Evaluating evidence-informed decision-making in the management and conservation of British Columbia's fish and wildlife resources

by

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Abstract

Wildlife managers are faced with decisions and issues that are increasingly complex, spanning natural and human dimensions. A strong evidence base that includes multiple forms and sources of knowledge would support these complex decisions. However, a growing body of literature demonstrates that environmental managers are far more likely to draw on intuition, experience, or opinion to inform important decisions rather than empirical evidence.

In 2018, I interviewed members from natural resource management branches of Indigenous (n = 4) and parliamentary (n = 33) governments, as well as nongovernmental stakeholder groups (n = 28) involved in wildlife management and conservation in British Columbia, Canada. I set out to: assess how interviewees perceive and use western-based scientific, Indigenous and local knowledge and the extent to which socio-economic and political considerations challenge the integration of evidence [Chapter 2]; examine perceptions on the current and future status of rainbow trout (*Oncorhynchus mykiss*) populations and fisheries [Chapter 3] (supplemented with n = 1029 online survey responses from rainbow trout anglers); and identify perceived benefits and existing barriers supporting or limiting the use of a particular type of evidence, conservation genomics [Chapter 4]. Then in 2019, I facilitated fuzzy cognitive mapping workshops with n = 12 participants from four groups of fisheries managers, detailing their perceptions on the evidence influencing freshwater fish and fisheries decisions [Chapter 5].

Collectively, this research suggests that wildlife management issues and decisions are time-sensitive and value-laden. Interviewees relied heavily on personal contacts with internal colleagues and institutional information to inform decisions and practices. Evidence which may influence decisions is within a closed social network, centralized to a handful of decision-making organizations and their partners. A lack of time and information overload were major barriers to external evidence use. A lack of trust and hesitancy to share were major barriers to Indigenous and local knowledge use. Abundant environmental evidence may not be immediately 'actionable' and relevant to known problems faced by decision-makers due in part to poor communication and dissemination. Participants perceived a diminishing role of evidence in decisions due to increases in socio-economic and political influence that may supersede conservation.

Acknowledgements

First and foremost, I heartfully acknowledge and thank my co-supervisors Dr. Steven J. Cooke and Dr. Nathan Young for tirelessly supporting me in all my work and continually championing on my behalf in all facets of research and career pursuits. I owe a special thank you to Dr. C. Scott Findlay who has been a continual mentor and idol since starting my M.Sc. in 2010. Thank you to all Cooke lab (FECPL) members past and present who made my PhD experience enjoyable and memorable – especially Amanda Jeanson, Vivian Nguyen, Andrea Reid, Jill Brooks, Trina Rytwinski, Graham Raby, Jordi Bergman, Lisa Kelly, Jess Reid, and JF Lane who helped provide me with educational resources, guidance, and support. Special thank you to FECPL lab manager Jess Taylor, who is somehow both jack of all trades and master of everything. Many thanks also to the University of Ottawa, Faculty of Social Science research staff, Sylvie Gareau, Marianne Saikaley (Beauchamp), Matthew Heatherington, and Souhail Nejjar who helped with field research planning and reimbursement of expenses.

Thank you to my committee members, collaborators, and key informants, including Michael Donaldson, Lenore Fahrig, Joseph Bennett, Mark Andrachuk, Mike Ramsay, Brett van Poorten. Two key informants/expert thought leaders who I now consider friends and mentors were especially crucial to the success of this PhD project – thanks Adrian Clarke of the Freshwater Fisheries Society of BC and Dean Joseph of the Yekooche First Nation. Special thanks to Matt Spencer, whose computational and algorithmic support was crucial to the work in Chapter 5. I wholeheartedly thank the 65 interview and 12 fuzzy cognitive mapping workshop participants whose support and collaboration made this research possible. I also graciously thank Elise Urness, Carmen Gudino and Danny Glassman who provided support in transcribing interview data. Thanks to the Young Ecosystem Services Specialists for being an incredibly supportive early-career, in-person and online researcher community since my membership began in 2014.

