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Accounting for intracultural variability in first nation environmental knowledge: A requisite for environmental monitoring and impact assessments

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ABSTRACT

In many environmental monitoring and impact assessment processes, Indigenous communities are treated as intellectually homogenous and intracultural variation in environmental knowledge often goes unaccounted for. This not only poses obvious risks to the effectiveness of environmental impact assessments but also gives standing to those who question the credibility of traditional ecological knowledge and its contribution to environmental monitoring and assessment programs altogether. In this paper we describe the steps that were taken to account for intracultural variability in First Nation knowledge of fish and the potential impacts associated with the Peace River oil sands development in Alberta, Canada. Involving the delivery of a household survey to 1,127 First Nation households in 11 Peace River communities, our approach was successful in identifying regional, community, and household variability in fishing activity, and has allowed us to differentiate novice from expert knowledge holders. This research demonstrates the need to account for intracultural variability in First Nations environmental knowledge in order for traditional ecological knowledge to make meaningful contributions to environmental monitoring and assessment programs.

1. Introduction

Over the past several decades traditional ecological knowledge (TEK) has gained a prominent role in environmental monitoring and impact assessment processes (e.g., Breckwoldt and Seidel, 2012; Fernandez-Gimenez et al., 2008). Owing to an in-depth knowledge of the environment, gained through long-term in-situ observations, the knowledge of Indigenous Peoples is being used alongside 'Western' science to arrive at more informed understandings of environmental change (Ferrari et al., 2015; Lyver et al., 2016; Ortega-Álvarez et al., 2017). Through a range of environmental monitoring programs, Indigenous Peoples and Western scientists are combining their respective expertise to arrive at sustainable solutions to environmental problems, from the local (Berkes, 2007) and global scales (Austin et al., 2019).

While the inclusion of TEK in environmental assessments is justified on both ontological (Walsh et al., 2013) and political grounds (Williams and Hardison, 2013), it is also true that the in-situ knowledge of Indigenous Peoples has been influenced by a range of social, economic, and political forces (Athayde et al., 2017). Acting together, these forces have led to considerable intracultural variation among knowledge holders; variation that can be attributed to age, gender, livelihood choices, and colonial histories. For example, First Nation peoples in Canada have for generations acquired comprehensive understandings of ecological systems. This knowledge has been gained through the direct utilization of natural resources (e.g., harvesting, processing, distributing) and through oral teachings and intergenerational instruction. Elders in particular are often recognized for their expertise due to their diachronic environmental knowledge, including spatial and temporal trends in resource availability. But in some cases, the environmental knowledge of Elders has been interrupted, either through changes in livelihood (e.g., subsistence to market economies), residency (e.g., seasonally mobile to reserve settlement), or education (e.g., experiential to residential\institutional learning). In such cases, being an Elder alone cannot be used as a proxy for environmental expertise. Younger generations face their own set of challenges in acquiring environmental knowledge, such as time limitations due to wage

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employment, having the necessary financial resources to access the land, or placing relative social value on environmental expertise (Natcher et al., 2016). These changes, and their subsequent effect on knowledge acquisition, influence the extent to which one is able to gain and put into practice environmental knowledge.

The variability found in Indigenous and local environmental knowledge systems has long been acknowledged in the literature (e.g., Boster, 1985, 1986; Boster et al., 1986; Ellen, 1979; Gardner, 1976; Gal, 1973) and has shown to influence one's ability to utilize environmental resources (Dovie et al., 2008). Yet in many environmental impact assessment programs, Indigenous communities are treated as intellectually homogenous and intracultural variation in environmental knowledge often goes unobserved. This has been the case in the Oil Sands Monitoring (OSM) Program in Alberta, Canada. Since 2012, the OSM Program has involved First Nation and Métis communities in an effort to better understand the cumulative effects associated with oil sands development (GoA, 2020). While the efforts of the OSM Program to engage First Nation and Métis knowledge holders has been laudable, little consideration has been given to the possibility of intracultural variability in environmental knowledge or to the consequences this variability may pose for identifying ambient environmental changes.

In this paper we describe the steps that were taken in one OSM project to account for intracultural variability in First Nation environmental knowledge. The project was entitled Bridging Knowledge Systems: Community-Led Approaches to Fish Monitoring in Alberta's Oil Sands Regions. The objectives of the project were to gain a better understanding of the changes that First Nation and Métis communities have observed in their local fisheries (Peace River, Athabasca River, Cold Lake), including the health and distribution of fish, as well as the local indicators that are used to monitor these conditions. Ultimately the goal of the project is to design a community-based environmental monitoring program for the oil sands regions that is informed by both Indigenous and western knowledge systems. The first step, which we describe here, was to identify the extent to which First Nation households participate in the Peace River fishery, and second, differentiate novice from expert knowledge holders, in order to establish a more informed starting point for environmental monitoring and assessment to proceed.

