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Recreational anglers' attitudes, beliefs, and behaviors related to catch-and-release practices of Pacific salmon in British Columbia

Vivian M. Nguyen [a,*], Murray A. Rudd [b], Scott G. Hinch [c], Steven J. Cooke [a]

[a] Fish Ecology and Conservation Physiology Laboratory, Department of Biology, Carleton University, 1125 Colonel By Drive, Ottawa, ON K1S 5B6, Canada
[b] Environment Department, University of York, Heslington, York YO10 5DD, United Kingdom
[c] Pacific Salmon Ecology and Conservation Laboratory, Centre of Applied Conservation Research and Department of Forest Sciences, University of British Columbia, Vancouver, BC V6T 1Z4, Canada

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ABSTRACT

The fate of captured and released fish in recreational fisheries depends in large part on fisher handling and behavior. As such, there is a need for promoting adoption of responsible fishing practices. We interviewed recreational sockeye salmon anglers in the lower Fraser River, British Columbia, to assess their awareness of responsible fishing practices and identify gaps where improved education could promote conservation-oriented behaviors. Based on our interview data, we developed three latent class models of salmon angler typologies based on: 1) anglers' fishing behaviors and preferences, 2) anglers' perceived risks to salmon survival due to post-capture live release, and 3) anglers' level of support for education programs. In the first model, we identified salmon-only anglers (33% of sample), lake-species specialists (46%), and all-around anglers (21%). These classes were differentiated primarily by non-salmon fishing activities (e.g., other target species). In the second model, we found four classes of anglers who differed with regards to key factors they thought affected post-release survival: air exposure (39% of sample); water temperature (24%); hook location (22%); and revival effort (15%). In the third model, we found anglers were either supporters (73%) or non-supporters (27%) of angler education programs. Heterogeneity existed among anglers but we found no correlations in angler classes across models, nor any significant demographic or experiential predictors of class membership. Respondents generally had high awareness and application of catch-and-release best practices, with lake-species specialists rating a higher awareness and usage of recommended catch-and-release technique, and were significantly more likely to cut the line on deeply hooked fish than other groups. Our findings provide resource managers with important insight into the attitudes and behaviors of sockeye salmon anglers in the important lower Fraser River recreational fishery. Our findings also highlight, however, the need for further research on the determinants of angler beliefs and behavior in order to customize programs to build anglers' awareness and adoption of responsible fishing practices.

1. Introduction

Recreational angling has been implicated in the decline of some freshwater fish populations (Post et al., 2002) through harvest, post-release mortality, or most likely a combination of both (Coggins et al., 2007). Anglers have access to some of the most sensitive ecosystems and critical habitats (Donaldson et al., 2011), often outnumber commercial fishers (Cooke and Cowx, 2006), and can represent a strong vocal and political constituency that may constrain managers' options for achieving conservation targets (Danylchuk and Cooke, 2011). In some situations, recreational angling may be a threat to ecosystem viability and fish survival but, in other cases, anglers can positively influence conservation outcomes if successfully engaged in the management process (Granek et al., 2008; Gray and Jordan, 2010; Danylchuk and Cooke, 2011).

The potentially pivotal role of recreational anglers in the conservation of freshwater species (Cowx et al., 2010) implies that close attention needs to be paid to recreational anglers' attitudes and behaviors. Anglers come from different socio-demographic backgrounds, seek different fishing experiences, and vary in avidity and commitment to fishing (Fisher, 1997; Wilde et al., 1998; Oh and Ditton, 2008). Anglers' motivations can range from catching trophy fish to simply enjoying the outdoor experience (Fedler and

* Corresponding author. Tel.: +1 613 520 2600x4377; fax: +1 613 520 3539.
E-mail addresses: vivian.m.n@gmail.com, vivian_nguyen@carleton.ca (V.M. Nguyen).

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Ditton, 1994; Hunt and Bettoli, 2007; Arlinghaus, 2006; Beardmore et al., 2011). Just as their motivations vary, so too can anglers' attitudes and preferences toward management and their willingness to engage in finding solutions to conservation challenges (Reichers et al., 1991; Salz and Loomis, 2004; Arlinghaus and Mehner, 2005; Dorow and Arlinghaus, 2012). Characterizing these differences among anglers (e.g., Fisher, 1997; Morey et al., 2006; Johnston et al., 2010) and the basis for such differences could assist managers in understanding and balancing stakeholder needs. Additionally, degree of angler specialization (skills, equipment, setting) has traditionally been used to characterize a continuum of general to specialized angler behavior, which may also influence angler preferences and attitudes toward various management paradigms (e.g., Bryan, 1977; Connelly et al., 1990; Salz and Loomis, 2005). The fate of captured and released fish thus becomes largely dependent on anglers' attitudes and behaviors (Cooke and Suski, 2005; Pelletier et al., 2007).

Stern et al. (1999) highlighted the importance of environmental values, threat salience, and peoples' ability to affect change as factors in designing management strategies that successfully facilitate behavioral change. Gray and Jordan (2010) recommended that similar goals and perceptions shared by managers, scientists, and anglers need to be highlighted for effective outreach strategies in promoting ecosystem-based management. They suggested that education should be framed around what is valued by the audience, not simply by managers supplying information. Threat salience is important because it directly affects people's willingness to take action to reduce threats to valued resources (Stern et al., 1999). Threat salience can be influenced directly by improved awareness of threats (e.g. increased angler awareness of the effects of water temperature on post-release survival) and indirectly via changes to deeper core values or worldviews (e.g., acceptance that climate change will inevitably lead to increased water temperature). How an angler reacts to a specific management measure – their propensity for compliance with water temperature-based fishery closures for example – depends on their perspectives on the legitimacy of that measure as well as the financial or other costs they personally bear. By better understanding behavioral aspects of recreational angling, it is possible to design and implement education and management strategies that have a higher likelihood of engaging anglers (Arlinghaus, 2006) and promote biological sustainability of fish populations (Johnston et al., 2010).

Increased education and awareness can potentially be an efficient and cost-effective mean for encouraging responsible fishing behavior (Cooke et al., in press). Little, however, is known about anglers' perspectives regarding responsible fishing practices despite the fundamental importance of such information (see Margenau and Petchenik, 2004; Arlinghaus et al., 2007; Cooke et al., in press). By understanding anglers' attitudes toward responsible fishing and conservation, their underlying beliefs about what affects survival of fish after a catch-and-release event, and their fishing behavior, managers can make better decisions regarding initiatives to increase salmon survival.

We used British Columbia's (BC) lower Fraser River sockeye salmon recreational fishery as a case-study to explore how improving our understanding of anglers' diversity may inform management strategies meant to shape behaviors important for successful fish conservation. Specifically, we assessed angler awareness and uses of catch-and-release techniques recommended by management agencies to identify knowledge gaps where improved education could increase responsible fishing. We used exploratory latent class models as a segmentation tool to characterize heterogeneity among Fraser River salmon anglers with regards to their fishing behaviors and preferences, perceived risks to salmon survival due to post-capture live release, and level of support for angler education programs on responsible fishing practices. We also sought to investigate relationships among selected predictor variables and identified angler subgroups from the latent class models to gain new insights on and possibly predict angler behavior, perceptions, and responses to potential management initiatives. This information is likely central to the design of effective management measures to improve fish survival and conservation.

2. Case study

The Fraser River in British Columbia (Fig. 1) is one of the most productive salmon rivers in the world (Northcote and Larkin, 1989). Fisheries management in the Fraser River system is complex (Healey and Hennessey, 1998) and expensive: about CAD$40 m is spent annually on salmon management and habitat conservation in BC. Multiple salmon species and stocks co-mingle during their migration upriver and more vulnerable non-target species and stocks (e.g., endangered, undersized) are required to be released alive after capture. Three fishing sectors (commercial, recreational and First Nations) target salmon in the Fraser watershed. Various organizations share management responsibilities and the Pacific Salmon Treaty guides transboundary management. First Nations depend on salmon for food, social, and ceremonial purposes (Muckle, 2007) and have opportunities to fish commercially in some years. Recreational fishers target salmon for both food and leisure purposes. Different stakeholders and sectors differ in their priorities and views, so there is a pressing need to identify management options that minimize potential conflicts and improve salmon specific conservation outcomes.