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I'd like to acknowledge the traditional unceded territory of the Algonquin Anishinaabeg people known today as Ottawa and the traditional and treaty territory of the Mississaugas of the Anishinaabeg, known today as the Williams Treaties First Nations and Clarington. I acknowledge their resilience and their longstanding contributions of the First Peoples on the lands on which most of my thesis writing work occurred.

I would like to acknowledge funding for this PhD project in which I was supported by Genome British Columbia/Genome Canada [242RTE] and the Natural Sciences and Engineering Research Council of Canada (NSERC) [PGSD2-534299-2019]. Thank you to Dr. Trish Schulte for her leadership with the Genome Canada grant.

Preface

The research presented in my thesis is part of a larger project supported with funding from Genome Canada titled "*Sustaining Freshwater Recreational Fisheries in a Changing Environment*". The project aims to develop conservation genomic tools and policy recommendations to help manage and preserve the genetic diversity of rainbow trout to sustain healthy populations and its recreational fishery. Genomics is the study of all genes of an organism (the genome), including interactions of those genes with each other and with the organism's environment. The project investigates questions at the intersection of genomics and society and thus includes both natural science (e.g., Zhang et al. 2018; Grummer et al. 2019; Taylor et al. 2019; Grummer et al. 2021) and social science (e.g., Andrachuk et al. 2021; Jeanson et al. 2021a) components to help bridge gaps between genomic research and stakeholder, rightsholder, and regulatory groups.

Thesis Format and Co-authorship

This thesis consists of six chapters, four of which are written in manuscript format (Chapters 2, 3, 4, and 5). Chapter 1 provides general background information, setting the context and study area, and thesis objectives. Chapter 2 examines how natural resource decision-makers and practitioners perceive, evaluate, and use western-based scientific, Indigenous, and local knowledge. Chapter 3 examines the perceptions from stakeholder, Indigenous rightsholder, and regulatory/governance groups on the current and future status of rainbow and steelhead trout populations and fisheries in British Columbia. Chapter 4 examines the perspectives and familiarity of conservation practitioners with a particular type of empirical evidence, conservation genomics – the use of new genomic techniques and genome-wide information to solve biological conservation problems. Chapter 5 explores the complex information flows between organizations and groups which inform decisions about freshwater fish and fisheries in British Columbia to identify key factors that exert the highest levels of influence on information flows which may in turn affect influence on decisions (to the extent decision-makers consider evidentiary information). Chapter 6 summarizes my general conclusions, the relevance of my research, and proposes future research to address limitations and knowledge gaps identified from the studies conducted in the present thesis. This thesis is composed of research that is all my own work, but much of it was conducted in collaboration with several other parties who are identified below.

Chapter 1: General introduction, study area and background, and thesis objectives.

The introduction and conclusion (Chapter 6) borrows heavily from a published essay that I led that stemmed from a Geomatics and Landscape Ecology Research Laboratory (GLEL) meeting in April 2019 at Carleton University I attended.

Kadykalo, A.N., Buxton, R.T., Morrison, P., Anderson, C.M., Bickerton, H., Francis, C.M., Smith, A.C., Fahrig, L. 2021. Bridging research and practice in conservation. Conservation Biology. 35(6): 1725-1737. https://doi.org/10.1111/cobi.13732

The idea for this essay was conceived by Kadykalo and Fahrig. Kadykalo wrote the original draft. All authors contributed to reviewing and editing drafts that lead to the prepared final manuscript.

Chapter 2 (published): The role of western-based scientific, Indigenous, and local knowledge in wildlife management and conservation.

Kadykalo, A.N., Cooke, S.J., Young, N. 2021. People and Nature. 3(3): 610-626. https://doi.org/10.1002/pan3.10194

This study was designed by Kadykalo, Cooke, and Young. Kadykalo collected and processed the data. Kadykalo analysed the data and wrote the original draft. All authors contributed to reviewing and editing drafts that lead to the prepared final manuscript.

Chapter 3 (unpublished): Uncertainty, anxiety, and optimism: Views of stakeholders, Indigenous rightsholders, and regulators on the past, present, and future status of Rainbow and Steelhead Trout fisheries governance in British Columbia

Kadykalo, A.N., Jeanson, A.L., Cooke, S.J., Young, N.

