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Understanding barriers, access, and management of marine mixed-stock fisheries in an era of reconciliation: Indigenous-led salmon monitoring in British Columbia

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Abstract

Wild salmon are central to food security, cultural identity, and livelihoods of coastal Indigenous communities. Yet ongoing inequities in governance, declining fish populations, and mixed-stock ocean fisheries may pose challenges for equitable access between Indigenous fishers and other non-Indigenous fishers. We sought to understand current perceptions among Haíłzaqv (Heiltsuk) fishers towards salmon fisheries and their management. We conducted dockside surveys with both Haíłzaqv fishers and sport fishers, and in-depth interviews with Haíłzaqv fishers, community members, and natural resource managers. From these surveys and interviews we quantified satisfaction among both food, social, and ceremonial fishers and visiting recreational fishers with the current salmon fishery and associated social-ecological drivers, and characterized perceptions among Haíłzaqv people of salmon fisheries and management. Second, we synthesized community perceptions of the revitalization of terminal, communally run salmon fisheries within Haíłzaqv territory as a tool for their future salmon management. Finally, we elicited information from Haíłzaqv fishers about the barriers people in their community currently face in accessing salmon fisheries. Our findings suggest that low salmon abundance, increased fishing competition, and high costs associated with participation in marine mixed-stock fisheries currently hinder access and equity for Haíłzaqv fishers. This community-based research can help strengthen local, Indigenous-led management of salmon into the future.

Key words: Indigenous fisheries, salmon monitoring, British Columbia, Heiltsuk First Nation, Indigenous management, Pacific salmon

1. Introduction

The well-being of coastal Indigenous Peoples and other remote communities is inextricably linked to the land, sea, and resources, which have sustained them since time immemorial (Turner et al. 2000; Heiltsuk Tribal Council 2015). In particular, salmon play an important role for coastal Indigenous Peoples of western Canada by providing food, livelihoods, and cultural identity (Levine and Chan

2013; Marushka et al. 2019). Traditional management of salmon (and other coastal resources) has promoted long-term sustainable harvest supporting large human populations and vibrant place-based cultures (Lepofsky and Caldwell 2013; Mathews and Turner 2017; Artelle et al. 2018). Thus, the ongoing and historical relationships between salmon and coastal Indigenous communities have shaped the development of complex societies, social organization, and political ways of life (Deur 1999; Campbell and Butler 2010). Archeological and ethnographic records throughout British Columbia (BC) from the time of European contact support evidence of the deliberate management of salmon fisheries by First Nations people (Harris 2001; Cannon and Yang 2006; White 2011), and highlight the efficacy of these place-based management systems in supporting thriving Indigenous societies (Atlas et al. 2021).

Prior to the colonization of Canada (~150 years ago), Indigenous Peoples along the Pacific coast of North America had long-standing and successful systems of governance and natural resource management based on traditional laws and practices (Campbell and Butler 2010; Turner et al. 2013; Ban et al. 2019). For at least 5000 years, Indigenous fishers caught wild Pacific salmon using traditional methods such as: weirs, fish traps, dip nets, seines, and a broad range of other harvesting technologies (Moss and Erlandson 1998; White 2006; Atlas et al. 2021). These harvesting technologies also served as important management tools. By catching salmon at or near the terminus of their migration, fishers could evaluate run strength and manage harvesting accordingly (Carpenter et al. 2000; Jones 2002; Menzies and Butler 2007). These terminal fisheries were typically managed by chiefs or families who held proprietary rights to specific fishing locations and regulated access and fishing activities to maintain abundance for future generations (White 2006; Atlas et al. 2021). When enough salmon had been harvested, traps or weirs would be opened to allow fish to migrate freely (Harris 2001; White 2006). However, the imposition of colonial laws and fishery management disrupted Indigenous harvest and stewardship when weirs and fish traps were banned in the late-19th century (Newell 1993; Harris 2001; Atlas et al. 2021).

Colonial policies and the commercial salmon fishery that emerged throughout the 19th century triggered transformations in traditional salmon fishing methods and management practices across Canada's west coast. This radical and rapid transformation consolidated control of salmon fisheries within colonial governments, removed the Rights of Indigenous Peoples, limiting the fishing methods and opportunities available to First Nations salmon fishers (Newell 1993; Harris 2001; Eckert et al. 2018a, 2018b). Notably the Canadian federal government seized control of resource access and management authority, banned traditional and locally managed terminal and in-river salmon fisheries, and shifted most harvest into mixed-stock fisheries that capture fish from numerous co-migrating salmon populations during their marine migrations (Atlas et al. 2021). Mixed-stock marine fisheries also broadened the spatial scale of management and extraction, requiring resource managers to quantify and manage fishing impacts on numerous fish populations simultaneously, setting the stage for a host of well-documented management and conservation issues (Pinkerton 1999; Walters et al. 2008; Connors et al. 2019). These management changes, in addition to many other colonial polices of assimilation, reduced access to salmon amongst First Nations, threatening the cultural transmission of stewardship knowledge and undermining food security for coastal Indigenous Peoples. However, despite these unprecedented challenges, many First Nations have continued to assert management over their traditional resources, and continue to do so today (e.g., Jones 2002; Berkes et al. 2000; Carpenter et al. 2000; White 2006, 2011; Lepofsky and Caldwell 2013; Housty et al. 2014; Ban et al. 2017, 2018; Eckert et al. 2018a, 2018b).

As a result of governance changes, commercial fisheries, and other stressors like climate change and the loss of riverine and coastal habitats, Pacific salmon (*Oncorhynchus* spp.) and their fisheries are in serious decline in many regions compared to their historical abundance and catch

(Kellogg 1999; Noakes et al. 2000; Bisson et al. 2009; Rensel et al. 2010; Katz et al. 2013; Gayeski et al. 2018; Walsh et al. 2020). Indeed, the 2019 commercial salmon season saw historical record low landings, across salmon management areas on the Central Coast (Areas 7–8: A–H; DFO 2019), and some did not receive a commercial fishery opening for chum, coho, or pink salmon. Such drastic salmon population declines undermine Indigenous peoples' ability to exercise their inherent and constitutionally protected food, social, and ceremonial (FSC) fishing Rights and to meet community needs (Ban et al. 2017; Bennett et al. 2018; Connors et al. 2019; Marushka et al. 2019; Walters et al. 2019; Walsh et al. 2020). For example, the Haíɫzaqv (Heiltsuk) Nation has recently identified that their community members are frequently unable to obtain enough salmon to meet their inherent Rights and FSC requirements (Central Coast Indigenous Resource Alliance 2018).