Knowledge of fish has proven to be an effective starting point for identifying intracultural variation in knowledge and for distinguishing expert and novice knowledge holders. For example, Boster and Johnson (1989) note that morphological information is generally available to anyone who has seen a fish, but the cultural knowledge that distinguishes expertise requires extensive and direct experience. Davidson-Hunt et al. (2013) makes a similar distinction between common and specialized environmental knowledge. Common knowledge refers to knowledge that is freely shared within communities that is transmitted through conversations or storytelling. Specialized knowledge, with an accompanying set of proficiencies, is acquired through an action-oriented approach to experiential learning. Within the domain of fish, there may be common knowledge of the morphological or taxonomic affinities that are known by many, but specialized knowledge is held by only a few and is constructed through patterns of use. This type of expertise embraces learning by doing, and is reflected in constructivist (Bruner, 1961) and Indigenous learning theory (O'Conner, 2016). In the case of fish, expertise is gained over time and through frequent interactions and observed associations.

Following this introduction, we provide a description of the Peace River region, including the Peace River oil sands. This is followed by a description of our methodology, including household surveys, constraints assessment, and social network analysis. Our results are then presented, which highlight the variability in fishing activity, including the mediating factors that influence knowledge acquisition. A discussion of these results is then presented, followed by a brief summary of our major findings.

Fig. 1. Alberta oil sands regions.

2. Research setting and methods

The Peace River extends 1923 km from its origins in British Columbia through Alberta, joining the Mackenzie River system, and eventually draining 50 billion m^3 of water annually into the Arctic Ocean (Bennett et al., 1973). Covering 323,000 km^2, the Peace River basin encompasses a diversity of ecosystems, including mountains, forests, and wetland. In 2018, 165,000 people lived within the Peace River basin, most of who reside in the regional centers of Grande Prairie (pop. 63,166), Fort St. John (pop. 21,155), Peace River (pop. 7152) and High Level (pop. 3159). Approximately 12% (19,800) of the population identifies as Aboriginal, many of whom reside in one of the 19 First Nation reserves or Métis settlements in the region. It is estimated that roughly 15% (48,450 km^2) of the Peace River watershed is affected by human activities (MPWA, 2015), largely in the form of agriculture, forestry, mining, and most significant here, the extraction of Peace River oil sands.

The Peace River oil sands is one of three regional oil sands deposits in northern Alberta; the others being the Athabasca and Cold Lake deposits. Alberta's oil sands regions encompass approximately 140,000 km^2, or 21% of Alberta's total land area (ABMI, nd). The Peace River oil sands is the smallest of the three deposits but still covers 29,120 km^2 in north central Alberta (Fig. 1). The Peace River oil sands came into production in 1977, when an experimental plant capable of producing 3500 barrels of bitumen per day was launched (GoA, nd). Based on its early success, the Peace River Expansion Project received approval in 1985 to increase its capacity to 10,500 bbl.\day, and as of 2018, produces 12,500 bbl.\day. Unlike the more expansive Athabasca deposits, the Peace River oil sands are located relatively deep underground, roughly 300 to 770 m below grade, and are extracted through the injection of pressurized steam. The injection of steam reduces the bitumen's viscosity, allowing it to be pumped to the surface (PREDA, 2010).

There has been relatively little documentation of local or traditional knowledge about the impacts of oil sands development. However, D'Souza and Parlee (2016) have reported on the concerns of First Nation and Métis communities regarding the historic, contemporary, and anticipated impacts of oil sands development on the Peace River's ecosystem. This includes the impacts on the 42 different species of fish that inhabit the Peace River watershed (BC Ministry of the Environment, 2017), and serve as dietary staples for many Aboriginal households (D'Souza and Parlee, 2016: 25).

The primary data collection method used in this research was a household wildlife harvest survey. Between 2016 and 2019, household surveys were delivered in 11 First Nation communities in the Peace River basin.[1] These communities were located in the Upper ($N = 2$), Central ($N = 4$) and Lower ($N = 5$) Peace River regions (Fig. 1). The survey was designed in collaboration with First Nation research coordinators and administered by trained First Nation research assistants. Our sample objective was a census of all on-reserve First Nation households. In this study, a household was defined as a residential unit where occupants share domestic and economic responsibilities.

The survey consisted of three sections. Section one identified household demographic information. Data included the number of members per household, along with their age, gender, and employment patterns. Section two of the survey recorded fish harvesting data. The survey asked the head(s) of households to recall the number and types of fish harvested by household members during the preceding 12 months. They were also asked to identify on an accompanying basin map where harvesting occurred. Although this approach assumes that the heads of household can recall the number, types, and locations where fish were harvested during the preceding year, previous research has shown the recall abilities of First Nations members to be quite detailed and accurate regarding quantities and even qualities of fish and animals harvested over time (see Jones et al., 2008; Krech, 1978). In addition to harvest data, household heads were asked to identify any constraints that may have kept household members from harvesting fish, or harvesting at a desired extent. We did not provide a pre-determined list of constraints but rather asked respondents to self-identify any constraints they, or members of their household may have experienced, be they social, economic, political, or environmental. While it would have been ideal to survey each household member, it was generally accepted that heads-of-household were aware of the economic activities of household members and could speak to the barriers that may have limited their participation in fishing and other harvesting activities (Natcher et al., 2016).