This study was designed by Kadykalo, Jeanson, Cooke, and Young. Kadykalo and Jeanson collected the data. Kadykalo processed and analysed the data and wrote the original draft. All authors contributed to reviewing and editing drafts that lead to the final manuscript which is currently in preparation for submission to the journal Society & Natural Resources.

Chapter 4 (published): Conservation genomics from a practitioner lens: Evaluating the research-implementation gap in a managed freshwater fishery.

Kadykalo, A.N., Cooke, S.J., Young, N. 2020. Biological Conservation. 241:108350. https://doi.org/10.1016/j.biocon.2019.108350

This study was designed by Kadykalo, Cooke, and Young. Kadykalo collected and processed the data. Kadykalo analysed the data and wrote the original draft. All authors contributed to reviewing and editing drafts that lead to the prepared final manuscript.

Chapter 5 (unpublished): Conceptualizing evidence exchange and mobilization in freshwater fisheries management decisions using fuzzy cognitive maps

Kadykalo, A.N., Findlay, C.S., Spencer, M., Callaghan, C., Cooke, S.J., Young, N.

This study was designed by Kadykalo, Findlay, Cooke, and Young. Kadykalo collected and processed the data. Kadykalo and Spencer analysed the data. Kadykalo wrote the original draft, which is currently being reviewed by authors and will then be prepared for submission to the journal Ecology & Society.

Chapter 6: General conclusions and future directions.

Two additional published manuscripts for which I was not the lead author are noteworthy as they were prepared with the data I collected for this thesis:

Andrachuk, M., Kadykalo, A.N., Cooke, S.J., Young, N., Nguyen, V.M. 2021. Fisheries knowledge exchange and mobilization through a network of policy and practice actors. Environmental Science and Policy. 125: 157-166. https://doi.org/10.1016/j.envsci.2021.08.023

This study was designed by Kadykalo, Cooke, and Young. Kadykalo collected the data. Andrachuk processed and analysed the data and wrote the original draft. All authors contributed to reviewing and editing drafts that lead to the prepared final manuscript.

Piczak, M., Kadykalo, A.N., Cooke, S.J., Young, N. 2021. Natural resource managers use and value western-based science, but barriers to access persist. Environmental Management. https://doi.org/10.1007/s00267-021-01558-8

This study was designed by Kadykalo, Cooke, and Young. Kadykalo collected, processed, and analysed the data. Piczak wrote the original draft. All authors contributed to reviewing and editing drafts that lead to the prepared final manuscript.

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Chapter 1: General introduction

1.1 Evidence-based conservation and the "implementation crisis"

Management of natural resources, such as wildlife and fish populations, is increasingly complex. Managers are tasked with providing a rational basis for decisions in the face of rapid environmental change and conflicting objectives from a diversified network of human actors. A strong evidence base that includes multiple forms and sources of knowledge is needed to support these complex decisions (Riley et al. 2002; Organ et al. 2012). Evidence in the environmental decision-making context can be broadly defined as: "relevant information used to inform a question or decision of interest" (drawing from Salafsky et al. 2019). However, despite a growing call for biodiversity conservation and environmental management to be more evidence-based (Pullin & Knight 2001, 2003; Sutherland et al. 2004; Pullin 2012; Nguyen et al. 2017a; Salafsky et al. 2019) managers are far more likely to draw on intuition, past experience or opinion to inform important decisions rather than evidence (see Section 1.2). This is well known in the environmental literature as the knowledge-action divide, and what I call an "implementation crisis", in which the available science is not widely used due to disconnects between a) scientifically generated research, and b) the needs, expectations, and practices of knowledge users for decision-making, policy, and practice (see Appendix A for a list of 19 commentary papers on the 'knowledge-action' or 'research-implementation' gap in conservation and environmental management). A lack of accessible or actionable evidence can lead to this "evidence complacency" in which, despite the availability of evidence, it is not sought or used to make conservation decisions (Sutherland & Wordley 2017). Similarly, a lack of political will or capacity to seek out, synthesize, and distill the relevant and credible evidence for a particular problem can equally lead to evidence complacency.