In this era of declining salmon populations and fisheries, Indigenous Peoples increasingly express their sovereignty as Rights holders by actively shaping the future of natural resources management in their homelands (e.g., Lepofsky and Caldwell 2013; Simms et al. 2016; Von der Porten et al. 2016; Diggon et al. 2019). Indigenous management systems and knowledge can also improve sustainability and social justice in fisheries management (e.g., Berkes et al. 2000; Frid et al. 2016). However, to envision and inform a new era of salmon fisheries within First Nations communities, there is an opportunity for co-created research that helps identify perceptions and needs among fishers, identifies barriers to First Nations access, and illuminates what factors influence fishery dynamics across FSC and recreational salmon fisheries. For example, First Nations may participate in current mixed-stock fishing methods—including trolling and gillnetting in marine waters—that require investments in boats, gas, and gear. Additionally, there are emerging initiatives that are revitalizing community participation in traditional fishing practices such as terminal weirs (fishing fences) that are communally run (e.g., Atlas et al. 2017).

This project was initiated by the Haíɫzaqv Nation, through the Heiltsuk Integrated Resource Management Department (HIRMD). Our team, comprised of Haíɫzaqv resource managers and academics from the University of Victoria, Simon Fraser University, and the Wild Salmon Center, co-created a study to understand contemporary Haíɫzaqv fisheries for salmon. Informed involvement of all project partners at all stages of the research (objective and study design, data collection, data analysis, and data verification/dissemination) took place. First, we sought to understand current perceptions among Haíɫzaqv fishers towards salmon fisheries and their management. We achieved this by quantifying both FSC (Haíɫzaqv or Indigenous status fisher who fish for FSC purposes) and sport fisher (recreational license holding, non-status fisher) satisfaction with the current salmon fishery and associated social-ecological drivers, and characterizing perceptions among Haíɫzaqv people of salmon fisheries and management. Second, we synthesized community perceptions of the revitalization of terminal, communally run salmon fisheries within Haíɫzaqv territory. Finally, we identified barriers Haíɫzaqv fishers currently face with regards to FSC salmon fisheries. This study was carried out in the context of a community-based salmon dockside-monitoring program (volunteer dockside surveys with Haíɫzaqv FSC fishers and sports fishers) and in-depth interviews. This dockside monitoring program remains as the foundation of ongoing catch monitoring and sampling of salmon harvested within Haíɫzaqv territory that is producing estimates of sport and FSC fishing effort, and catch of Chinook, sockeye, and coho salmon. These raw data are owned and managed by HIRMD and are not included in this paper.

2. Study area

The territory of the Haíɫzaqv Nation encompasses 35 553 km^2, geographically situated within what is now known as the Central Coast region of BC. The Central Coast is part of the largest remaining expanse of coastal temperate rainforest in the world (Paquet et al. 2004). Bella Bella is a remote Haíɫzaqv community located on Campbell Island with ~1500 year-round inhabitants. There are over

2500 registered Haíłzaqv members, making it one of the largest First Nations on the Central Coast of BC (Housty et al. 2014; Heiltsuk Tribal Council 2015).

The Haíłzaqv Nation's terrestrial and marine natural resources are managed by the Heiltsuk Integrated Resource Management Department. HIRMD was created in 2010 as a way for the Haíłzaqv Nation to take an integrated approach to stewardship and management of land, water, and cultural resources throughout their territory, and the department now provides technical advice to the Haíłzaqv tribal government, forestry initiatives, and assists in managing all natural resources within Haíłzaqv Territory. HIRMD is governed by an elected board of 5 directors, including one chairperson (Heiltsuk Integrated Resource Management Department 2019).

3. Methods

To achieve the research objectives of this project, we used a mixed-methods sampling approach (Bernard 2006). We collected qualitative and quantitative data during informed and voluntary in-depth structured interviews and short dockside surveys (16 June to 13 September 2019, in Bella Bella, BC; UVic ethics protocol 19-0186-02). To identify barriers for Haíłzaqv community members to access FSC salmon, and to improve current knowledge of salmon catch in sport and FSC fisheries, we conducted dockside surveys at the two public docks in Bella Bella using convenience-sampling approaches (Wiber et al. 2004). To quantify current perceptions towards salmon fisheries and their management among the Haíłzaqv community, and to evaluate ideas and perceptions related to the revival of traditional terminal and in-river salmon fisheries, we conducted structured in-depth interviews with Haíłzaqv salmon fishers throughout the 2019 summer season.

3.1. Dockside surveys

The dockside surveys encompassed voluntary and convenience sampling techniques (Ryan and Bernard 2003; Wiber et al. 2004; Bernard 2006), with the aim of targeting participants that included segments of the Haíłzaqv First Nation population participating in the FSC salmon fishery within Haíłzaqv territory. There was no predetermined sample size of survey participants, as the surveys intended to create the most comprehensive snapshot of the 2019 FSC salmon fishing season in Bella Bella. Jointly, one HIRMD staff member and one researcher from the University of Victoria (JS and JW) spent a total of 67 days conducting dockside surveys.