The recreational Fraser River sockeye salmon (*Oncorhynchus nerka*) fishery, one of the primary recreational fisheries in the river system targeting Pacific salmon, can consist of over 1000 anglers fishing simultaneously. Although a 'sport' fishery, it is primarily a harvest-oriented fishery and has a catch limit of two sockeye salmon per person daily (DFO Creel Survey, 2010). However, catch-and-release in this fishery becomes prominent when non-target species (e.g., protected species and/or stock, undersized or juvenile fish) co-migrate with sockeye salmon. Also, anglers may voluntarily release sockeye salmon (e.g., if seeking to catch a larger fish or continuing catch-and-release fishing after the daily bag limit is reached) or when a fish is not hooked by the mouth or lip (i.e. foul hooking), of which the fish must be released to remain compliant with regulations. Of the estimated 200,000 sockeye salmon landed in 2010, just over 100,000 were released (DFO Creel Survey, 2010).

The effects of recreational salmon catch-and-release is of particular concern in the Fraser River system in the face of climate change. Rising river water temperatures and changing hydrological regimes are forecasted and will lead to higher en-route mortality of migrating adult salmon (Battin et al., 2007; Farrell et al., 2008; McDaniels et al., 2010; Martins et al., 2011). Capture events during warm water temperatures can cause increased stress, behavioral impairment, and potentially increased mortality of migrating adult salmon (Gale et al., 2011). Therefore, it is critical that appropriate handling and release methods (i.e., 'responsible fishing') are developed now and used to minimize additional physiological disturbances and mortality in the Fraser River system.

3. Methods

3.1. Survey instrument

We conducted face-to-face semi-structured interviews to collect both quantitative (rating and rankings) and qualitative (open end) data needed to explore the attitudes and behaviors of active Fraser River sockeye salmon anglers (see Appendix A in the online

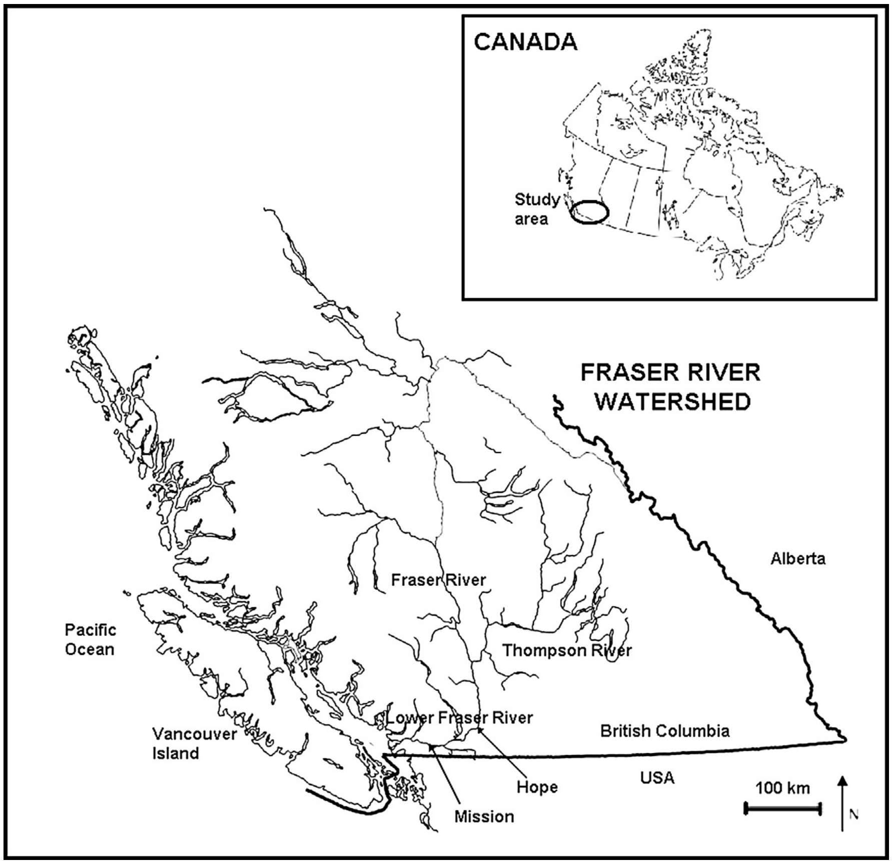

Fig. 1. Lower Fraser River case-study area, British Columbia. Interviews were conducted primarily between the cities of Mission and Hope.

supplemental information for interview guide). Interviews followed a mixed-methods approach (Creswell, 2009) to increase the external validity of quantitative data while generating new knowledge and capturing a diversity of qualitative and in-depth opinions. Interview questions relevant to policy makers were identified in collaboration with local fisheries managers, reviewed by fisheries experts, and tested in face-to-face pilot interviews with eight experienced salmon anglers.

Interviews began with questions designed to help categorize angler typology (i.e., fishing behaviors) with conventional segmentation variables (e.g., fishing experience and avidity, target species, fishing location preference). We asked respondents to rate whether they were “not aware”, “somewhat aware”, or “very aware” of various handling and revival techniques. We also asked respondents to describe their catch-and-release and revival techniques, followed by questions regarding their awareness and use of selected catch-and-release best practices for Pacific salmon. We used the Canadian Department of Fisheries and Oceans (DFO) best catch-and-release practice guidelines given that they were available online and in the recreational fishing regulation guide. In addition, we included the use of circle hooks as a potential catch-and-release conservation tool, a measure not yet part of DFO guidelines, but under review for potential implementation (DFO, 2012).

Insights from the value-belief norm theory (Stern et al., 1999) suggested that anglers’ support for particular conservation regulations or adoption of responsible fishing practices should be affected by the salience of perceived threats to migrating salmon and the degree to which anglers perceive their personal behavioral or financial sacrifices to have an effect on salmon survival. As such, respondents ranked the top three risks to post-release survival of incidentally caught salmon they perceived to be most important. The 12 possible options we presented included: air exposure; [lack of] angler experience; beach dragging; capture location in river; fight time; fishing technique used; hook location; predation density; revival efforts; warm water temperatures; ‘do not know’; and other. Finally, we asked open-ended questions that queried anglers about their general thoughts regarding angler education programs, whether there was a need for angler education programs, and whether participation in education programs should be required in order to obtain a fishing license. Standard socio-demographic data (age, gender, ethnicity, education, occupation, and household income) was collected, as well as information about fishing and hunting club membership, self-reported knowledge of fisheries management, and importance of fishing to anglers’ lifestyle (i.e., Buchanan, 1985; Sutton and Ditton, 2001).

3.2. Sample frame and survey delivery

We defined our sample frame as age 18+ recreational anglers who were active in the Pacific salmon recreational fishery in the lower Fraser River. We used opportunistic sampling as an exploratory method for selecting study sites. As such, we visited the majority of accessible and busy fishing sites and boat launches during the 2010 sockeye harvest recreational fishery (August 9 – September 19, 2010). This enabled us to sample a large number of on-site anglers and target those actively engaged in salmon fishing. We acknowledge that this sampling method may not include remote sites that are accessible only by boat or known to few anglers. Due to safety concerns, time and resources constraints, we could not survey all anglers and be on fishing sites at all times (e.g., at dawn). We sampled anglers at 17 different fishing sites, primarily between the towns of Mission (49°N, 122°W) and Hope (49°N, 121°W) (Fig. 1). This stretch of the river is considered to be the non-tidal recreational fishery and is the focus of the majority of recreational fishing effort in the lower Fraser River. We visited fishing sites every day from approximately 07:00 until 17:00 between July 30 and August 26, 2010. Sampling period was slightly earlier than the salmon sockeye season because openings were announced in real-time and there was no certainty that there would be a season for sockeye. The first few interviews were conducted as pre-tests and allowed time for the interviewer to familiarize with the respondents and study sites. High-use sites were revisited periodically to maximize the number of anglers that we could interview per sampling day. We attempted to interview every second angler along the river to randomize responses. However, we also paid attention to timing and opportunities, approaching anglers taking a break, fixing their gear, or who were finished for the day. At boat launches, anglers were approached at the end of their fishing trip as anglers tended to decline interview requests when approached before their fishing trip. With angler consent, all interview responses were noted and audio recorded.