1.2 Best available evidence

Throughout this thesis there are many statements that wildlife management decisions (e.g., Organ et al. 2012; Artelle et al. 2018a; Ryder 2018; Powell 2020) and government decisions broadly (e.g., Government of British Columbia 2017) are appropriately informed by the 'best available evidence'. But what is best available evidence? "Best" evidence is the information that changes one's belief in the truth of a factual claim by the greatest amount that is likely to change as scientific knowledge accumulates (i.e., it is inflationary: new pieces of evidence may be added over time as new research is conducted and consequently a weight of evidence assessment of a factual claim may change over time). In practice, "available" evidence is delimited by reducing susceptibility to bias to the greatest extent possible from inevitable issues like the file drawer problem (Rosenthal 1979), resource constraints and the comprehensiveness of search strategies. In reality, available evidence may represent only a small subset of the evidence universe and decision-makers must consider carefully the potential for the sample of gathered evidence to be biased and adjust their belief in the results of a weight of evidence analysis accordingly.

1.3 Current use of evidence in conservation and environmental management and major barriers

To examine the current status of evidence use in biodiversity conservation and environmental management, I reviewed the scientific literature for studies that used surveys or interviews to understand how conservation practitioners use evidence (Table 1.1; methods in Appendix B). I found 19 relevant studies that, taken together, suggest that evidence, especially peer-reviewed science, is rarely the first or most widely used or the most valued source of knowledge or information considered in conservation decisions. The available studies were primarily limited to interviews with natural resource managers. Other kinds of practitioners, such as farmers and other private landowners, may access and use evidence differently in conservation and environmental decision-making but such users have not been extensively studied.

The review reveals that decision makers tend to rely heavily on judgement and experience, including personal experience, anecdotes, and personal contacts with colleagues and experts – often without clear links to evidence (Table 1.1). When evidence existed, it was often not in a form suitable for use by practitioners (Table 1.1). Using the typology developed by Walsh et al. (2019), I found the most common barriers to use of scientific evidence were accessibility of the evidence (12 studies); relevance and applicability of the evidence (4 studies); organizational capacity, resources, and finances (4 studies); time required to find and read evidence (3 studies); and researcher communication and dissemination skills (3 studies).

Table 1.1 A summary of articles investigating the use of evidence in conservation decision-making (ordered chronologically).

Reference	Potential Evidence Users	Use of evidence in decision-making	Major barriers to using scientific evidence*
Morrison-Saunders and Bailey (2003)	Environmental impact assessment practitioners (Australia)	While science was perceived to provide the basis for baseline data collection, impact prediction, and mitigation design, it was seen as less important during decision-making and ongoing project management.	• Organizational capacity, resources, and finance • Social, political, and economic context of the decision
Pullin et al. (2004) Pullin and Knight (2005)	Conservation management plan compilers (United Kingdom and Australia)	Most frequent evidence sources were existing management plans (60%), expert opinion (49%), secondary literature (47%), and accounts of traditional management practices (46%). Less frequent sources were published scientific papers (23%). Those that always used published scientific papers were in the minority (8% U.K., 17% Australia), and 12% of U.K. compilers said they never accessed the primary literature.	• Accessibility of the evidence • Organizational capacity, resources, and finance
Sutherland et al. (2004)	Wetland site managers (United Kingdom)	In total, 77% of sources were anecdotal ('common sense', personal experience and speaking to other managers), whereas only 2% were based upon verifiable scientific evidence.	Not assessed
Cook et al. (2010)	Protected area managers (Australia)	Around 60% of conservation management decisions rely on experience-based information	• Accessibility of the evidence
Young and Van Aarde (2011)	Protected area managers (South Africa)	Most managers base decisions on experience-based information. Only 28% of managers developed objectives, 30% identified issues, 8% selected management methods, 30% selected the conservation objective, and 5% selected the intervention method, according to science-based information.	• Accessibility of the evidence • Relevance and applicability of the evidence • Quality, credibility and legitimacy of the evidence • Researcher communication and dissemination skills
Bayliss et al. (2012)	Practitioners and stakeholders working with invasive species (United Kingdom)	The most widely used information sources were general internet searches, invasive species websites, and colleague knowledge (used by 87.8% of respondents).	• Accessibility of the evidence
Cook et al. (2012)	Protected area managers (Australia)	While valuing empirical evidence most highly for their decisions, managers reported having poorer access to these data than other information or knowledge such as experience-based anecdotes, management plans, and legislation, which they viewed as less valuable.	• Accessibility of the evidence
Cvitanovic et al. (2014)	Marine protected area management plans (Australia, Kenya and Belize)	Most management plan information sources were commissioned technical reports (52%), followed by local government reports (23%). Primary science was the third most frequently used knowledge source (14%). Information was not available on whether recommendations in technical reports and government documents were based on peer reviewed science or personal judgement.	• Accessibility of the evidence • Relevance and applicability of the evidence • Researcher communication and dissemination skills
Matzek et al. (2014)	Land managers and restoration professionals (United States)	Practitioners rely on their own experience, and generally do not read the peer-reviewed literature, which they regard as only moderately useful. Less than half of managers who do research carry out experiments	• Accessibility of the evidence • Practitioner skills for understanding and using science