Overall, we conducted 256 dockside surveys with volunteer fishers in Bella Bella. Of these surveys, 191 were either Haíłzaqv FSC or visiting sport fishers, and the remaining 65 surveys were from commercial fishers (any fisher who holds a valid commercial fishing license) delivering their catch to the Bella Bella fish plant. Since our study focused on FSC and sport fisheries, dockside survey data from commercial fishers were removed from the data set for the purpose of the analyses presented here. The survey encompassed 10 broad to narrow questions about a fisher's trip, with salmon being the target species (see **Supplementary Material 1**). Key qualitative information collected from the surveys included: what gear type was used, the fishers' personal perceptions of the success of their fishing trip—with reported trip success categorized as good, okay, and bad—and the quality for fishing during the 2019 season in general. Key quantitative data collected during dockside surveys included the number of salmon of each species caught, how much fuel was used, what marine areas were visited, the number of other FSC and sport fishing boats (competition) in the area fished, and the number of hours fished (effort). All fishers who conducted volunteer dockside surveys provided free and informed verbal consent.

The main gear types recorded included the use of "trolling with rods" and "trolling with snubbers" for salmon. When trolling with rods, fishers employ hooks and lines that are suspended from fishing poles extending from the rear of the vessel. Fishers alter the type and arrangement of lures used and control the depth that lures are suspended in the water column using a downrigger, allowing various fish species to be targeted (Nelson and Turris 2004). Trolling with snubbers includes the use of short lines that are attached directly to the downrigger cable at regular intervals. Unlike trolling with rods where there is only one hook attached to each individual line, there are multiple hooks attached to each line called "snubbers". The later method is very similar to the techniques employed by commercial salmon trollers, albeit at a smaller scale. At present, only Indigenous salmon fishers with FSC Rights can utilize snubbers while trolling for salmon; sports fishers are limited to two rods per angler.

We analyzed the answers from our dockside surveys by thematically categorizing responses in Excel, and running basic statistics in R (R Core Team 2020). We determined the proportion of survey respondents who mentioned costs and barriers to accessing FSC salmon, and improved current knowledge of FSC salmon catch, run timing, and spatial distribution within Haíłzaqv territory. From these dockside survey data we also estimated the average fishing trip duration, distance travelled (**Fig. S1**), fuel costs, and the number of salmon caught for FSC fishers both trolling with rods and trolling with snubbers. We also estimated catch per trip for sports fishers trolling with rods. To estimate the cost per salmon for the 2019 season we divided number of salmon caught during the specific fishing trip by the fuel costs as estimated by participants. Notably, our cost estimates did not include the initial costs of purchasing or maintaining a boat, and these values should be viewed strictly as fuel-related costs. Catch per unit effort (CPUE) was estimated using the number of salmon caught per hour for a given fishing trip.

Cost per fish estimates were assessed separately for each gear type utilized and for Haíłzaqv FSC and visiting sport fishers. A total of 70 out of 191 dockside survey entries from both FSC and sport fishers did not report fuel costs, suggesting that either people are unsure of how much they are spending on fuel or were unwilling to share this information. The estimated cost per fish was not biased by the lack of responses among some fishers, since there was not statistical evidence for a difference in average catch and trip distance among fishers who did and did not report their fuel costs. Finally, specific salmon species catch rates and fishing locations are not presented within this paper due to information sensitivity. Many First Nations, including the Haíłzaqv, have experienced negative outcomes in the past when sharing sensitive raw data with colonial government agencies or other non-Indigenous groups. As such, some First Nations may be hesitant to share sensitive data out of fear that it could be used against them, i.e., reduced licenses or fisheries catch allocations, misused or taken out of context, or due to a lack of trust.

3.2. Statistical analyses

3.2.1. Model

We used categorical regression to analyse trip- and season-level characteristics associated with fisher's satisfaction (Train 2009). Categorical regression helps to model discrete outcomes (e.g., satisfaction categories like "good" or "bad" fishing trips) by estimating the effect(s) from one or more covariates on the odds of a particular category being chosen relative to some baseline category (i.e., odds-ratio). Specifically, we used an integrated multinomial-logit model consistent with utility theory to assess the discrete choices of fisher's trip and season-level satisfaction from the dockside survey data (Train 2009; Wilson et al. 2020). Utility theory assumes fisher's discrete choices in response to the dockside surveys arise from the utility (e.g., well-being or satisfaction) realized on their trip or season. This utility arises from interactions between fisher preferences for trip (or season) characteristics and the provisioning of those characteristics during the trip (or season). Because neither utility nor the satisfaction process were directly observable, we described utility via a probabilistic model assuming fisher satisfaction was revealed through their choices to the dockside interviews.

In our satisfaction model, utility (u) for a fisher on trip (t) choosing satisfaction category (j) was composed of observable deterministic utility (v) and random unobservable utility (ϵ) such that:

$$u_{jt} = v_{jt} + \epsilon_{jt} \tag{1}$$

Deterministic utility was then composed of characteristics hypothesized to influence fisher satisfaction:

$$v_{jt} = \beta_j x_t \tag{2}$$

where β was a vector of coefficients for the set of trip characteristics x at the time of the dockside survey. Assuming errors ϵ_{jt} were independent, the probability of a fisher satisfaction choices j from a set of categorical responses J becomes the conditional multinomial-logit:

$$P_{jt} = \frac{e^{v_{jt}}}{\sum_j^J e^{v_{jt}}} \tag{3}$$

Thus, fisher's revealed satisfaction y_t followed the categorical distribution:

$$y_t \sim \text{categorical}(P_{jt}) \tag{4}$$

where y_t choices were either "good", "okay", or "bad" depending on fisher's answers to the dockside interviews (such that $J = 3$). We used a similar model to also evaluate fisher's satisfaction of the whole fishing season (up to the time of the survey) where fisher choices were either "good", "okay", or "slow". The integrated choice model thus estimated both trip and season-level satisfaction on a joint posterior distribution.