Four versions of semi-structured interviews were administered to minimize the interview length for individuals. All versions included the same closed-ended questions (i.e., demographics, threat perception rankings, fishing practices) while the open-ended questions were different for each version of our semi-structured interviews. Each focused on different issues/themes of interest to fisheries managers and researchers: education programs; effects of maturity and capture location on post-release survival; support for fish revival gear; and angler awareness on DFO published catch-and-release techniques for Pacific salmon (see Appendix A in the online supplemental information for interview guide). As such, although we interviewed over 300 respondents in total, only a proportion of the sample answered each of the four sets of open-ended questions. Two researchers conducted the interviews; the lead interviewer administered three of the four survey versions, and the secondary interviewer focused only on the angler awareness on catch-and-release techniques.

3.3. Data analysis

Questions about angler awareness of catch-and-release best practices were qualitatively assessed to provide context and understanding of current awareness and use of catch-and-release practices. We summarized common themes and patterns in responses for open-ended questions, and noted alternative responses (Patton, 1990). Open-ended questions relating to angler support for education programs were manually transcribed and coded following standard qualitative research protocol (e.g. Strauss, 1987; Creswell, 2009) by the lead interviewer. Codes were developed according to emergent themes based on keywords, phrases, and topics raised by anglers. Consistencies between codes (similar topics) revealed categories that identified angler support for education programs. Coded themes were subsequently used as indicator variables in our latent class cluster analysis.

Latent class (LC) cluster analysis (Vermunt and Magidson, 2002) is an exploratory, probabilistic cluster analysis technique that can group items that share similar underlying characteristics into "classes". It identifies unobserved (latent) class membership using information from a set of observed variables (indicators) that imperfectly measure underlying true class membership. The probabilistic LC clustering methodology minimizes within-cluster variation while maximizing between-cluster variation (Vermunt and Magidson, 2007), an advantage compared to arbitrarily-defined traditional clustering methodologies. The LC approach has been applied in social science, tourism, and marketing research but is relatively novel in the conservation field (but see Morey et al., 2006; Ward et al., 2008). Here, we apply LC clustering to angler characteristics, attitudes, and behaviors, seeking to identify the factors that define their heterogeneity. Here, we use this method as a segmentation tool to identify angler subgroups within a population, where predictor variables typically used for identifying specialization are used in an exploratory manner that permit the data to identify potential angler classes (i.e., subgroups) without a hypothesis.

Information criteria diagnostics are typically used to identify parsimonious LC models, often in conjunction with other measures of fit (e.g., Morey et al., 2006; Ward et al., 2008). We used the Akaike Information Criterion (AIC) and tested local independence between indicators using bivariate residuals. Significant bivariate residuals ($\chi^2 > 3.84$, 1 d.f., $p < 0.05$) indicated that our assumption of local independence between variables was violated. Functionally, that meant that two or more indicators provide redundant information not useful for angler segmentation. Note that redundancy between two indicators does not mean that one is necessarily 'unimportant' to anglers; both are simply not necessary to identify heterogeneity in the sample. We eliminated those indicators with the most and largest bivariate residuals sequentially when they were significant (see Appendix B in the online supplemental information for diagnostic measures of all LC models). Additionally, if AIC did not present a clear 'best' model, the final LC model was chosen based on logic, analyst/interviewer experience and judgment, and weighted information gained or lost with the addition or removal of classes (Scarpa and Thiene, 2005). Latent Gold software (Vermunt and Magidson, 2005) was used to estimate all LC models. Lastly, for each LC model, we used posterior probabilities from the LC analysis to assign each angler to the various classes in which they had the highest probability of membership and tested for correlations between classes and among LC models using Spearman rank correlation and Fisher's exact tests (PASW 18.0). Additional analyses exploring the influence of *fishing behaviors and preferences* and *risks to post-release survival* models on the awareness and application of catch-and-release techniques as well as support for education programs are found in Appendix C of the online supplemental information. Differences in awareness and application of catch-and-release techniques were not assessed for the *angler education support* model because we used different survey versions and not all of them contained the full suite of data needed for such analyses.

Latent classes were derived based on response patterns to survey questions; we did not use demographic or other covariates in the LC cluster analyses. Chi-square tests (Bonferroni adjusted) were subsequently used to identify demographic and professional characteristics predictive of LC membership patterns (Magidson and Vermunt, 2005). Covariates tested as predictors of LC membership included standard socio-demographic characteristics, self-reported management knowledge, fishing organization membership, and importance of fishing to one's lifestyle, which was measured on an adapted 5-point scale from Sutton and Ditton (2001) 4-point scale. The Chi-Squared Automatic Interaction Detection (CHAID) software (Magidson, 2005) was used to systematically test all possible combinations of covariates and identify any that were statistically significant.

We examined three LC models (Table 2): (A) *fishing behaviors and preferences model*, which was based on indicator variables relevant to fishing behavior (fishing experience, days fished in last 12 months, site access, other [than salmon] target species, and proportion of non-tidal fishing); (B) *risks to post-release survival model*, which used the top three perceived threats to fish survival after handling as indicator variables; and (C) *angler education program support model*, based on response patterns from relevant coded open-ended questions.

4. Results

4.1. Survey response and respondent characteristics

We approached 395 recreational anglers on fishing sites and boat launches of the lower Fraser River. A total of 311 respondents (79%) consented to be interviewed; their socio-demographic characteristics are summarized in Table 1. Twenty five of 84 non-respondents declined to participate because they had “no time”, 22 were “not interested”, and 14 spoke too little English to participate. Twenty three declined for other (or no) reasons. The demographic profile for the overall population of Fraser River anglers is unknown, so it was not possible to test if our sample was representative of the entire population.

4.2. Angler awareness and use of responsible fishing techniques

Of the 311 respondents interviewed, 89 were queried on catch-and-release techniques and awareness of DFO recommendations. All respondents were very aware of barbless hooks and all use barbless hooks in the Fraser salmon fishery (Fig. 2). There was generally a very high level of awareness and application of catch-and-release practices identified by DFO. However, we found a relatively low level of awareness and application for: avoiding sunscreen when handling fish; using a soft knotless dip net; using large lures during catch-and-release to avoid catching undersized fish; and use of circle hooks (Fig. 2). In terms of revival techniques, over 90% of anglers were both aware and have used the technique of holding fish until they swim away. Over 84% of anglers were aware of and had used the “rocking back and forth” revival technique prior to releasing fish.

Prior to assessing angler awareness of DFO catch-and-release recommendations, we asked respondents to qualitatively describe their own approach to catch-and-release. Most respondents (69% of 86 responses) described keeping and unhooking fish in the water and 27% stated that they avoided or minimized touching the fish. Only four of the interviewed anglers described landing fish on shore/rocks (i.e., beaching or beach dragging) to identify fish, to stay dry, or to take a photo. Fish were described as being held by the tail, the tail and belly or just behind the gills to restrain struggling, and a couple of respondents use the leader to control the fish or use a “buddy system”, where one removes the hook while the other angler holds the fish. There were contradicting descriptions regarding fight times. A majority of respondents (67% of 24 responses) described reeling captured fish in as quickly as possible to minimize fight time, but some described “bringing it in smooth and gently” or to “play according to the fish” or tire the fish “to take the hook out more easily”. Fifty-six percent (of 62 responses) reported using pliers to remove a hook, while seven anglers used a release tool. Less than 10% of respondents mentioned using a dip net during a catch-and-release event and three described using gloves to handle fish. Fourteen respondents did not use any tools; some explained that because barbless hooks are used, there is no need for tools to remove the hook.