Reference	Potential Evidence Users	Use of evidence in decision-making	Major barriers to using scientific evidence*
		conforming to the norms of hypothesis testing, and their results are not broadly disseminated.	• Practitioner time to find and read evidence • Relevance and applicability of the evidence
Addison et al. (2015)	Marine protected area management agencies (Australia)	Even when long-term monitoring results are available, management agencies are not using them for quantitative condition assessment. Instead, many agencies conduct qualitative condition assessments, where monitoring results are interpreted using expert judgment only.	Not assessed
Ntshotsho et al. (2015)	Natural resource managers (South Africa)	Intuition was a common determinant of what, where and how to clear invasive alien plants, thus emerging as a particularly strong factor in the location of clearing projects. Only three of the seven documents analyzed made specific reference to scientific literature.	• Social, political, and economic context of the decision
Cvitanovic et al. (2016)	Ningaloo Marine Park managers and decision-makers (Australia)	While the Ningaloo Research Program generated expansive and multidisciplinary science outputs directly relevant to the management of the Ningaloo Marine Park, decision-makers are largely unaware of this knowledge, and little has been integrated into decision-making processes.	• Accessibility of the evidence • Practitioner awareness of the literature • Researcher-practitioner links • Researcher communication and dissemination skills
Young et al. (2016a)	Government fisheries managers and scientists, stakeholders (Canada)	The percentage of respondents consulting scientific publications as a first source of information is 9% and 13% for government employees and stakeholders, respectively.	• Accessibility of the evidence
Giehl et al. (2017)	Protected area managers (Brazil)	Managers most frequently made decisions based on their personal experience, with scientific evidence being used relatively infrequently.	• Accessibility of the evidence • Practitioner skills for understanding and using science
Artelle et al. (2018a)	Wildlife management agencies (United States and Canada)	For most species in most jurisdictions, natural resource management lacked the basic elements of a scientific approach, i.e., measurable objectives, evidence, transparency, and independent review.	• Social, political, and economic context of the decision
Koontz and Thomas (2018)	Ecosystem management state agency (United States)	Ecosystem management plans contained no references to peer-reviewed scientific journal articles in the text. The most common documents in summary tables were grey literature.	Not assessed
Lemieux et al. (2018)	Protected area managers (Canada)	Information produced by staff within the organizations is given priority over other forms of empirical evidence such as Indigenous knowledge and peer-reviewed literature.	• Organizational capacity, resources, and finance • Practitioner time to find and read evidence • Researcher-practitioner links
Fabian et al. (2019)	Professionals in government, NGOs, national parks, private consultancies, forestry (Switzerland)	Experience-based information sources such as personal experience and direct exchange with colleagues and experts are more important than evidence-based sources such as guidelines, specialized journals, and textbooks targeted to professionals. Articles from international scientific journals are hardly ever consulted.	• Accessibility of the evidence • Practitioner time to find and read evidence • Relevance and applicability of the evidence

*Major barriers to using scientific evidence were categorized according to the typology developed by Walsh et al. (2019).