We considered the same set of characteristics for both satisfaction models including: (*i*) travel distance for fishers to their chosen site on trip t (**Fig. S1**), (*ii*) status as an FSC or non-FSC fisher, (*iii*) number of coho salmon caught, (*iv*) number of Chinook salmon caught, (*v*) weekend or weekday trip, (*vi*) number of FSC boats observed during the trip, (*vii*) number of non-FSC boats observed during the trip, and (*viii*) the week of the season (preliminary results suggested this effect closely followed a second-order polynomial). In both satisfaction models, the "good" categorical choice was set as the baseline by fixing their respective β_j coefficients to zero, which allowed the choice model to be identifiable. Exponentiating the estimated β_j coefficients allows the coefficients to be interpreted as the relationship between a per-unit change in the covariate x and the odds that fishers responded to the interview with choice j (e.g., "bad" trip) compared to a baseline "good" trip. For example, a negative β_j for the number of coho salmon caught would imply a decrease in the odds of fishers reporting a "bad" fishing trip, which would suggest that catching a coho salmon increased fisher satisfaction. All characteristics had variance inflation factors $\leq$2.0 suggesting multicollinearity among predictors was not problematic (Zuur et al. 2010).

3.2.2. Model selection and diagnostics

We estimated the integrated discrete choice models on a joint Bayesian posterior in Stan with 6 Markov Chain Monte Carlo (MCMC) chains using the "rstan" pack in R version 4.0.0 (Carpenter et al. 2017; R Core Team 2020; Stan Development Team 2020). Each chain took 2000 posterior samples with a warmup period of 50% for 4000 total samples. Parameter values for the satisfaction coefficients β_j started at 0 for each chain. We used several complementary methods to diagnose model suitability. MCMC chain convergence was inspected visually on trace plots. In addition, we ensured effective sample sizes were >1000 for each parameter (Gelman et al. 2013). We used the Gelman–Rubin diagnostic test on each parameter to determine whether independent chains converged to a common posterior mode, with potential scale reduction factors <1.1 suggesting convergence. We then used graphical posterior predictive checks to test for model misspecification by comparing the predictive distribution of satisfaction choices (simulated from the posterior sample for each fisher's trips) to observed choices.

We evaluated the main characteristics associated with fisher's trip satisfaction by comparing 10 candidate models using approximate leave-one-out cross-validation (LOO; Vehtari et al. 2017). LOO measures a model's expected predictive accuracy through point-wise comparisons of the log-likelihood across all posterior samples. We used the package "loo" in R to measure the expected log predictive density for new data (ELPD) and the standard error σ_m of the difference in ELPD for a given model to the "best" predictive model. We then compared candidate models such that models with the highest ELPD were the "best-fit" model and models with an ELPD differentiated by >2 σ_m were considered substantially different.

3.3. In-depth interviews

In addition to dockside surveys, we used in-depth interviews to (*i*) understand and quantify perceptions among the community towards current salmon fisheries and their management and (*ii*) evaluate ideas and perceptions related to the revival of traditional terminal and in-river fisheries for future Haíłzaqv salmon fisheries and stewardship. We conducted voluntary in-depth interviews with Haíłzaqv participants towards the end of the 2019 salmon fishing season, in late August and early September. Conducting interviews during this time built upon the relationships and trust previously established among us (JS and JW), Bella Bella community members, and Haíłzaqv FSC fishers. In total we performed 18 in-depth interviews.

In-depth interview participant recruitment focused on Haíłzaqv residents aged 18+ who fish for salmon for FSC purposes or have some knowledge or background in Pacific salmon fishing, past or present. We attempted to interview individuals who represented a range of ages to capture a variety of cultural knowledge and values related to FSC salmon fisheries. All interviews took place at participants' chosen location in Bella Bella and were voice recorded. Each participant provided informed and written consent prior to conducting interviews (UVic ethics protocol 19-0186-02). During the interviews, we asked 24 predetermined questions, ranging from participants' histories in salmon fishing to their perceptions of current management and their thoughts towards the future (**Supplementary Material 1**). We designed interview questions such that they could be answered by assigning scores (−4 to +4) depending upon if they agreed (+4) with a statement or not (−4). Additionally, in-depth interview questions were co-developed by researchers from the University of Victoria (JS, NB), Simon Fraser University (WA), and HIRMD (JW, WH).

Interviews encompassed three sub-sections. First, we posed questions about participants' personal insights and experiences related to salmon fisheries. The second section focused on management of salmon fisheries and barriers the community faces to access salmon, and asked questions regarding participant's thoughts about how salmon fisheries currently support the community of Bella Bella's livelihoods and employment. This section also touched upon ways in which Haíłzaqv members could become more involved in salmon fishing. The last section focused on participant's perceptions of salmon fisheries within the territory in the future, and assessed their support for the revitalization of communal, terminal fisheries as a tool for FSC salmon harvest and stewardship of salmon. Overall, the interviews provided an opportunity for participants to voice their concerns and hopes towards the future.

Analyzing the transcribed interviews involved several tasks: (*i*) discovering themes and subthemes, (*ii*) summarizing themes to a manageable few, (*iii*) building hierarchies of themes, and (*iv*) linking themes to project objectives (Ryan and Bernard 2003). The main themes chosen from the transcriptions stemmed from both the collected data (an inductive approach) and from previous theoretical understandings (a priori approach) (Ryan and Bernard 2003). In total, six overarching themes were generated through open coding of the interview transcripts, with 30 additional codes compiled. Many of the codes incorporated qualitative descriptions and could be representative of numerous themes.

4. Results

4.1. Dockside surveys: identified costs and barriers to FSC salmon access

During the 2019 salmon-fishing season, a total of 191 dockside surveys were conducted with Haíłzaqv FSC fishers or sports fishers (non-Indigenous). Overall, 103 individuals were identified. A total of 33 survey participants identified as "visitors" to the territory and 70 participants self-identified as Haíłzaqv Nation members. The average age of survey participants was approximately 46 years old. Throughout the dockside survey data collection process, Haíłzaqv FSC fishers and sports fishers commonly expressed their frustrations towards the 2019 fishing season and the ongoing declines in local salmon populations. The common barriers identified by FSC fishers through dockside surveys to access salmon were grouped into themes: (*i*) lack of salmon abundance, 61.1%; (*ii*) competition with other fishing sectors—sports fishers, 61.1% and commercial fishers, 77.8%; (*iii*) climate change, 27.8%; (*iv*) expensive gas prices, 66.7%; and (*v*) high costs associated with owning and maintaining a boat, 38.9%.