In the last section of the survey, household heads were asked to identify who in the past year they had given or received fish from. The relationships between giving and receiving households were recorded, as were the corresponding household numbers (coded for confidentiality). We did not ask for the quantities of fish given or received but were interested only in the frequency and relational aspects of exchange. The fish-sharing component of the survey identified the distribution of fish between households and distinguished between high harvesting - high sharing households, from those households that were recipients of fish only, and households that were excluded from fish harvest\sharing networks entirely. UCINET and NetDraw were used to analyze and visually represent fish-sharing networks (Borgatti and Halgin, 2011). Network density scores were calculated to determine the ratio between actual exchanges and all possible exchanges between households. Network density is defined as the number of connections a household has, divided by the total possible connections it could have. If there are 100 households in a community, each household could potentially connect to 99 other households. A density of 100% is the highest possible density. Network density can be used as a proxy measure for quantifying the cohesiveness of community sharing networks. Reciprocity was measured to determine the degree to which sharing was mutual. Freeman Degree Centrality scores were then calculated for each household, and aggregated into community averages. Centrality scores reflect the number of times a household gave (known as out-degree) or received (in-degree) fish from any other households involved in the food-sharing network.

All surveys were scanned and the responses were entered manually into Excel spreadsheets. A double data entry method was used to ensure accuracy. The preliminary tables of demographic, harvesting, sharing, and cultural consensus data were reviewed and verified by respective First Nations research coordinators. Community findings were reported and verified locally during community presentations and meetings with representative Chiefs and Councils.

3. Results

Surveys were completed by 1127 households in 11 First Nation communities. This sample represents 89% of all on-reserve households and a survey population of 4009 First Nation citizens. Our results indicate that 520 (46%) households harvested fish during the survey periods. These households harvested an estimated 25,530 fish, resulting in a processed food weight of approximately 27,386 kg. The median household harvest was 20 fish, with a household minimum of 1 and a maximum of 920 fish. Northern pike (*Esox Lucius)* accounted for 40% of the total fish harvest, followed by walleye (*Sander vitreus*), goldeye (*Hiodon alosoides*), whitefish (*Prosopium williamsoni*), lingcod (*Ophiodon elongatus*), trout (*Salvelinus confluentus, Salvelinus namaycush, Oncorhynchus mykiss*), sucker (*Catostomus commersonii*), grayling (*Thymallus thymallus*), and kokanee (*Oncorhynchus nerka*).

Considerable variability was found between regions, communities, and households. For example, in the Upper Peace River region, 141 First Nation households from two First Nation communities were surveyed. Of these households, 35 (25%) reported fishing during the survey period. These 35 households harvested 1087 fish, or 4% of the total Peace River harvest. The mean and maximum harvest levels for Upper Peace River region households were 31 and 463 fish respectively. In the Central Peace River region, four First Nation communities were surveyed. Of the 498 households surveyed, 309 (62%) reported fishing activity. These households harvested 13,706 fish (54% of total), with a mean harvest of 44 fish per household, and maximum household harvest of 820. Last, among the five Lower Peace River region communities ($N = 488$ HHs), 176 (36%) households harvested 10,737 fish. This harvest accounted for 42% of the total fish harvest, and a household mean harvest of 61 fish and maximum harvest of 920 (see Table 1).

While 520 households reported harvesting fish during the survey periods, relatively few households were responsible for harvesting the majority of fish. For instance, the top 10% of fish harvesting households ($N = 112$) harvested approximately 18,368 fish with a total processed food weight of over 19,122 kg, roughly 70% of the sum harvest weight (Table 2). Furthermore, the top 20% of fishing households ($N = 224$) accounted for 87% of the total harvest and the top 30% of households ($N = 336$) accounted for 96% of the total harvest. Among the top 10% of harvesting households, three were from the Upper Peace River region, whereas 61 households were located in the Central Peace River region and 51 were from the Lower Peace River region.

Within the top 10% of harvesting households, there were an even smaller number of ‘super-harvesters’. Twenty households (1.8%) were identified as super-harvesters that harvested far more fish than the average household. Whereas the average fishing household harvested

[1] Due to concerns over confidentiality, the names of participating First Nations in this study are not included. Rather each community is distinguished by region and a number ranging from 1 to 11.

Table 1
Fish harvesting by community and region of the Peace River.