There were two major revival techniques described by anglers in our study. The first was to hold fish facing upstream until it “swims or kicks away” (described by 47% of 83 respondents) and the second involved moving fish “back and forth” with the intent of increasing oxygen over the fish’s gills (39% of 80 respondents). Less than 10% (7 respondents) do not revive fish primarily because they did not know how and one person stated that revival does not work. Two respondents said that they “torpedo” and “plunge” fish into the water or “move” or “wiggle” the fish in the water by its tail.

Table 1
Socio-demographic and other covariates, and fishing characteristics of the Fraser River recreational sockeye salmon angler sample.

Socio-demographics and other covariates	Number of respondents	Percentage (%)	Socio-demographics and other covariates	Number of respondents	Percentage (%)	Angler typology variables	Number of respondents	Percentage (%)
Gender ($n = 311$)			*Income in Canadian \$*[a] ($n = 241$)			*Fishing experience* ($n = 311$)		
Female	19	6.1	<\$50,000	73	23.5	<5 yrs	28	9
Male	292	93.9	\$50,000–99,999	23	7.4	5–9 yrs	31	10
Age ($n = 311$)			\$100,000–149,999	52	16.7	10–14 yrs	28	9
<20 years	9	2.9	\$150,000–200,000	14	4.5	15–20 yrs	29	9.3
20–29 years	40	12.9	>\$200,000	6	1.9	>20 yrs	195	62.7
30–39 years	51	16.4	Prefer not to answer	73	23.5	*Avidity: how many days did you fish in the last 12 months?* ($n = 311$)		
40–49 years	66	21.2	*Occupation* ($n = 263$)[b]			<10 days	93	29.9
50–59 years	75	24.1	White-collar	67	25.5	10–29 days	77	24.8
60–69 years	43	13.8	Blue-collar	114	43.3	30–50 days	67	21.5
>70 years	27	8.7	Service industry	22	8.4	>50 days	74	23.8
Education ($n = 311$)			Student	9	3.4	*Site use and access* ($n = 302$)		
No high school	12	3.9	Retired	45	17.1	Paved and easy access	107	35.4
Some high school	32	10.3	Un-employed	6	2.3	Hike and difficult access	109	36.1
High school completion	125	40.2	*Fishing club membership?* ($n = 310$)			Boat access only	56	18.5
Post-secondary	126	40.5	Yes	32	10.3	Camping on site	21	6.9
Post-graduate	10	3.2	No	278	89.7	*Other target species* ($n = 288$)		
Incomplete	6	1.9	*Importance of fishing* ($n = 311$)			Sockeye only	82	28.5
Ethnicity ($n = 310$)			Very low importance (1)	13	4.2	Other salmon species	21	7.3
Asian	55	17.7	Low importance (2)	25	8	Single FW species	115	39.9
Caucasian	230	74	Neutral (3)	79	25.4	Multiple FW species	45	15.6
European	21	6.8	High importance (4)	77	24.8	Single SW species	9	3.1
Other	4	1.3	Very high importance (5)	117	37.6	Multiple SW species	5	1.7
Knowledge of management decisions and strategies ($n = 310$)						Anything	11	3.8
Low (1)	128	41.3				*Location: % of non-tidal fishing* ($n = 298$)		
Moderate (2)	122	39.4				<25	76	26
High (3)	60	19.4				25–75	99	33
						>75	123	41

FW = Freshwater, SW = Saltwater.
[a] \$1.00 Canadian = \$0.9614 USD (13 August 2010).
[b] Some definitions for occupation categories found in Appendix A of the online supplemental information.

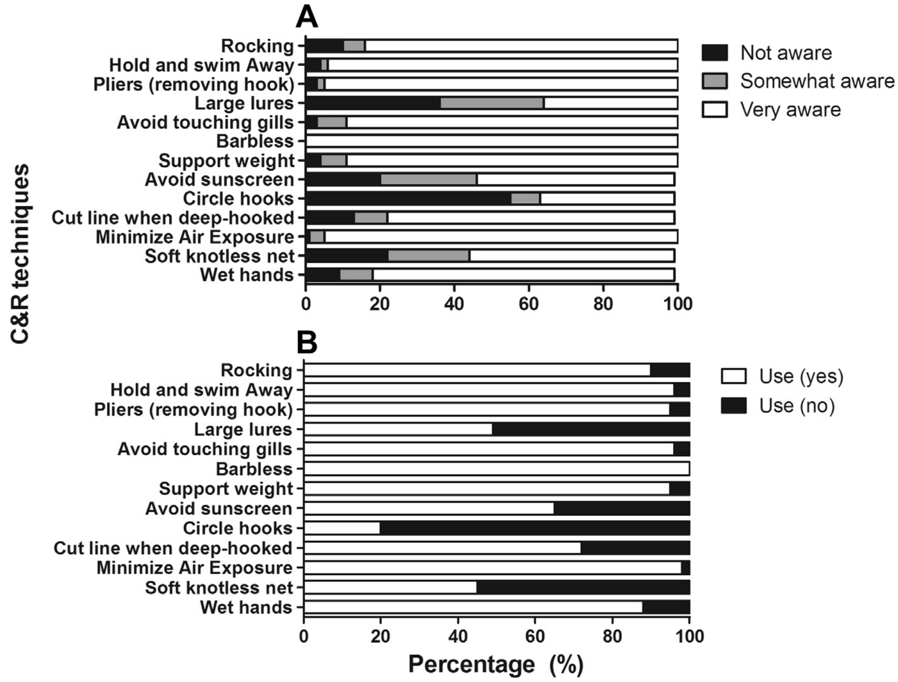

Fig. 2. Rating responses (%) of interviewed anglers ($N = 89$) who were "not aware", "somewhat aware" and "very aware" of selected Department of Fisheries and Oceans' recommended catch-and-release techniques (A); and the application of these techniques (B).

4.3. Model A: fishing behaviors and preferences

Our first LC model, *fishing behaviors and preferences*, used data on anglers' ($n = 287$) experience, avidity, fishing preferences (i.e., location, target species other than salmon), and site use and accessibility, to categorize anglers according to their fishing behavior, practices, and orientation. AIC was minimized with a 3-class LC model. No significant bivariate residuals were detected, so the final *fishing behaviors and preferences* model retained five indicators in total: days fished in last 12 months; number of years fishing; other target species; proportion of non-tidal (i.e., freshwater) fishing; and site access. Based on their patterns of recreational fishing, we labeled anglers (Fig. 3) as *lake-species specialists* (46%), *salmon-only anglers* (33%), or *all-around anglers* (21%).

Lake-species specialists specialized in fishing freshwater species (mainly trout) and preferred fishing in lakes. They fished often and a large proportion hiked to fishing sites or camped out, which suggests that they may seek activity-general experiences (e.g., enjoying outdoors) in addition to angling. *Salmon-only anglers* fished primarily for Pacific salmon (including steelhead, *Oncorhynchus mykiss*) and were not active compared to others, fishing mainly during salmon season. Lastly, *all-around anglers* had a high level of commitment to fishing (i.e., high fishing frequency and experience), targeted a broad range of species, and were more likely than anglers in other classes to own or have access to a boat (Table 2). We did not detect any significant demographic predictors of LC membership in this model.

4.4. Model B: risks to post-release survival

Beach dragging made up 18% of the responses chosen as one of the top three greatest risk to post-release fish survival. This was followed by angler's experience (14%), hook location (14%), air exposure (13%), fight duration (13%), revival efforts (8%), water temperature (7%), and fishing technique (7%). Predation density, capture location in river, and other factors were chosen by less than 2% of respondents.