> "My dad used to go out fishing and used to bring salmon in for the whole community. That kind of disappeared in the last 20 years… Gas is expensive. That's another reason why a lot of people don't go out because it's expensive."—Haíłzaqv Guardian Watchman and FSC Fisher.

Fishers in Bella Bella primarily employed trolling methods to catch salmon. Throughout the season of 2019, the main gear types recorded during dockside surveys of FSC fishers was "trolling with rods" and "trolling with snubbers". On average, FSC fishers who reported trolling with rods caught 4.6 salmon per trip, while FSC fishers utilizing snubbers caught an average of 5.1 salmon per trip. Gillnets were the least common gear type used by FSC salmon fishers in the 2019 season (used in only 15 of 191 trips with survey data). On average, gillnet fishers were older (mean = 55.6 years) than other surveyed fishers, and these fishers were more likely to have had past experience as commercial gillnet fishers. Gillnets are generally used to target sockeye, chum, and pink species that are less likely to bite trolling gears, although gillnets are nonselective and also capture coho, Chinook, and occasionally steelhead. While sockeye and chum returns in 2019 were record low in many rivers near Bella Bella (DFO 2019), gillnets are highly effective fishing gear, and catches were consistently higher than troll methods. FSC gillnet fishers reported catching an average of 55 salmon per outing. Due to the low number of reported FSC gillnet trips, differences in efficiency, and target species between gillnet and trolling gear, we focused the remainder of our analysis on the dynamics of the FSC and sport troll fishery.

Numerous factors influenced the trip satisfaction reported by salmon fishers, and Haíłzaqv fishers had different perceptions of trip success than sport fishers. Trip success appeared to vary by week, was lower on weekends and among Haíłzaqv FSC fishers, and was influenced by number of salmon caught (**Table S1**). In total, all salmon fishers surveyed reported "good" trip satisfaction in ~81% of 152 responses, "okay" satisfaction in ~8%, and "bad" satisfaction in ~11%. The top three models for trip satisfaction (according to LOO predictive accuracy) included whether a fisher identified as a Haíłzaqv

FSC fisher (FSC status), salmon catches, and the "best-fit" model also included week and weekend effects. However, high variability in survey responses suggested some predictive weight for both the null model (i.e., no differences) and an alternate model that included additional effects of travel distance and crowding from sport fishers on trip satisfaction (Table S1). In general, there was little evidence that either CPUE or crowding from FSC fishers affected overall trip satisfaction. However, there is evidence suggesting that increased crowding from sports fishers (non-FSC) had a moderate effect on trip satisfaction by all fishers.

Not surprisingly, catching salmon strongly increased fishers' trip satisfaction (Fig. S2a). Overall, the odds of fishers experiencing a "bad" fishing trip decreased by 88% (80% credible intervals (CI): 78–96) and 48% (80% CI: 5–81) if they caught at least one coho or Chinook salmon, respectively. Interestingly, salmon catches had an inconsistent effect on fisher's reporting only an "okay" trip, with the odds of an "okay" trip increasing by 33% (80% CI: −61 to 156) and −5% (80% CI: −67 to 79) if they caught coho or Chinook salmon, respectively. Trip satisfaction and catch rates appeared to vary between Haíłzaqv FSC and sport fishers. For example, Haíłzaqv FSC fishers were nine-times more likely to report an "okay" trip compared to sport fishers (Fig. S2a), but both fisher groups were similar in their probability of experiencing "bad" trip satisfaction. Among FSC fishers, 79% rated their trip "good" and these individuals caught an average of 4.65 salmon during their outing. For sports fishers, 85.7% rated their trip a success with an average of 3.2 salmon caught. Comparatively, 11.1% of FSC fishers and 11.4% of sports fishers stated their trip was "bad" or unsatisfying.

Fisher satisfaction of their individual trips and the whole 2019 fishing season appeared to change across the season. Approximately 40% of all fishers reported the season was "good" overall, 24% reported the season was "okay", and 33% of fishers surveyed reported that the 2019 season was "slow". Season-wide perceptions were shaped by multiple factors including weekday fishing, salmon catches, and the week of the season (Fig. S2b). Thus, satisfaction with trip-level experiences, like catching salmon, also appeared to shape fishers' statements regarding their overall perceptions from the season. Season satisfaction was similar for both FSC and sport fishers. Overall, both trip and season satisfaction varied across the season following a U-shaped pattern such that there were lower odds of fishers' experiencing a "good" trip or season in the middle weeks of the season (Fig. S3). Additionally, fishers were less likely to experience a "bad" fishing trip on weekdays (all else equal) with the probability of a "bad" trip on a weekday of 0.01 (80% CI: 0.001–0.06) and the probability of a "slow" season of 0.10 (80% CI: 0.03–0.27). However, fishers were more discerning when fishing on the weekend with the odds of "bad" and "okay" trip increased by 489% (80% CI: −47 to 173) and 178% (80% CI: −1 to 411), respectively, compared to weekday fishing. However, whether or not fishers were surveyed on a weekend appeared unassociated with their overall assessment of the season. Thus, the probability of fishers stating the season was slow was the same on weekend days (i.e., Saturday and Sunday) vs. week days (i.e., Monday–Friday).

4.1.2. Current FSC salmon fisheries within Haíłzaqv Territory

The main targeted salmon species for FSC purposes identified in the 2019 dockside surveys were Chinook and coho; however, sockeye were also frequently targeted, particularly by fishers using gill-nets. Over the course of the fishing season, 24 of 189 documented FSC fishing trips were unsuccessful and caught 0 salmon during their outing. On average, FSC fishers reported catching 3.7 salmon per trip and visitors reported 3.2 salmon per trip. Average fishing effort for FSC fisher trips trolling throughout Haíłzaqv territory was 6.1 h, with an average round-trip distance of 42.2 km (Fig. S1). The average FSC gillnet trip was 7 h, with an average of 35.5 km round-trip. Comparatively, the average sport/visitor trolling trip was 4.6 h, and 44.2 km.