Region	Community (No. of Households)	No. of Fishing HHs (%)	Total No. of Fish Harvested	Total Food Weight (kg)	Mean (Max) Harvest	Percent of Total Peace River Fish Harvest	No. of HHs in Top 10% of Harvesting HHs
Upper	Com. 1 (*N* = 66)	25 (39%)	968	916	39 (463)	3%	2
Upper	Com. 2 (*N* = 75)	10 (13%)	119	112	12 (50)	< 1%	1
Central	Com. 3 (*N* = 131)	93 (71%)	5128	5964	55 (700)	22%	27
Central	Com. 4 (*N* = 206)	153 (74%)	4929	6389	32 (463)	23%	21
Central	Com. 5 (N = 48)	31 (65%)	2368	2620	76 (820)	10%	5
Central	Com. 6 (*N* = 113)	32 (28%)	1281	1199	40 (620)	4%	5
Lower	Com. 7 (*N* = 90)	25 (28%)	616	584	25 (123)	2%	3
Lower	Com. 8 (*N* = 133)	70 (53%)	5067	5069	72 (920)	19%	27
Lower	Com. 9 (*N* = 87)	46 (53%)	3499	3100	76 (540)	11%	13
Lower	Com. 10 (*N* = 100)	13 (13%)	149	166	11 (43)	< 1%	1
Lower	Com. 11 (*N* = 78)	22 (28%)	1406	1267	64 (500)	5%	7
Total	(*N* = 1127)	**520**	**25,530**	**27,386**	**48(920)**	**100%**	**112**

Table 2
Distribution of Fish Harvest by Peace River Fishing Households.

Decile Sorted by Most to Least Fish Harvested	# of Fish Harvested	Food Weight (kg)	% of Harvest
1st decile (N = 112):	18,368	19,122	70%
2nd decile (*N* = 112):	4041	4561	17%
3rd decile (N = 112):	2083	2469	9%
4th decile (N = 112:	886	1047	3%
5th decile (N = 112):	152	187	1%
6th through 10th decile (*N* = 567):	0	0	0%
Total *N* = 1127	25,530	27,386	100%

49 fish, the top 20 fishing households harvested between 250 and 920 fish (Fig. 2). In fact, the top 20 fishing households were responsible for harvesting 37% of all fish caught. These households were located predominantly in the Central (*N* = 11) and Lower (*N* = 8) Peace River regions, with only 1 super-harvesting household located in the Upper Peace River region.

In addition to community and regional differences, harvest levels also varied by age group. For example, households whose heads were between 20 and 29 years of age (yoa) (Type 1) represented 10% (*N* = 121) of all surveyed households. Of that 10%, 62 households harvest 1974 fish, or 8% of the total fish harvest (Table 3). Households whose heads were 60+ yoa represent 20% of all households, but only

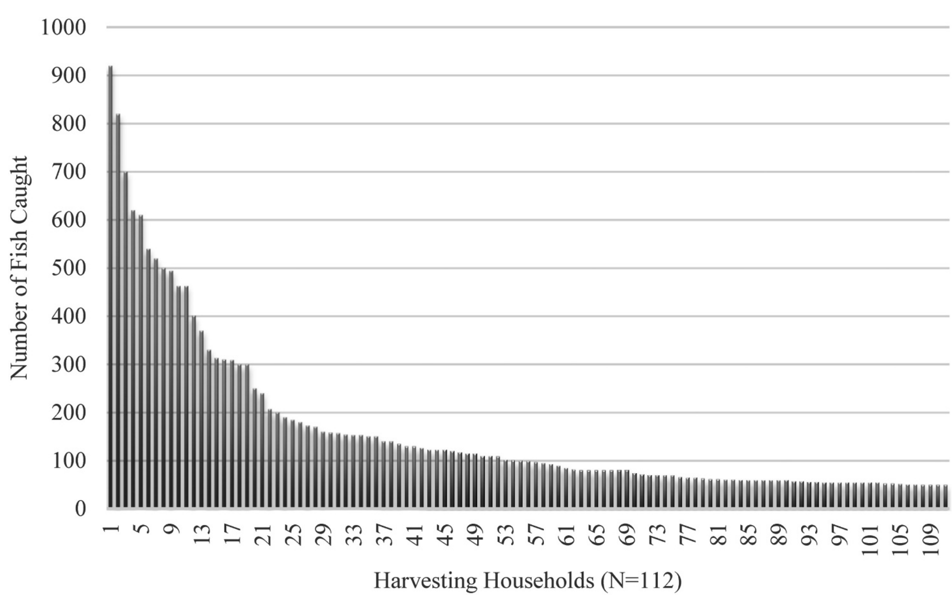


Fig. 2. Harvest Distribution of Top 10% of Fish Harvesting Households (*N* = 112).

Table 3
Fish Harvesting by Household Age Type.