The final LC analysis minimized AIC with a 4-class model (Table 2). Three indicators (fight time, beach dragging, and angler experience) were sequentially removed from the model until all significant bivariate residuals were eliminated. Our final *risks to post-release survival* retained nine indicators: water temperature; air exposure; revival effort; hook location; predation density; technique used; capture location in river; 'do not know'; and 'other'. The four classes (Fig. 4), which we labeled according to the most prevalent perceived risk, were: *air exposure* (39% of all respondents); *warm water temperature* (24%); *hook location* (22%); and *revival effort* (15%). Again, we found no significant demographic predictors of class membership.

4.5. Model C: angler education program support

Participants were asked about their attitudes on education programs that taught responsible fishing in the *angler education program support* model. Five general themes were coded from open-end angler responses: (1) negative protests responses (7%), responses that were negative but did not address the issue at hand (e.g., they simply criticized fisheries management); (2) negative but legitimate responses (3%) that were negative for reasons reflecting the issue (e.g., education programs were not perceived to be helpful); (3) neutral (10%) response; (4) positive conditional (13%) responses that were positive but given a condition (e.g., education programs for first-time license buyers only, offered for free, or for children), and; (5) fully positive (65%) that included for example responses such as "it's a really good idea, like the boating certificate… [because there] are lots of fishers who don't know what they are doing."

Note that 82% of respondents believed there was a need for education programs in some form. When, however, asked to describe their support for mandatory education programs prior to obtaining a fishing license, respondents were more negative. Negative responses emphasized licensing as "a money grab", that "charging to learn how to fish will deter people from wanting to enjoy the outdoors", that there are "are other people around to give advice", and that training

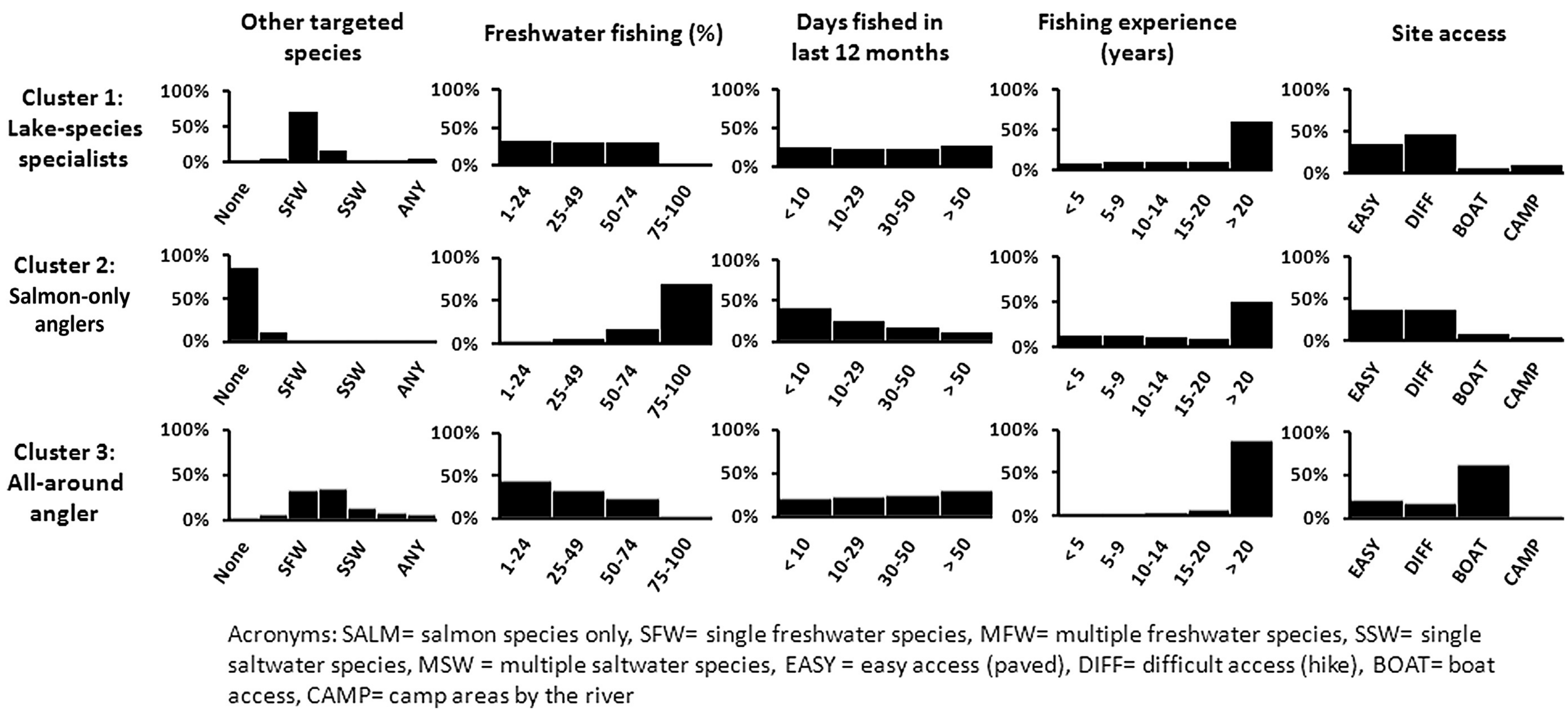

Fig. 3. Latent class membership profile illustrating the coded responses (*X*-axis), and probability (%) of responses for the three *fishing behaviors and preferences* classes (*Y*-axis) to the relevant interview questions.

Table 2
Summary and description of the latent class models. No significant predictor variables were detected.

Model		Questions	Indicator used for classification	N	Class label	%	Class description
A	*Fishing behaviors and prefe-rences*	Fishing experience, fishing days in last 12 months, site access, other targeted species, % non-tidal/freshwater fishing,	Segmentation variables: fishing experience, days fished in last 12 months, site access, other target species, non-tidal fishing	287	Class 1: lake-species specialists	46	- Prefer fishing in lakes. Primarily fish for trout. Fish numerous days per year.
					Class 2: Salmon-only anglers	33	- Primarily fish for salmon species. Fish very few days per year
					Class 3: all-around anglers	21	- Fish both fresh- and saltwater species. Very experienced and avid. Likely to own or have access to a boat.
B	*Risks to post-release survival*	Rank the top three factors (of 10) you believe has the greatest influence on whether incidentally caught fish released will live or die.	Air exposure, capture location in river, fight time, fishing technique used, predation density, revival effort, warm water temperatures, I don't know and other	287	Class 1: air exposure focus	39	- 98% perceive air exposure as a major influence with some concerns with fishing technique, water temperature and revival.
					Class 2: water temperature focus	24	- 57% perceive water temperature as a major influence with some concerns with fishing technique, revival and capture location.
					Class 3: Hook location focus	22	- 97% perceive hook location as a major influence to survival with some concerns with fishing technique, revival and capture location
					Class 4: revival focus	15	- 95% perceive revival and 48% hook location as major influences.
C	*Angler education program support*	1) What are your thoughts on angler education programs that focused on responsible fishing? 2) Should participation in education programs be required to purchase a fishing license?	1) Thoughts on education program: negative[b] neutral, positive[c]; 2) Need for education program: yes, no; 3) Support for mandatory education programs: No support[3], Support[b]	61[a]	Class 1: supporters	73	- Positive attitude towards angler education programs, generally believe there is a need for education programs and supportive of mandatory implementation
					Class 2 non-supporters	27	- Primarily believe there is no need for angler education programs, showed more neutral attitude towards the idea of education programs and primarily unsupportive of implementation of education programs

[a] Sample size is a result of this model being based on open-ended questions and the questions presented in 1 of 4 interview versions only.
[b] Includes negative protest and negative legitimate.
[c] Includes fully and conditional.

is not required "to catch a little food". Coded responses for mandatory education program consisted of: negative protest responses (10%); negative but legitimate (20%); negative conditional (16%), who are those unsupportive but open to change; neutral (1%); positive conditional (19%); and positive fully (33%). Anglers who gave alternative and conditional responses, included statements such as: "I would much rather see the money go into fisheries management functions like habitat protection or research. Fisheries agencies have a tendency to spend a large portion of their budget on consultation and when they get through with that, they don't have any money left to do the real work". Some respondents suggested a small quiz was more suitable than a formal education program or that educational programs should be grandfathered in for the younger taking up fishing and taken only once in a lifetime.