Fuel cost per salmon harvested varied dramatically between fisher trips and depended upon several factors. Gear type played an important role in driving the overall costs of each salmon caught in the FSC fishery, as did fuel prices. During our research, tax-exempt marine fuel prices in Bella Bella were $1.66 CAD per liter for Haíłzaqv members with a valid status card, and $2.09 CAD per liter for others (i.e., non-status fishers). In total, fishers reported their fuel cost for 125 of 203 FSC and sport fishing outings. These results reveal that trolling methods are more expensive per salmon compared to gillnetting. For example, the average cost of a troll-caught salmon for an FSC fisher was $17.74 CAD. Fishers who trolled with snubbers averaged $15.93 CAD per salmon, while fishing with rods was slightly more expensive per fish ($19.10 CAD). Fuel costs reported for salmon caught by FSC fishers using gillnets was $13.19 CAD per salmon. Sports fishers who reported their fuel costs spent an average of $29.22 CAD per salmon.

4.2. In-depth interviews: current perceptions towards FSC salmon fishing and management

A total of 18 Haíłzaqv research participants took part in an in-depth interview. The interviewees encompassed a wide range of professions and backgrounds, including: Haíłzaqv Tribal Council members, HIRMD employees, retired commercial fishers, FSC fishers, carvers, Elders, Guardian Watchman, Coast Guard employees, sport fishing lodge guides, and health care professionals. The age range varied from ~18 to 62 years old, and 14 of the 18 interview participants self-identified as male.

We found that 55% of the interviewed participants felt that current salmon management is not working well for the community of Bella Bella and themselves personally. Most (10/18) interview participants answered the question "is current management of salmon working well for you personally" with a score of −4 (disagreed greatly and (or) it is a large issue). We asked participants to elaborate on their personal perceptions towards management of Pacific salmon, and in general many people highlighted failures by Fisheries and Oceans Canada (DFO) as the main cause of "mismanagement". Participants identified that "creek robbers" (the act of an FSC fisher fishing at the mouth of a river, inside of boundary markers intended to reduce harvest of staging salmon) were further causes of salmon mismanagement. Additionally, the lack of continued river and stream monitoring by HIRMD and DFO, high staff turnover rates within resource management positions, high harvest rates and lax monitoring of sports fisheries, historical mismanagement of the commercial salmon fishery, and low salmon abundance exacerbated by continued commercial fishery openings were also highlighted concerns of mismanagement by participants (Fig. S4).

> "Current salmon management—it's not working, it hasn't worked in decades and now they're going to put a Band-Aid on a gunshot wound. How many homes got sockeye this year? When I was a kid we got what we needed, majority of the years, and now were scrounging for sockeye and that's all to mismanagement."—Haíłzaqv FSC Fisher and Sports Fishing Guide.

In particular, many fishers raised concerns over the ongoing decline of sockeye salmon, and the inability of Haíłzaqv community members to access this culturally important species. Sockeye are the preferred food fish amongst most Haíłzaqv FSC fishers, and the majority of research participants stated that they wish to primarily consume sockeye, or consider sockeye a superior salmon species to other species like Chinook or coho.

> "I am really stubborn and picky, I only like to eat sockeye. All the rest are a little bit down the totem pole. I prefer sockeye… So I'm really, really upset because it seems like there is no sockeye. And if there are, they are way out. I don't like going way, way out there."—Haíłzaqv FSC Fisher.

4.2.1. Current perceptions of salmon fisheries and moving forward: Haíłzaqv governance and stewardship (communal, terminal fisheries)

In-depth interview participants often shared their worries for the future. One participant identified that they feel like [the Haíłzaqv] currently have no control over their traditional resources, especially salmon. In addition, the majority of research participants (83.3%) wished to see sports fisheries managed more conservatively within the territory as their perceptions were: (*i*) current salmon abundance is insufficient for the community to meet their needs; (*ii*) there are conflicts between visitors and locals, with local FSC fishers getting pushed out of prime fishing grounds; and (*iii*) Haíłzaqv members view visitors coming in, exploiting Haíłzaqv territory, and then leaving—drawing direct parallels to the past history of extractive commercial fisheries that eventually collapsed (i.e., Pacific Herring, Abalone, Pacific salmon) (Price et al. 2008; Gauvreau et al. 2017; Lee et al. 2019). Participants stated that they also have grievances with current management and operations of commercial fisheries. In recent fishing seasons, commercial fishery closures have limited opportunities throughout most of BC due to low salmon returns. However, the gillnet fishery on the Central Coast (Area 8) that occurs in both Haíłzaqv and Nuxalk Nation territory, has remained open, resulting in high concentration of fishing effort during commercial openings.

Among in-depth interview participants, 94.4% stated that they have witnessed great change in employment and livelihood opportunities from commercial salmon fishing. Almost all participants (89%) also stated that the commercial salmon fishery is no longer a viable career option for Haíłzaqv members, as commercial opportunities and openings continue to decline throughout BC.

> "Oh, it's completely changed (commercial fishing). It's almost down to nothing now, you can't even get any fishing time anymore compared to when I was a gillnetter. I fished for four years, and in that time, I was in the breaking even stage of fishing. After that it was just too much, it's not worth it. For the amount of money you spend on your nets and your fuel, groceries. People just seem to go backwards, you have to pay for the license, everything… You look down at Martins dock and see all those derelict boats down there, just sitting there… people just don't want to go fishing anymore. It's declined a lot. We used to be one of the biggest fishing communities on the coast."—Haíłzaqv FSC Fisher and Former Commercial Fisher.

The act of creek robbing within Haíłzaqv territory was also identified as a barrier to sustainably fish for salmon populations, and many interview participants suggested that ongoing creek robbing is one factor limiting access to salmon, especially sockeye. Creek robbing is the act of fishing (generally using a gillnet) inside of fishing boundary markers at a river mouth, and is a concern to Haíłzaqv members because of the potential population-level impacts of harvesting large numbers of staging salmon before they are able to enter freshwater. While this type of fishing is a legally protected Aboriginal Right, it is generally viewed negatively by the community, since a fisher may take a large portion of salmon that have yet to enter their spawning grounds, thereby jeopardizing the future of that run. Interview participants suggested that the challenge posed by creek robbing stems from a number of historical factors including: the displacement of local management and governance authority, the impact of residential schools on the transmission of cultural knowledge about salmon harvesting practices, the general lack of monitoring and enforcement, as well as a lack of economic opportunity and food insecurity among members of the community. In total, 83.4% of interview participants agreed that creek robbing is a large issue for salmon populations, and 16.6% participants stated they were unsure, or held no opinion on the matter.