HH Type (Age)	Non-Fishing HH (%)	Fishing HH (%)	Number of Fish caught (%)	Harvest by Food Weight (%)
Type 1 (20–29) N = 121	59 (5%)	62 (5%)	1974 (8%)	2249 (8%)
Type 2 (30–39) *N* = 254	132 (12%)	122 (11%)	3198 (12%)	3638 (13%)
Type 3 (40–49) *N* = 264	149 (13%)	115 (10%)	6545 (26%)	6673 (24%)
Type 4 (50–59) *N* = 258	126 (11%)	132 (12%)	9984 (39%)	10,652 (40%)
Type 5 (60–69) *N* = 230	141 (13%)	89 (8%)	3829 (15%)	4174 (15%)
Total N = 1127	607 (54%)	520 (46%)	25,530 (100%)	27,386 (100%)

Table 4
Household Constraints to Fishing.

Barrier to Fishing	Number of households by age group (% from age group)					
	20–29 YOA	30–39 YOA	40–49 YOA	50–59 YOA	60+ YOA	Total
Cost	48 (48%)	77 (39%)	68 (32%)	69 (31%)	97 (39%)	359 (37%)
Not enough time due to work	39 (39%)	77 (39%)	81 (39%)	80 (36%)	62 (25%)	339 (35%)
Physically unable	22 (22%)	21 (11%)	18 (9%)	29 (13%)	83 (34%)	173 (18%)
Industrial development	10 (10%)	35 (18%)	32 (15%)	34 (15%)	56 (23%)	167 (17%)
Childcare	20 (20%)	38 (19%)	31 (15%)	33 (15%)	12 (5%)	134 (14%)
Concerned about food safety	3 (3%)	19 (10%)	28 (13%)	20 (9%)	40 (16%)	110 (11%)
No knowledge to harvest	6 (6%)	25 (13%)	35 (17%)	18 (8%)	17 (7%)	101 (10%)
Not enough time due to school	18 (18%)	30 (15%)	23 (11%)	23 (10%)	7 (3%)	101 (10%)
Lack of interest	7 (7%)	16 (8%)	27 (13%)	19 (9%)	23 (9%)	92 (9%)
Environmental change	2 (2%)	13 (7%)	24 (11%)	24 (11%)	27 (11%)	90 (9%)
Recreational Competition	4 (4%)	12 (6%)	12 (6%)	8 (4%)	32 (13%)	68 (7%)
Lack of transportation	4 (4%)	6 (3%)	16 (8%)	7 (3%)	15 (6%)	48 (5%)

8% reported harvesting fish. These 89 households harvested 3829 fish, or 15% of the total fish harvest. Contributing most significantly were households whose heads were between 50 and 59 yoa. There were 258 households in this age category, slightly over half ($N = 132$) of which harvested 9984 fish, or approximately 40% of the total harvest. Among the top 10% (N = 112) of fishing households, 37 (33%) were headed by individuals between the ages of 50–59 yoa, including 12 of the top 20 fishing households.

3.1. Fishing constraints

Our results indicate that 54% (N = 607) of households did not fish during the survey periods. In addition, 293 households (deciles 3–5) harvested 3121 fish, or an average of 11 fish per household. These no-harvesting and low-harvesting households reported a number of constraints that kept household members from harvesting fish, or limited the extent they would have desired. In total, 916 responses were recorded, and were sorted into 12 general constraint categories (see Table 4).

The most frequent constraint reported was the prohibitive costs associated with fishing (38% of responses). This includes the costs of equipment (e.g., nets, rods), boats, outboards, and fuel. In addition, the costs of maintenance and upkeep were noted to be a limiting factor, with a number of respondents acknowledging that they have the necessary equipment to fish but overtime it has fallen into disrepair (4%). The second most cited constraint was having limited time to fish. Time constraints were attributed to employment commitments (34%), particularly industrial work rotation schedules, wildland fire fighting which often requires extended periods of time spent away from home communities, and the regular 40-h work week which has become more or less common for most on-reserve employment. Time limitations were also attributed to school attendance (10%). This included school attendance of young children which limited the time families could be away (14%), post-secondary attendance of young adults (18–24 yoa), and vocational training programs that are delivered in regional centers. Other noted constraints include being physically unable to fish (17%), concerns over food safety (11%) stemming from industrial development (15%) and environmental change (8%), increased competition with recreational resource users (7%), and lacking the necessary knowledge to fish (10%) or an interest to do so (9%).

