they consider to be the experts and stewards of salmon-based knowledges. Knowledge holders in this research included fishers, fisheries managers, fish processors, healers, historians, ceremonialists, spiritual leaders, caregivers, and advocates—individuals who carry current knowledge that is fluid, dynamic, and constantly responding to new phenomena (e.g., emerging threats) as they arise. If we define scientific knowledge as we have done here as that which is gathered through a systematic enterprise into testable laws and principles (**Table 1**), these individuals can very well be described as salmon scientists, deserving of inclusion at the salmon management decision-making table. Here, we purposefully privilege these voices so they can be heard by the Western scientific community and be viewed as stemming from legitimate knowledge systems, founded on worldviews that are not rendered invalid by virtue of being distinct from the philosophy of Western science.

We conceptualize the research process undertaken in this study as an exercise in building and maintaining relationships. It involved a professional network of colleagues and experts and created an opportunity for visiting, conversations, and knowledge sharing, not strictly one-way data gathering (TallBear 2014b). Following the migratory route of salmon throughout the field season meant that the research often went far beyond having recorded, deliberate interviews with knowledge holders, it involved spending time at fish camps, helping get fish home for Elders, and showing up to feasts—it was in essence dedicated time to participate in salmon ceremony and culture and for these experiences to shape the research itself. It served as a legitimate mode of inquiry that yielded localized insights that otherwise would have been missed, altering the very course of conversations with knowledge holders where being able to relate to, understand, and query place-based references and concerns was crucial.

Likewise, the methodological workflow, while directional and deliberate in appearance in retrospect, was not something the research team could have mapped out precisely prior to doing the work. It arose responsively as we navigated university–community relationships, as we listened to communities articulate their needs and priorities and as knowledge holders graciously welcomed the work into their homes and lives. We had also not envisioned two separate outputs (this research article and a forthcoming book project) at the outset, but this arose as one way to reconcile (*i*) elevating Indigenous knowledges and voices as sources of expertise in the domain of salmon science, on the one hand (this work) and (*ii*) maintaining and respecting Indigenous intellectual traditions by not divorcing knowledges and stories from the rich context to which they are tied or the knowledge holders who carry them, on the other (future book). These contextual relationships require time and space to be carefully considered, they cannot be reduced to a number as a simpler threat ranking can be, and they need not be validated by external referents to be considered truth. Operating outside of the academic literature with knowledge holders as collaborators and co-authors (see Cooke et al. 2021; Marshall et al. 2021 for examples), as will be the case with the future book project, allows a great deal more flexibility to appropriately engage with these knowledges. The book will be written collaboratively and in an accessible manner, with the next generation as the primary intended audience given Elders' concern for knowledge maintenance and transference. While these were not our specific

intentions at the inception of this project, their need was made clear through the research process itself. As well articulated by Kim TallBear (2014b, p.2), "A researcher who is willing to learn how to "stand with" a community of subjects is willing to be altered, to revise her stakes in the knowledge to be produced."

Conclusion

The right of Indigenous Peoples to fish is constitutionally protected in Canada (s.35 of the Constitution Act; Government of Canada 1982) and inherent to UNDRIP (Articles 25 and 29.1; United Nations General Assembly 2007), and yet there is ample evidence from this study and from across the continent (from the Mohawk Nation at Akwesasne (juncture of New York, Ontario, and Quebec) to the Ojibwe First Nations of Aamjiwnaang (near Sarnia "Chemical Valley", Ontario) and Asubpeeschoseewagong (Grassy Narrows near Kenora, Ontario) to the Yupik communities of St. Lawrence Island (in the Bering Sea, Alaska); Hoover et al. 2012; Ilyniak 2014) to show that rapidly changing fish populations due a growing array of anthropogenic stressors is undermining and restricting Indigenous fisheries opportunities, fish-based knowledge systems, and the very relationships between fish, people, and place. We are perhaps faced with the reversal of the old adage "give a person a fish and you feed them for a day; teach a person to fish and you feed them for a lifetime." When the fish disappear, what becomes of the associated teachings? Where do salmon-linked cultures, economies, knowledges, languages, laws, well-being, and worldviews go as salmon dwindle—more simply put, what becomes of Salmon People? The right to fish is far more than a right to eat, it is the right to practice, share knowledge, learn language, and a fundamental part of who Indigenous Peoples are and how they identify in Canada and around the world. As we contend with mounting environmental challenges globally, there is a need to create space for the insights, concerns, and knowledges of those that live in relationship with the land and waters, and who have inherent rights to access and steward them, to contribute to an enriched understanding and a more resilient path forward. In protecting the knowledge systems, we are also compelled to protect the environments from which they emerged as well as the keepers who carry them. This work demonstrated one approach to engaging with salmon-based knowledge systems to bring forward Indigenous voices on Indigenous terms, but we are not alone in providing a practical example to inform how others might work towards or support Indigenous resurgence and self-determination. We are part of a larger movement within the scientific community that recognizes Indigenous rights and responsibilities to a healthy environment, and that embraces respectful, relevant, reciprocal, responsible, and relational approaches to research that we encourage other researchers to consider, reflect on, and practice.

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Community involvement

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Author contributions

All authors conceived the ideas for this project and were involved in methodological design. AJR built and maintained research relationships, led interviews with knowledge holders, and handled manuscript preparation. All authors contributed to manuscript drafts and approved the final version for publication.

Data availability statement

The knowledge shared in the context of this research remains with the knowledge holders and communities who partnered in this work. Access to interview materials stored in partnering communities' archives is to be determined by those communities.

Competing interests

Steven Cooke is on the Editorial Board for *FACETS*.

Supplementary material

The following Supplementary Material is available with the article through the journal website at doi:10.1139/facets-2021-0089.

Supplementary Material 1

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