> "Definitely creek robbing is a problem. I've been super vocal over the past ten years, even before… Something needs to happen to these people that continue to do it and it's the same ones who do it. These people, they just don't care. And again, it comes back to the effects of

> residential school, because those were teachings that were lost."—Haíłzaqv Tribal Council Member.

Participants suggested that re-creating communally run terminal fisheries would provide a path forward for improving salmon fisheries management within Haíłzaqv territory. We found near universal support and openness amongst (94.4%) research participants towards the revival of communal and in-river fisheries for future salmon stewardship and harvest. Of those interested, participants agreed that a communally run fish weir could provide an opportunity to increase access to salmon, uplift Haíłzaqv traditional laws/governance, and increase equity within the salmon fishery for community members. Participants are also optimistic that the continuation and revival of community and culturally based education systems—which focus on teaching youth cultural values and practices related to salmon fishing and stewardship—can be a positive way forward despite the continued effects of colonization, and uncertainties around the effects of shifting climatic and marine conditions.

> "I would be interested in becoming involved in that and getting back to that (traditional, in-river fisheries). I think it would increase Haíłzaqv jurisdiction in management of our resources, if we established that. And I think it would also connect us back to certain parts of our territory a bit more than we are right now and I think of course the overall benefit is bringing access back to the community and the food source back to the community as its definitely the number one goal. I would definitely be interested in being involved."—HIRMD Employee and Haíłzaqv FSC Fisher.

Lastly, many interviewed participants expressed the hope that fisheries management and governance authority will be returned to the Haíłzaqv Nation, as 94.4% of respondents agreed that Indigenous governance structures and Haíłzaqv laws should guide future management of salmon fisheries operating within Haíłzaqv territory.

> "We as Haíłzaqv people, that's our staple, salmon. It's our main food, and the future of our salmon is declining, it's a bit of a risk to even go out there and fish. But if we tell the fisheries to go away, and look after it ourselves we will be fine. We know how much to take and not to take, its embedded in most people here. For me, if we looked after our own fisheries and resources here everything would be fine. We don't need the government to tell us what to do, they own everything else: They own our car, our house, and our licenses. It's the only way we are going to survive, so I think we should look after our own resources, that's the only way it's going to work."—Haíłzaqv FSC Fisher and Retired Commercial Fisher.

5. Discussion

Wild Pacific salmon continue to hold significant cultural, economic, and social value for coastal Indigenous People throughout North America (Garibaldi and Turner 2004; Gerwing and McDaniels 2006; Page 2007). However, recent declines in Pacific salmon abundance pose numerous challenges for the food security of First Nation communities in BC (Young 1999; Bennett et al. 2018; Marushka et al. 2019). Additionally, Indigenous fishers face intensifying barriers to accessing salmon within their traditional territories (Pinkerton et al. 2014). Our research suggests that the high cost of marine fuel, trolling fishing gear costs, boat maintenance fees, increased fishing pressure from sports fisheries, and ongoing commercial and sports fisheries create barriers for Haíłzaqv access to sustainable wild salmon fisheries. For example, our dockside surveys indicated relatively high fuel costs among Haíłzaqv fishers using trolling gear ($17.74 CAD per salmon), not including the cost of purchasing, equipping, and maintaining a boat. Additionally, 66.7% of participants identified high gas prices as a barrier to accessing salmon, and 61.1% stated that the sports fishery poses challenges for Haíłzaqv access to salmon.

Haíłzaqv perceptions of salmon and similar studies in other First Nation communities (White 2006; Thompson et al. 2007; Carothers et al. 2012) demonstrate that Indigenous FSC fishers are increasingly targeting Chinook and coho rather than chum, pink, and sockeye that formerly dominated FSC catch. This reflects both a cultural shift, and also a response to declines in salmon productivity, as chum and sockeye have seen dramatic decreases in their abundance in recent decades (Peterman and Dorner 2012; Litzow et al. 2019). These species declines have been be attributed to the effects of changing ocean temperatures on Pacific salmon productivity (Litzow et al. 2019) and competition between wild salmon originating from BC and large numbers of hatchery-origin salmon that are released from Alaskan, Japanese, and Russian hatcheries (Connors et al. 2020). Importantly, both of these factors are beyond the control of Haíłzaqv Nation and other Indigenous communities, creating inequities in the distribution of benefits and impacts under current multinational salmon management regimes (Vierros et al. 2020).

A direct line can be drawn between the loss of traditional management and governance systems and current conflicts over salmon management (Pinkerton 1994, 1999; Turner et al. 2013). Historically, families or clans held hereditary Rights to particular streams or rivers and regulated access accordingly (Trosper 2002). This governance system enabled placed-based in-season salmon management and selective fishing at each stream or river. Colonization disrupted these systems of local governance and consolidated Haíłzaqv people onto a single reserve in Bella Bella, creating a vacuum in local governance authority, and the conditions under which creek robbing has become a threat to wild Pacific salmon populations. Colonization and the disruption of Indigenous governance systems not only created conditions for creek robbing, but also a suite of long-lasting and damaging activities impacting Pacific salmon populations (stream habitat destruction, intensive mixed-stock fisheries, loss of stewardship knowledge, etc.) (Ricker and Smith 1975; Higgs 1982; Newell 1993; Morishima and Henry 2000). Indeed, many of the challenges and barriers coastal Indigenous Nations currently face (to accessing salmon) can be attributed to colonization in some form. Indigenous communities (like Bella Bella) are well positioned to conduct monitoring and enforcement of fisheries management objectives (Artelle et al. 2019), and efforts to empower Indigenous-led resource management—i.e., where the Indigenous Nations have decision-making authority—can foster more locally legitimate management by empowering local and traditional ecological knowledge (Pinkerton and John 2008; Gauvreau et al. 2017). Preliminary data and strong community participation in the community-based salmon dockside monitoring program (dockside surveys) in Bella Bella demonstrates the power of community-based monitoring to inform fishery management. Importantly, community-based monitoring initiatives and Indigenous-led programs are providing foundational information on Indigenous fishers perceptions, needs, and goals for salmon fisheries management and supporting outcomes that are beneficial to both wild salmon and First Nations in BC (Ban et al. 2018; Eckert et al. 2018a; English et al. 2018).