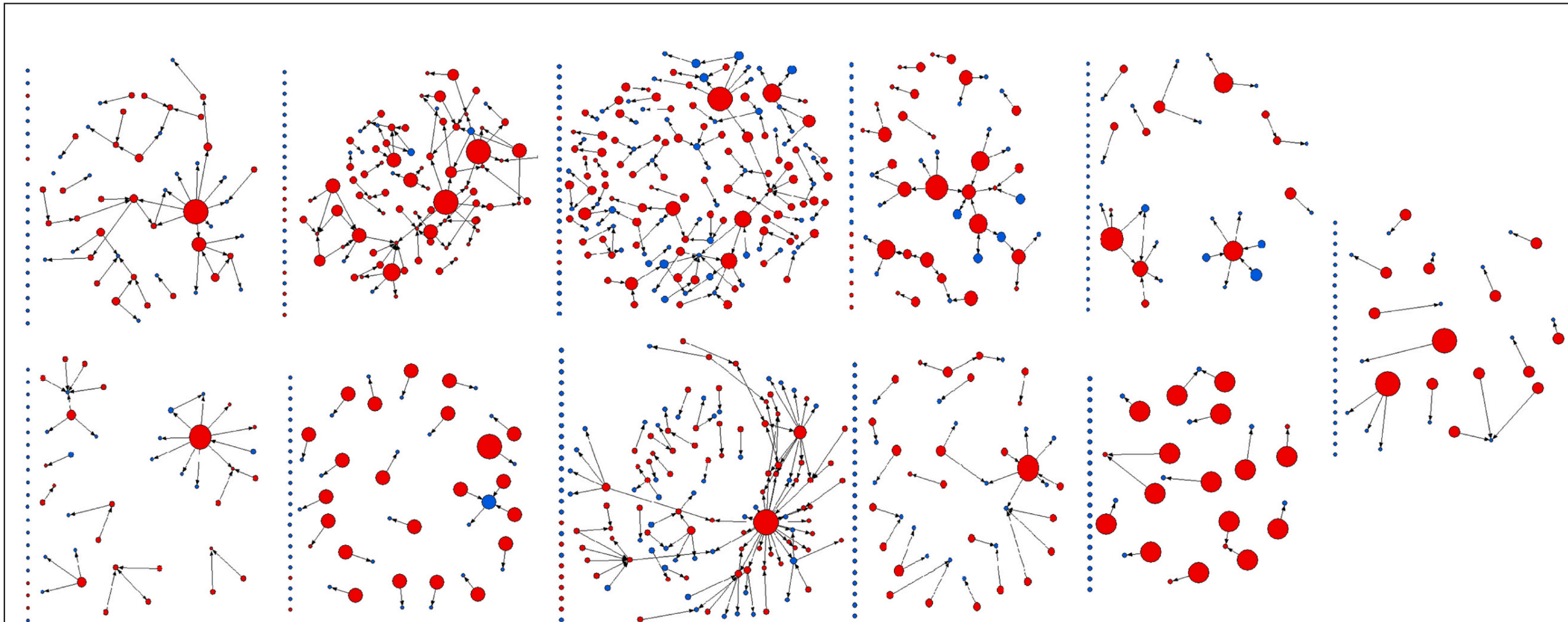
Specific to food safety concerns, First Nation respondents expressed considerable anxiety over the level of industrial contaminants they believe are in fish and other wildlife resources. The origins of these contaminants were often linked to the Peace River oil sands, but were also attributed to agricultural run-off, discharge of pulp mill effluents, and hydroelectric development (e.g., believed responsible for high levels of mercury in fish). Many respondents ($N = 73$) stated that they no longer fish because fish in the Peace River are simply unsafe to consume. For these households, fishing is no longer a part of their seasonal round of harvesting activities. For other households, their concerns about food safety have motivated catch-and-release practices; something largely unheard of a generation ago. For these households, the act of fishing remains culturally important (e.g., being at fish camp, transmitting fishing skills), but concerns over food safety have reduced their household's fish consumption.

The constraints reported by heads-of-household did vary depending on the age and gender of household members. For example, being physically unable to fish was a limiting factor among all age groups. However, those over 60 yoa experienced this constraint most frequently. Similarly, the demands of childcare were reported by 126 households, 35 (28%) of who were between the ages of 30–39. The lack of knowledge to fish and the interest to do so was distributed evenly between all age groups. This finding differs to some extent with Natcher et al. (2016) who found that younger generations whose parents were subjected to residential schools often missed the opportunities to acquire harvesting skills. Lacking the opportunity to learn these skills, this demographic often lacked an interest to participate in subsistence harvesting later in life (Natcher et al., 2016). However, our findings indicate that this is a factor affecting all age groups.

In addition to generational differences, these constraints were experiences differently between men and women. For example, women frequently cited childcare as a constraint to fishing, whereas less than 1% of men ($N = 2$) identified childcare as limiting factor. Similarly, more women than men reported school attendance (particularly in post-secondary) as a constraint, while more men cited employment and costs as the two most significant limiting factors. Aside from these categories, men and women experienced the other constraints more or less evenly, and all cited concerns over food safety, environmental change, competition with recreational resource users, and knowledge to fish and the interest to do so as constraints to their involvement in fishing.