Anglers were also asked to suggest themes and topics to be taught in an education program and the most frequent responses (in order from most to least) included: appropriate release/handing/revival techniques; river and fishing etiquette (e.g., norms and informal rules); fishing techniques; species identification; regulations; conservation; and "other" (e.g., how management make decisions, differences between hatchery and wild fish, salmon biology and welfare, river safety, population estimates). Here, two or more themes could be associated with one respondent.

A 2-class LC model minimized AIC and there were no significant bivariate residuals. The two classes (Fig. 5) were labeled as *supporters* (73%), who included respondents that believed there was a need for education programs and were supportive of mandatory implementation, and *non-supporters* (27%), who were skeptical of the need

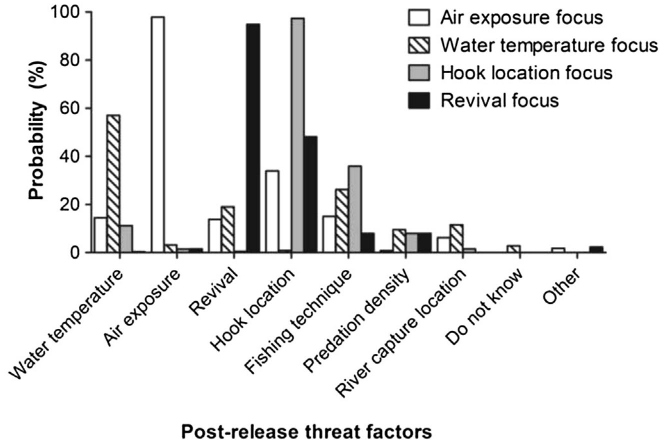

Fig. 4. Latent class membership profile for 4-class *risks post-release survival* model with illustration of the probability of response (%) for each class.

for education programs and all, had negative thoughts about mandatory education programs. We did not detect any significant demographic predictors of educational program support.

4.6. Model correlations and comparisons

When we tested whether angler latent class membership was correlated across models, we found no significant correlations among anglers' fishing behaviors and preferences, perceived effects of fish handling on post-release survival, nor angler education program support models (Appendix C: Table 3, in the online supplemental information). Although it appears that *lake-species specialists* class is more likely to use catch-and-release techniques (Fig. 6b), only the use of 'cutting the line' when a fish is deeply hook ($N = 85, p < 0.05$) was significant. Furthermore, *salmon-only anglers* self-reported a greater percentage of "not aware" responses to the list of catch-and-release best practices than the other angler classes (Fig. 6a); however, this trend was not significant.

5. Discussion

Our exploratory study used a combination of quantitative and qualitative data to explore angler attitudes and behaviors relating to responsible catch-and-release recreational fishing in the seasonal harvest-oriented sockeye salmon fishery. We applied a latent class modeling approach to differentiate anglers based on their fishing behaviors and preferences, perceived risks to post-release survival of salmon, and their support of angler education programs.

5.1. Angler awareness and use of recommended catch-and-release practices

Overall, anglers' awareness of DFO-recommended catch-and-release practices in our study was relatively high, with the exception for circle hooks and the use of large lures. Circle hooks are meant to prevent "deep" or "gut" hooking (i.e. fish ingesting the hook; Cooke and Suski, 2004), while using large lures can presumably prevent catching undersized fish and may also reduce deep hooking (Arlinghaus et al., 2008). It was not surprising that anglers were less aware of these techniques given that sockeye salmon stop feeding during their upriver migration and the primary method to hook these fish is through "snagging" rather than baiting as well as the obvious reason that majority of fish are harvested. This notion is further supported by the general trend that the *salmon-only anglers* reported greater lack of awareness in the catch-and-release techniques recommended, due to the likeliness that these anglers primarily fish for consumption, and participate in more harvest-oriented fisheries. Both awareness and use of each technique were relatively consistent, indicating some influence of awareness on the use of these techniques. However, this was not empirically tested and some form of bias may exist from self-reporting (Bertrand and Mullainathan, 2001) "recommended" fishing techniques, which have been observed in self-reported catch and harvest rates from mail surveys (Roach et al., 1999).

To increase reliability of angler responses to the awareness and application of recommended techniques, we asked anglers to

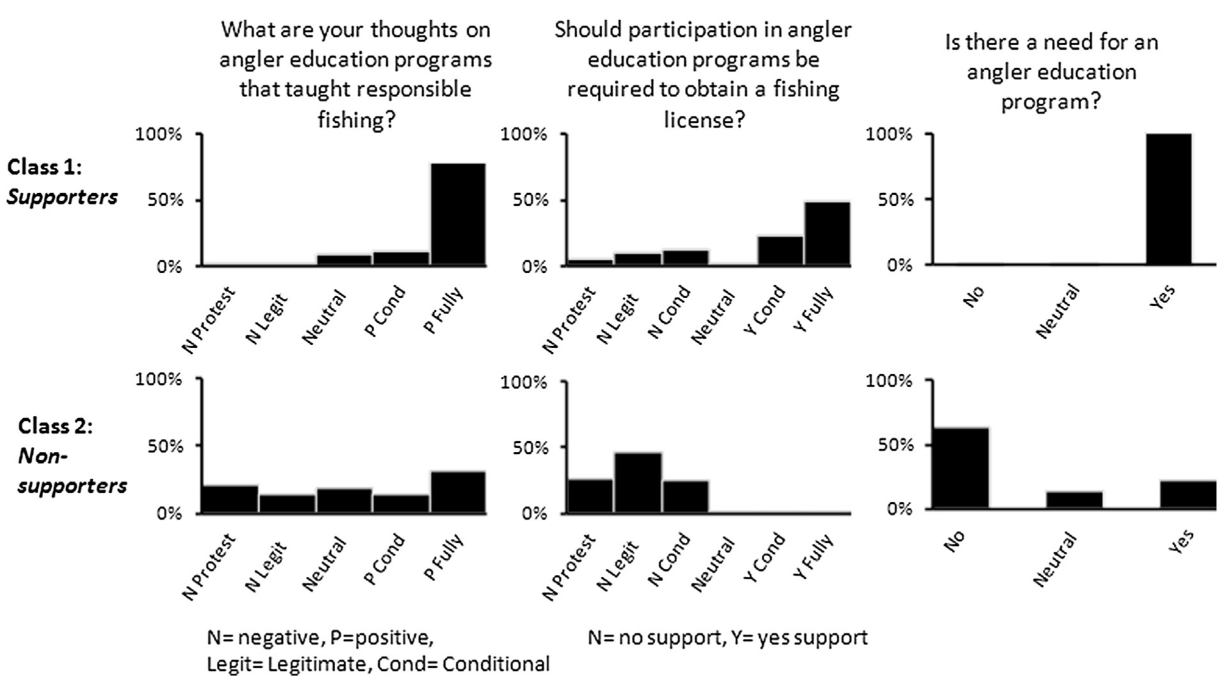

Fig. 5. Latent class membership profile for 2-class *angler education program* support model with the probability of responses (%) for each class and coded responses to interview questions.