Our in-depth interviews revealed that major knowledge gaps remain in stock assessment and fishery monitoring, as well as in the understandings of Indigenous community perceptions of FSC fisheries and how to manage fisheries to meet community needs. These knowledge gaps currently hinder efforts to manage and restore salmon-centered social-ecological systems. For example, the Pacific Salmon Foundation synthesized escapement data for all 79 conservation units of salmon on the Central Coast and found that only 33 had adequate data to evaluate their population status (Connors et al. 2018). Estimates of harvest rates in sport, commercial, and FSC fisheries are also highly uncertain, and reflect numerous untested assumptions (English et al. 2018). Thus Indigenous and local knowledge can contribute to effective and informed fishery management. Community monitoring initiatives like our dockside survey have the potential to dramatically improve baseline understanding of current FSC and recreational salmon fisheries and whether these fisheries are meeting the needs and objectives of Indigenous and local people.

Identifying barriers to access and whether individual needs are met can reveal important information with policy implications. Similar studies have sought to identify whether fishery-induced declines in Dungeness crabs have undermined the ability of Indigenous fishers to meet their FSC needs (Frid et al. 2016; Ban et al. 2017). This research and other works like it provides an avenue for evaluating the efficacy of current management and allocation regimes, and their impacts on the constitutionally protected harvesting Rights of Indigenous people (Pinkerton and John 2008; Salomon et al. 2015; Jones et al. 2017). From our statistical analysis, Haíłzaqv fishers have different (and lower) satisfaction rates than fishers who are not Haíłzaqv. Sports fishers (non-FSC) were generally more satisfied with the current state of salmon fishing and the 2019 season within Haíłzaqv territory, than Haíłzaqv FSC fishers (**Figs. S2a** and **S2b**). This is a meaningful finding, as non-Indigenous voices are oftentimes more privileged in salmon management. We believe that understanding Haíłzaqv perceptions and fishing satisfactions matter most when improving salmon management strategies within Haíłzaqv territory moving forward.

One promising avenue for transformation with widespread support among Haíłzaqv Nation members we interviewed, is the revival of traditional, communally managed in-river fisheries for salmon. The reinvigoration of these traditional technologies (fish weirs and stone traps) could drastically reduce costs associated with participation in current mixed-stock fisheries, increasing access to salmon for food security, while contributing to the rebuilding and re-assertion of Indigenous governance (Atlas et al. 2021). The revitalization of these technologies could also provide numerous cultural, social, and economic benefits, while improving the data that underpin sustainable harvest management methods (e.g., Atlas et al. 2017). For example, the creation of a communal fish weir in the Koeye River watershed, BC, has provided scientific understandings as well as created an outlet for healing and intergenerational knowledge transfer (Atlas et al. 2017; Bennett et al. 2018).

Maintaining and protecting traditional foods systems and stewardship over resources is a key pillar of food security and sovereignty for Indigenous communities throughout Canada (Lowitt et al. 2018). Empowering Indigenous governance and reviving traditional management systems are effective avenues to greater environmental, social, and economic sustainability (e.g., Jones 2002; Carpenter et al. 2000; White 2006, 2011; Augustine and Dearden 2014; Ban et al. 2017). Thus, official recognition by Canadian federal governments of inherent Indigenous management Rights is necessary moving forward, and the reassertion of these Rights can lead to improved social-ecological outcomes for Indigenous communities and culturally important fisheries resources (Eckert et al. 2018a, 2018b; Long and Lake 2018).

Our findings reveal the potential power of community-based data collection and fisheries monitoring at the nexus of Indigenous-led management. This collaborative research was designed to improve understanding of community members' perceptions linked to FSC salmon fisheries among the Haíłzaqv Nation. Salmon catch data and information on fisher's satisfaction with their trip and the season as a whole were recorded, providing insights into the experiences of individual FSC fishers within the Haíłzaqv community and their ability to meet their FSC needs. This research and other similar community-based initiatives can help increase access to salmon for FSC fishers while promoting long-term sustainability in Pacific salmon fisheries by providing important information for policy makers, natural resource managers, and other First Nations as they evaluate opportunities for transforming management of salmon species on the North and Central Coast of BC under newly ratified *Fisheries Reconciliation Agreements* (Coastal First Nations 2019). With continued Haíłzaqv-led data collection, HIRMD resource managers can look back on previous FSC seasons and identify what fishing seasons were considered "good years" from Haíłzaqv fishers' perspectives and distinguish the shared properties of these seasons. By continuing to collect these critical data in the forthcoming years, the Haíłzaqv Nation can guide future policies and development of inclusive management approaches supporting sustainable and equitable salmon fisheries.

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Author contributions

JRS and WIA conceived and designed the study. JRS and JWM performed the experiments/collected the data. JRS, WIA, and KW analyzed and interpreted the data. NCB and WGH contributed resources. JRS, WIA, NCB, KW, WGH, and JWM drafted or revised the manuscript.

Competing interests

The authors have declared that no competing interests exist.

Archival data

Data collected through this research will be stored long term under the supervision and management of the Lands and Resources Department at Heiltsuk Integrated Resource Management Department office, Bella Bella, British Columbia.

Data availability statement

All relevant data are within the paper and in the Supplementary Material.

Supplementary material

The following Supplementary Material is available with the article through the journal website at doi:10.1139/facets-2020-0080.

Supplementary Material 1

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