3.2. Fish sharing network

Our results indicate that 520 Peace River households were involved in fishing. However, 680 households were identified as having received or given fish to others households. These exchanges occurred predominantly between households within the same community ($N = 526$), but also between households in different communities ($N = 154$). Fig. 3 below shows the respective fish sharing network of each community. Nodes (households) are sized in terms of their network centrality (i.e., the extent to which they were involved in the giving of fish). The red nodes indicate harvesting households and the blue nodes represent non-harvesting households. The arrows between the nodes indicate the directional flow of fish between households. Isolated nodes indicate households that neither gave or received fish.



Community	Com. 1	Com. 2	Com. 3	Com. 4	Com. 5	Com. 6	Com. 7	Com. 8	Com. 9	Com. 10	Com. 11
Total No. of Surveyed HHs (N=1127)	66	75	131	206	48	113	90	133	87	100	78
Total Number of Fishing HHs	25	10	93	153	31	32	25	70	46	13	22
Total Number of Fish Harvested	968	119	5,128	4,929	2,368	1,281	616	5,067	3,499	149	1,406
HHs Participating in Fish Sharing Total	47	38	117	85	39	49	43	149	48	27	30
Intra Comm. Sharing	30	27	74	78	25	41	29	135	43	16	28
Inter Comm. Sharing	17	9	43	7	14	8	14	14	5	11	12
Reciprocity	0.00%	0.00%	0.03%	0.00%	3.13%	0.00%	0.00%	1.77%	8.11%	0.00%	8.33%
Density (% of possible exchanges)	2.40%	0.01%	0.09%	1.10%	2.30%	2.00%	0.02%	0.70%	1.90%	0.02%	3.10%
Ave.\Max Number Households Fish were GIVEN to (SD)	1.29\3 (0.81)	1.04\2 (0.54)	2.19\31 (3.14)	1.61\6 (1.21)	1.62\10 (1.65)	1.65\10 (1.58)	1.43\7 (1.16)	1.77\10 (1.42)	1.64\4 (1.02)	1.00\1 (0.50)	1.94\5 (1.33)
Ave.\Max. Number of Households Fish were RECEIVED from (SD)	1.29\3 (0.81)	1.14\3 (0.66)	1.45\5 (0.97)	1.68\6 (1.17)	1.48\5 (1.04)	1.50\3 (0.89)	1.50\4 (0.94)	2.04\12 (1.55)	1.28\4 (0.84)	1.25\2 (0.68)	1.48\4 (1.01)

Fig. 3. Fish Sharing Networks of Peace River Communities.

As reflected in Fig. 3, Peace River communities differ in the degree to which they share fish with other households. Among the 11 Peace River communities, network densities range from 0.01% to 3.1%, indicating a relatively low density of sharing households. On average, First Nation households gave fish to 1.36 other households and received fish from 1.46 households. However, in some cases, households gave fish to a large number of other households. For example, in one community a household gave fish to 31 other households, some of which were harvesters themselves. Similarly, some households received fish from a large number of other households, for instance in community 8 where one household received fish from 12 other households. Reciprocity was generally low and ranged from 0 to 8.33%. However, this indicator only accounts for exchanges of fish and does not account for other forms of reciprocity, for example fish for moose, fish for bison, or fish for some other form of service. In general, our analysis of fish sharing indicates that fishing households, particularly the top 10% ($N = 112$) and those characterized as super-harvesters ($N = 20$), were responsible for distributing fish to a large number of households through intra- and intercommunity sharing networks.

4. Discussion and conclusion

Berkes (2012: 218) found that the expertise of Cree fishers develops through an interplay between practice and knowledge acquisition. Through trial and error experimentation, followed by incremental modification and adaptation, Cree fishers participate in a dynamic process of knowledge acquisition that is well suited for detecting variance from ecological norms (Berkes, 2012: 221), particularly when changes are non-linear and episodic. Persky and Robinson (2017) explain that the knowledge gained through practice develops progressively, where one begins as a novice, advances to a beginner, gains proficiency to the point of competence, and then attains expertise. Through this process, knowledge of the environment is accumulated over one's lifetime, starting at childhood and becoming more comprehensive as one matures (Saynes-Vásquez et al., 2016). During this progression, an individual eventually distinguishes her or himself by encountering different experiences that provide a cognitive basis for interpreting and formulating adaptive responses; although outcomes may never be certain (Persky and Robinson, 2017). Through the accumulation of knowledge, acquired through frequent and sustained associations, one can, in time, become an expert (Hunn, 1982).