1.4 Knowledge translation, exchange and mobilization

With the objective of reducing the knowledge-action divide and evidence complacency, a growing research field, so-called 'knowledge translation', 'knowledge exchange' or 'knowledge mobilization', has been focusing on how knowledge is exchanged and mobilized, and with whom it is exchanged. The origins of knowledge translation and exchange can be traced to informal networks linking academic researchers with the German dye (late 1800s) and agricultural industries (1906) (Lomas 2007). However, in modern academic contexts, this research field is rooted in the health professions and the concept of *knowledge translation* which emerged in the 1990s, when knowledge producers "pushed" their research messages onto end-users (Graham et al. 2006; Grimshaw et al. 2012; Peprah 2020). *Knowledge translation* is defined, for example, by the Canadian Institutes of Health Research (https://cihr-irsc.gc.ca/e/193.html) as a dynamic and iterative process that includes synthesis, dissemination, exchange, and ethically sound application of knowledge to improve health, provide more effective health services and products, and strengthen the health care system (Graham et al. 2006; Straus et al. 2009). In conservation and environmental science, the similar concept of *knowledge exchange* has gained prominence. Fazey et al. (2012) define it as "processes that generate, share, and/or use knowledge through various methods appropriate to the context, purpose, and participants involved." In the social sciences fields, the term *knowledge mobilization* has been used to capture the same concept (Bennet et al. 2007; Levin 2008; Provencal 2011; Levin 2013). *Knowledge mobilization* is the term preferred by the Social Sciences and Humanities Research Council (SSHRC; https://www.sshrc-crsh.gc.ca/funding-financement/policies-politiques/knowledge_mobilisation-mobilisation_des_connaissances-eng.aspx) and Research Impact Canada (https://researchimpact.ca) and is defined by SSHRC as an umbrella term encompassing a wide range of activities relating to the production and use of research results, including knowledge synthesis, dissemination, transfer, exchange, and co-creation or co-production by researchers and knowledge users. Because this thesis spans both natural and social dimensions of biodiversity conservation and environmental management I use "knowledge exchange" and "knowledge mobilization" throughout.

1.5 Goal and objectives

I aim to investigate the role of evidence in conservation and environmental management decisions, policies, and practices using the case of managed fish and wildlife resources in British Columbia, with particular emphasis on rainbow trout (*Oncorhynchus mykiss*) fish and fisheries. My objective here is to analyze how potential evidence users (government employees, Indigenous rightsholders, and stakeholders) perceive and evaluate evidence. In doing so I hope to reveal barriers and opportunities to enable effective knowledge exchange.

Specifically, this research investigates *how* decisions are made and on *what* or *which* evidence those decisions are based. This research seeks to: assess how decision-makers and other potential knowledge users (a) perceive, evaluate and use western-based scientific, Indigenous and local knowledge and (b) the extent to which social, political and economic considerations challenge the integration of different forms of evidence into decision-making [Chapter 2]; examine perceptions on the current and future status of rainbow and steelhead trout (*Oncorhynchus mykiss*) populations and fisheries [Chapter 3]; identify perceived benefits and existing barriers supporting or limiting the use of a particular type of empirical evidence, conservation genomics in conservation practice by analyzing how potential knowledge users (conservation practitioners) perceive and evaluate genomics using the case of managed rainbow trout (*Oncorhynchus mykiss*) fisheries [Chapter 4]; and examine freshwater fisheries managers perceptions on the type, amount, rate, and reliability of evidence (i.e., information flows) influencing fish and fisheries decisions [Chapter 5].

Each data chapter and the research collectively in this thesis explored variability in quantitative and qualitative data through interpretivism and inductive and abductive reasoning to draw insights, generate hypotheses, and develop guidelines and recommendations. Thus, this research explores this data beyond testing or generating hypotheses.

1.6 Case: study area and background

1.6.1 The North American model of wildlife conservation

The so-called "North American Model of Wildlife Conservation" is the prevailing model of state, provincial, and federal agencies based on regulated management, science-based policies and equitable access and public ownership (Organ et al. 2012; Krausman & Cain 2013; Ryder 2018; Mahoney & Geist 2019). Thus, in North American fish and wildlife management agencies decisions are purportedly evidence-based, supported by the best available science (e.g., population dynamics, surveys, statistics, habitat information, and behavioural studies) (Organ et al. 2012; Ryder 2018; Powell 2020), however recent research suggests that the "hallmarks" of science including measurable objectives, evidence, transparency, or independent review are missing from management (see Artelle et al. 2018a).