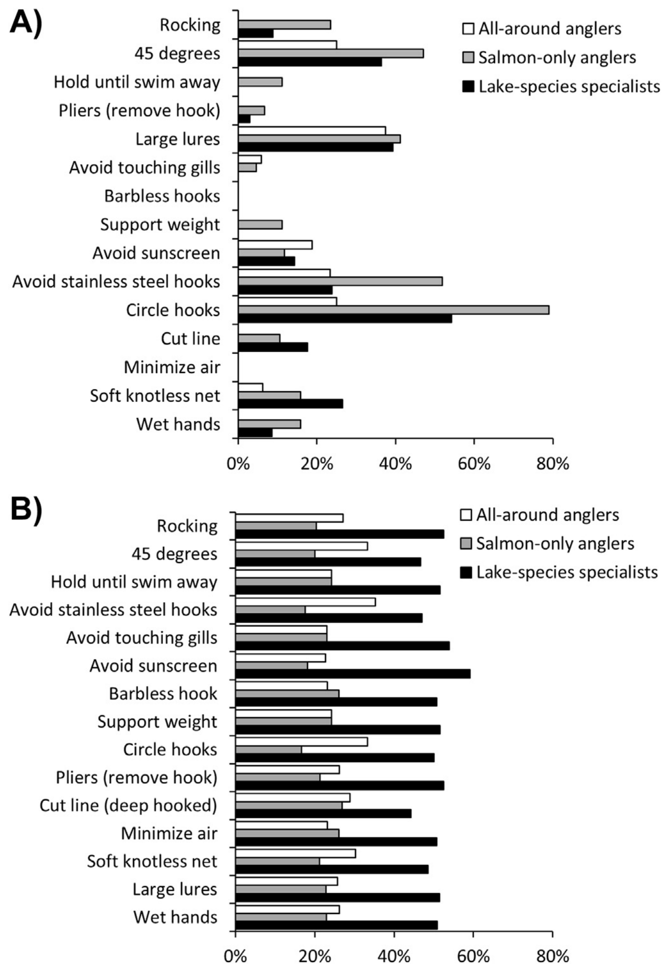

Fig. 6. Self-reported response frequency (%) of interviewed anglers who were "*not aware*" of selected Department of Fisheries and Oceans' recommended catch-and-release techniques (A); and frequency of self-reported application of these techniques (B) broken down by classes identified in the *angler fishing behaviors and preferences* LC model (all-around anglers, salmon-only anglers, and lake-species specialists).

describe their own catch-and-release methods prior to rating the list of DFO-recommended techniques. Most interviewed anglers accurately described responsible fishing techniques; however, the most prominent responses that were inconsistent relative to DFO guidelines were found regarding playing/fight time, the use of gloves, holding fish behind the gills or behind the head, and the inconsistent revival techniques used among anglers. Other independent sources of information are also used by anglers to obtain responsible fishing information, such as various independent websites, forums and blogs; tackle shops; printings (e.g. magazines, books, leaflets); fishing clubs; media (e.g. television, videos), and informal communication among anglers (Nguyen et al., 2012). These information sources can potentially influence angler knowledge and actions.

Inconsistencies also exist among natural resource agencies and contemporary scientific literature (Pelletier et al., 2007). DFO recommends that: "if the fish is exhausted, revive it in the water by keeping a grip on its tail; move it back and forth slowly to increase water flow over the gills." This is not recommended scientifically because water must pass through the fish's mouth and exit via the opercula in the opposite direction to produce a gradient that drives oxygen transfer, and efficiently transfer oxygen from the water to its blood (Gilmour, 1997). As such, the back and forth resuscitation does not optimize oxygen uptake and could potentially harm the fish. This is of concern since 84% of interviewed anglers have noted that they have used this technique. The other common revival technique is to hold fish pointed upstream with their mouth into the water flow until they swim away – a method that remains to be validated as it may be more consistent with basic physiological processes.

5.2. Model A: Fishing behaviors and preferences

We identified angler typologies that cleaved apart primarily by their *site use* and *non-salmon fishing activities* (other target species and lake fishing). This suggests that the primary underlying difference among these salmon anglers is their participation in other forms of fishing and could imply that this particular seasonal fishery attracts a number of different 'types' of anglers from other fisheries and that may be associated with different subcultures (e.g. fly fishing, catch-and-release anglers, boat anglers, consumptive anglers, etc.). Beardmore et al. (2011) illustrated that angler motivation in Germany varied with target species. German anglers targeting Atlantic herring, *Clupea harengus,* (a seasonal fishery) had consumptive motives, whereas small-bodied and abundant coarse fish (i.e. roach; *Blattaria* spp. and bream; *Acanthopagrus* spp.) were sought by anglers who wished to enjoy nature. Consequently, it appears that anglers' motives are dynamic and can shift in response to changes in target species or fishing activities. Clearly, salmon anglers on the Fraser River are not a homogeneous group despite participating in a specific sockeye sport fishery in a discrete location and period.

The heterogeneity of Fraser River sockeye anglers could have implications for management where different angler subcultures and specialization levels (Bryan, 1977) bring different skill sets, values and preferences, which can influence their behavior and response to management initiatives and efforts to increase conservation-oriented/responsible fishing behaviors. For example, the *salmon-only anglers* appear to engage in only one form of "utilitarian" fishing and may be the "true" salmon anglers. The highly specific activity and commitment of *salmon-only anglers* can play a role in their willingness to support restrictive harvest regulations. Sutton and Ditton (2005) described low willingness of an angler to substitute one type of fishing for another for individuals who place high importance on activity-specific motivations (i.e. experience of the catch, catching to eat, catching trophy fish, etc.) as well as those with monetary investment and strong emotional attachment to the activity. Also, Dorow and Arlinghaus (2012) observed that highly committed German eel anglers were less likely than other anglers to limit their fishing activities for conservation of eels, which was explained by greater resource dependency and their perception that recreational harvest has little impact on eel populations. Highly committed anglers in harvest-oriented fisheries have been found to be less willing to accept constraining harvest regulations (Dorow et al., 2010; Dorow and Arlinghaus, 2012), and reduced access to the resource (Salz and Loomis, 2005; Dorow et al., 2010). As such, from a management perspective, *salmon-only anglers* likely have low fishing type substitutability (Sutton and Ditton, 2005) because of the lack of engagement in other fishing activities and higher level of commitment to the salmon fishing (Ditton and Sutton, 2004), and may therefore be more impacted than other groups when salmon fishing regulations are changed. On the other hand, *lake-species specialists* and *all-around anglers* engage in various forms of fishing and may respond to management restrictions more positively due to the enjoyment they derive from fishing other species and simply the fishing experience (also known as activity-general motivations; Ditton and Sutton, 2004). This, however, is speculative and greater research is needed to assess whether angler behavior varies among fisheries (e.g. species, technique) and with motives (Beardmore et al., 2011).

5.3. Model B: perceived risks to post-release survival

Four classes were identified in the *risks to post-release survival* model. Understanding underlying beliefs and values can be insightful for natural resource managers for constructing conservation strategies and engaging angler groups in more effective manners (Fulton et al., 1996; Stern, 2000; Bruskotther and Fulton, 2007, 2008). Overall, no single threat factor appeared to be prominently distinguished by respondents as the most influential factor on post-release survival of fish. The fact that water temperature, an environmental factor, was chosen by 7% of interviewed anglers suggests that the majority of anglers (the remaining 93%) are aware that their own actions have consequences on the fate of released fish – an encouraging result and opportunity for improved education.

With our latent class model, differences and similarities in angler perceived risks to post-release survival of salmon are illustrated in a more visual and tangible manner, allowing managers to focus on ‘segments/subgroups’. These classes shed light on what anglers believe to be the most important steps in a fish capture event. For example, *air exposure* class members emphasize time from landing to hook removal and keeping fish in water is critical, whereas *hook location* members may believe foul-hooking is harmful to salmon, and so on. This information is important for understanding potential support for, and compliance with, measures relating directly to fish capture, handling, and release practices, all of which have the potential to influence fish welfare and post-release survival (Arlinghaus et al., 2007). These classes reveal alternative ways for managers to approach adaptation strategies for angling in the face of climate change. In the face of climate change, the *water temperature* class may likely be more supportive of closures and restrictive regulations during high temperatures. The remaining groups believe that threats can be ameliorated at the individual level, who can make investments that cost money (e.g. investment in recovery bags to permit fish a prolonged recovery period prior to release) or time (e.g. learning about improved handling procedures or changing fishing techniques using circle hooks) to reduce fish stress and mortality. We suggest that assessing the underlying values and beliefs of resource users and stakeholders in general, is a good step-wise approach that can be useful to various natural resource management cases, especially with a larger sample size that could potentially increase the power of detection for significant predictor variables or correlation of certain beliefs with certain behaviors.