The degree to which one acquires knowledge is therefore contingent upon one's direct experience. This is particularly true for the acquisition of fish knowledge, because fish, unlike terrestrial species, are most often unseen by novices or passive observers. Given the domain of fish, the opportunities for novices to make observation are infrequent, happen by chance, or occur in assembled environments such as market places or during meal times. Limited to these types of encounters, the knowledge that novices acquire may simply reflect physical appearances, taxonomic affinities, or pertain to certain qualities such as taste, color or texture of the meat. Experts on the other hand, who typically gain their knowledge through direct and frequent experiences, may construct their cognitive understanding of fish by way of behavioural and ecological characteristics, or by the ecological niches that fish occupy (Shafto and Coley, 2003: 641). Moreover, experts may recognize symbiotic or competitive relationships between species and the historic or emergent conditions that influence those associations (Shafto and Coley, 2003: 641). For this reason, the gulf separating those who have acquired expertise in fish from those who are novices can be quite significant (Boster and Johnson, 1989).

It is for this reason we chose to first identify those First Nation households that are most involved in the Peace River fishery. Because one's knowledge of fish is informed by one's participation in fishing, our objective was to identify those most active fishers because they may be in the best position to evaluate the impacts of oil sands development. Approached in this way we presumed that environmental knowledge within Peace River communities is variable and socially distinct. Based on this presumption we delivered household surveys to 1127 First Nation households in 11 Peace River communities. Our results found that less than half (46%) of all households were involved in fishing. These 517 households harvested 25,530 fish, which had a processed food weight of 27,386 kg. This harvest was regionally distributed, with a higher percentage of harvesting households in the Central and Lower Peace River regions. We also learned that among fishing households, 112 (10%) were responsible for harvesting 70% of the total fish harvest, with 20 of those households harvesting nearly 40% of all fish caught on the Peace River. Twelve of the 20 households had household heads between 50 and 59 yoa. We also learned that 54% ($N = 607$) of households did not fish during the survey periods, and 293 households were marginally involved. These households experienced a number of constraints that limited fishing opportunities, most notably cost, time, and health concerns over fish consumption. The households that continue to fish share their catch with an extensive network of households, both within and beyond their respective communities.

In choosing this approach we were cognizant of the risks of using a harvest survey to identify expertise. By focusing on a single year of fishing activity, we neglect critical stages of household development, where human and financial resources change over time, as do one's involvement in fishing. During different phases of household development, households may have access to sets of resources that in other times are unavailable, for instance household labour, finances, and the physical abilities to participate in fishing. The approach used here captures a very limited period of time in an otherwise lifetime of experience. It is for this reason that Ellen (1986: 89) argues that systematic data collection procedures should be avoided in favour of nondirective, unobtrusive observation that involves simply listening and using prompts to facilitate the flow of desired information.

We certainly agree that engaging First Nation knowledge holders directly is most ideal for sharing knowledge, and in the context of TEK, is more culturally appropriate. However, a qualitative approach does not overcome the fact that environmental expertise is socially distributed within First Nation communities. The environmental knowledge that First Nations have accumulated is extensive but it has also been exposed to a number of outside influences, whether in the form of globalization, geographic and linguistic displacement, or other culturally mediated influences that have interrupted opportunities for knowledge acquisition or have diminished its relative social value. Because the geographical focus of this research is the Peace River system, including 11 communities and more than 1100 First Nation households, a more systematic approach was necessary in order to demarcate, in a reasonable period of time, experts from novices. In doing so, the survey approach was successful in identifying regional, community, and household variability, which otherwise would have gone unknown. Had we abandoned a systematic data collection strategy for a more unobtrusive methodology, we may have ended up interviewing a large number of homogeneous informants whose knowledge, although valuable, may have been based on less frequent and direct observations of the Peace River fishery. We also know from our own research (Natcher, 2015, 2019) and the research of Berkes (2012), that Cree fishers avoid sharing information that is not derived from their own personal experience, and are critical of those who report observations made by others (Berkes, 2012: 221). For this reason, we set out to identify those households that were most involved fishing, and could speak directly from personal and current experience. With this knowledge in hand we are now in a better position to explore with First Nation experts the indicators they use for assessing the aquatic and ecosystem health of the Peace River. For instance, how the presence or absence of certain harvested fish species are used locally to monitor fish habitat and species distribution (e.g. Δ catch\effort).

We entered into this research with the sense that environmental monitoring programs too often treat Indigenous communities as intellectually homogenous. By generalizing the intellectual variability that exists within Indigenous communities, there is a risk that the true contributions of TEK are displaced by the inclusion of knowledge that is based on limited personal exposure. In addition to being of marginal value to the environmental monitoring and impact assessment processes, these contributions may even misrepresent the actual conditions observed by more knowledgeable resource users. This not only poses obvious risks to the effectiveness of environmental monitoring programs but may also give standing to those who question the credibility of TEK (e.g., Howard and Widdowson, 1996) and its contribution to environmental monitoring and assessment programs altogether (e.g., Widdowson and Howard, 2006).

Authors statement

DN was the principal Investigator of the project and led the writing of the manuscript. NB co-led the research and contributed to the writing. SI performed the computations and AMB conducted the social network analysis. All authors discussed the results and contributed to the final manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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