5.4. Model C: support for angler education programs

The decrease in positive responses from asking anglers their thoughts on education programs (in general) to more negative responses toward mandatory angler education programs indicate that encouraging education or promoting awareness is likely more successful than implementing “mandatory” programs. Examples of mandatory angler education programs are found in some European countries, such as Germany (von Lucowicz, 1998), Poland (Polsi Zwiazek Wedkarski, 2012), and potentially Austria. No evaluations of its effectiveness have been found in the literature. Here, the negative responses regarding mandatory education programs suggest that imposing such programs could deter participation. These findings were consistent with a snow-ball internet survey of anglers in North America where 52% of respondents disagreed with the need for courses on mandatory training in responsible fishing practices (Hasler et al., 2011). Fostering voluntary participation in education and stewardship may be the preferred alternative to mandatory angler education programs in the Fraser River salmon fishery. Cooke et al. (in press) argued that informal institutions and associated public outreach, awareness, and education can improve the effectiveness of formal institutions and regulations by increasing compliance. Additionally, voluntary regulations and informal institutions, such as adoption of conservation-oriented gear (like barbless or circle hooks) or voluntary creel or size limits, can even be alternatives to the formal institutional and regulatory approaches that are often costly and require enforcement to be effective (Walker et al., 2009). In many cases, these initiatives have been developed in cooperation with stakeholders or even initiated and led by stakeholders. One successful case include voluntary black bass season and area closures (voluntary conservation zones) established by conservation-oriented residents of three eastern Ontario lakes to provide additional protection for spawning individuals. The success of these ‘voluntary conservation zones’ can be attributed to the social norms and peer pressure that were set by the local residents. Additionally, although we did not test this empirically, it is worth noting that the relationship between angler type and regulation support has been found to correlate with angler specialization level (Bryan, 1977; Ditton et al., 1992) due to the greater dependency on the resource and greater awareness of threats to the fish population. However, some contradictions have been noted where advanced or more specialized anglers were less supportive of stricter regulations than more casual anglers (e.g., Dorow et al., 2010; Dorow and Arlinghaus, 2012; Salz and Loomis, 2005). Nonetheless, there exists little peer-reviewed research (but see Cooke et al., in press) on the transaction costs of voluntary stewardship versus mandatory regulations in fisheries management. Considering that voluntary stewardship was preferred in our study, we suggest that greater empirical research should focus on the trade-offs and successes between voluntary and mandatory regulations (see Cooke et al., in press), which will ultimately help managers construct cost effective and successful conservation initiatives.

Moreover, a number of respondents were willing to conform if certain conditions or alternatives were considered, such as the program being a “one-time only”, or “a small quiz”, or being “grandfathered in”. Management should consider angler alternatives to develop appropriate education programs that also consider angler interests, and increase the likelihood of adoption. Here, our LC model (Fig. 5) shows that the most evident differentiation between *supporters* and *non-supporters* was the perceived need for an education program and the strong objection for mandatory programs by *non-supporters*. This is useful for managers as it highlights that the lack of support for this kind of initiative comes from underlying beliefs and perceptions of angler education. As such, fisheries managers need to understand angler perceptions and also consider opportunity costs for investments in education and outreach programs as they can be costly in terms of time, resources, and maintenance.

5.5. Can we predict angler responses?

Overall, our findings revealed a complex matrix of motivational and behavioral dimensions that create substantial diversity among the Fraser salmon angler population. It is unlikely to predict responses of anglers to management initiatives based on simple socio-demographic information (Fedler and Ditton, 1994). Instead, we preferred an approach that gathered psychometric data to quantify the latent constructs underpinning angler responses and explored class membership which could reveal interesting associations with measurable environmental behavior or socio-economic covariates. This is a growing approach found in the environmental economics literature for predicting consumers/recreationists' behaviors and choices (e.g., Boxall and Adamowicz, 2002; Scarpa and Thiene, 2005; Scarpa et al., 2007), and could potentially be a useful avenue to explore from a conservation angle. Although we failed to identify any associations among our psychometric data, socio-economic covariates and latent class membership, we argue the heterogeneity identified calls for a nuanced approach to management interventions. This poses a challenge for fisheries managers because they will need to consider customizing conservation initiatives by targeting angler segments rather than the fishing community as a whole. Furthermore, it is possible that our in-person coverage compromised our sample size, and that perhaps with a much larger sample (>500 respondents) gathered using greater number of interviewers or a longer sampling period, correlations could be detected among predictor variables and angler classes.

While we acknowledge that interviews may be biased toward English-speaking anglers and those who use accessible fishing sites, our extensive in-person coverage of primary shore-based fishing sites and boat launches helped ensure that our results captured in-depth perspectives from a wide array of active recreational angler. These are the active anglers that have potential to affect conservation outcomes of interest to fisheries managers. Still, as with any social science study, our findings are highly dependent on the context of the research and caution should be taken when applying them to other angler populations or contexts. While latent class model validity, reliability, and power could be improved with a larger sample, we argue – based on our extensive interviews in 2010 and interactions with anglers by our research team over the past three years – that the distinct behaviors and attitudes expressed in our sample of active Fraser River salmon anglers are relatively stable and capture core factors affecting angler heterogeneity along multiple lines. Nonetheless, responses could vary among years based on fishing opportunities, run sizes, and fisheries management activities, which emphasizes the much needed context-specific research. It is worth noting that the year of this study coincided with the largest sockeye salmon run in the Fraser River since the early 1900s. The value of further research in the future may arise because of the increased potential of data from large samples to be used to identify relatively subtle relationships between various types of anglers and their threat perceptions.

6. Management implications and conclusions

Our findings may help managers understand angler diversity, identify gaps in angler knowledge, craft new conservation initiatives customized for particular market segments, and anticipate responses to those initiatives aimed at improving fish handling and reducing post-capture and release mortality in the Fraser River. Latent class modeling was a useful tool to explore segmentation of an angler population based on certain themes of interest using psychometric data, while also estimating the size of angler subgroups that have been identified, which may be useful for fisheries managers to prioritize and effectively allocate management initiatives and resources. The advantages of LC modeling were quite compelling (see Boxall and Adamowicz, 2002; Morey et al., 2006), however, it often requires highly specialized software and analyses.

Collectively this research revealed that anglers are reasonably aware of and already use a variety of best practices for release, with potential differences in knowledge and use of these practices among angler classes. We also identified some inconsistencies leading to opportunities for further education, and we stress that information being conveyed to anglers (by governments, media and other sources) should be scientifically-defensible best practice, something that is not always the case (Pelletier et al., 2007). The fact that a surprising proportion of anglers were open to voluntary education (about responsible fishing) suggests that if managers want to encourage behavioral changes, efforts should be focused on stewardship among the Fraser salmon angler population. Angler perspectives on the most important drivers of fish mortality are informative for directing education efforts (e.g., or those where we have scientific evidence emphasizing their importance but where anglers do not believe it to be the case – such as for circle hooks – Cooke et al., 2012) or for focusing research on potential drivers that have yet to be studied scientifically (e.g., beach dragging).

In such complex social-ecological systems like the salmon fishery in the Fraser River, there is clearly a strong role in salmon conservation for natural science research to determine where and why post-release mortality of vulnerable fish takes place and an equally strong role for social science in understanding how that new knowledge will be interpreted and if, or how, that knowledge will result in anglers changing their fishing behavior. A holistic approach between the natural and social sciences is critical to inform management and build angler awareness in a way that meaningfully improves conservation-oriented behavior.

Acknowledgments

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jenvman.2013.06.010.

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