While I define wildlife as free-ranging, non-domestic animals (Chapter 2), in North American natural resource management 'wildlife' is often restricted to terrestrial and aquatic vertebrates other than fish because of a long (and unclear) policy history (Krausman & Cain 2013). Some suggest fish are historically not valued in the same ways as other more charismatic species, because the characteristics of an animal, its habitat type, commercial value, and ideas about property affect perceptions (see Wadewitz 2011). Regardless of the cause of this disconnect, in British Columbia, the provincial natural resources and environmental ministries maintain this separation between fish and other animals (e.g., 'Fish and Wildlife Resource Management' – the British Columbia Ministry of Forests, Lands, and Natural Resource Operations and Rural Development; 'Fish and Wildlife Branch' - the British Columbia Ministry of Environment and Climate Change Strategy). In this thesis, since much of it is focused on the management of rainbow trout (*Oncorhynchus mykiss*) or fish and fisheries broadly, I use fish/fisheries and wildlife management interchangeably, with the intention that wildlife management captures fish and all other free-ranging, non-domestic animals.

1.6.2 Natural and human dimensions of British Columbia

British Columbia (BC), the mountainous and most westerly province of Canada is rich in natural resources contributing substantially to local and national economies. It is also home to ethnically and culturally diverse people (Indigenous peoples with traditional and constitutional rights, European and Asian immigrants, engaged resource-user groups). The province is experiencing rapid biophysical changes to its highly diverse ecosystems impacting tightly linked social-ecological systems. Climate-driven hydrological changes (e.g., increased summer freshwater temperatures, more hypoxic lakes; reduced snowpack; earlier onsets of spring snowmelt) are a primary concern (Healey 2011; Zwiers et al. 2011; Islam et al. 2017). Meanwhile, BC's boreal forests have suffered extreme wildfire seasons and a severe mountain pine beetle (*Dendroctonous ponderosae Hopkins*) outbreak (Dhar et al. 2016; Kirchmeier-Young et al. 2019). These vulnerable habitats support charismatic at-risk wildlife species of major significance to Indigenous and non-Indigenous people alike such as cutthroat (*Oncorhynchus clarkii*) and bull trout (*Salvelinus confluentus*), and mountain caribou (*Rangifer tarandus*). Moreover, they support social, cultural, and economic well-being of BC's people in in the form of, for example, water supply, subsistence and recreational fisheries and hunting, wild foods, sense of place, cultural identity, and heritage.

1.6.3 Rainbow trout and fisheries

Rainbow trout (*Oncorhynchus mykiss*) are a cold-water salmonid fish native to most of BC (Figure 1.1). Rainbow trout include freshwater residents and an anadromous form called ‘steelhead’ trout, which migrate from marine to freshwaters to spawn. In BC, rainbow trout populations (when and where thriving) support recreational, subsistence, and ceremonial fisheries, which in turn support cultural, social, and economic well-being. Rainbow trout recreational fisheries in inland BC are multistock fisheries, distributed across a landscape of approximately 500 000 km^2 that includes over 4000 lakes, of which nearly 600 are stocked annually with hatchery-raised wild-strain rainbow trout. Rainbow trout represent 58% (4.3 million) and steelhead trout represent 2% (151,372 [129,884 wild; 21,488 hatchery-raised]) of the annual 7.5 million fish caught in the province translating into $957 million CAD direct (e.g., licence sales, accommodations, packages etc.) and indirect (e.g., sales of equipment, boats, fuel etc.) economic contributions and in the employment of 5,000 persons (Bailey & Sumaila 2012; Freshwater Fisheries Society of BC 2013). Non-material benefits are also associated with the harvest of rainbow trout (e.g., cultural identity and heritage; spirituality and religion, sense of place, aesthetic experience), many of which cannot be represented effectively in monetary terms.

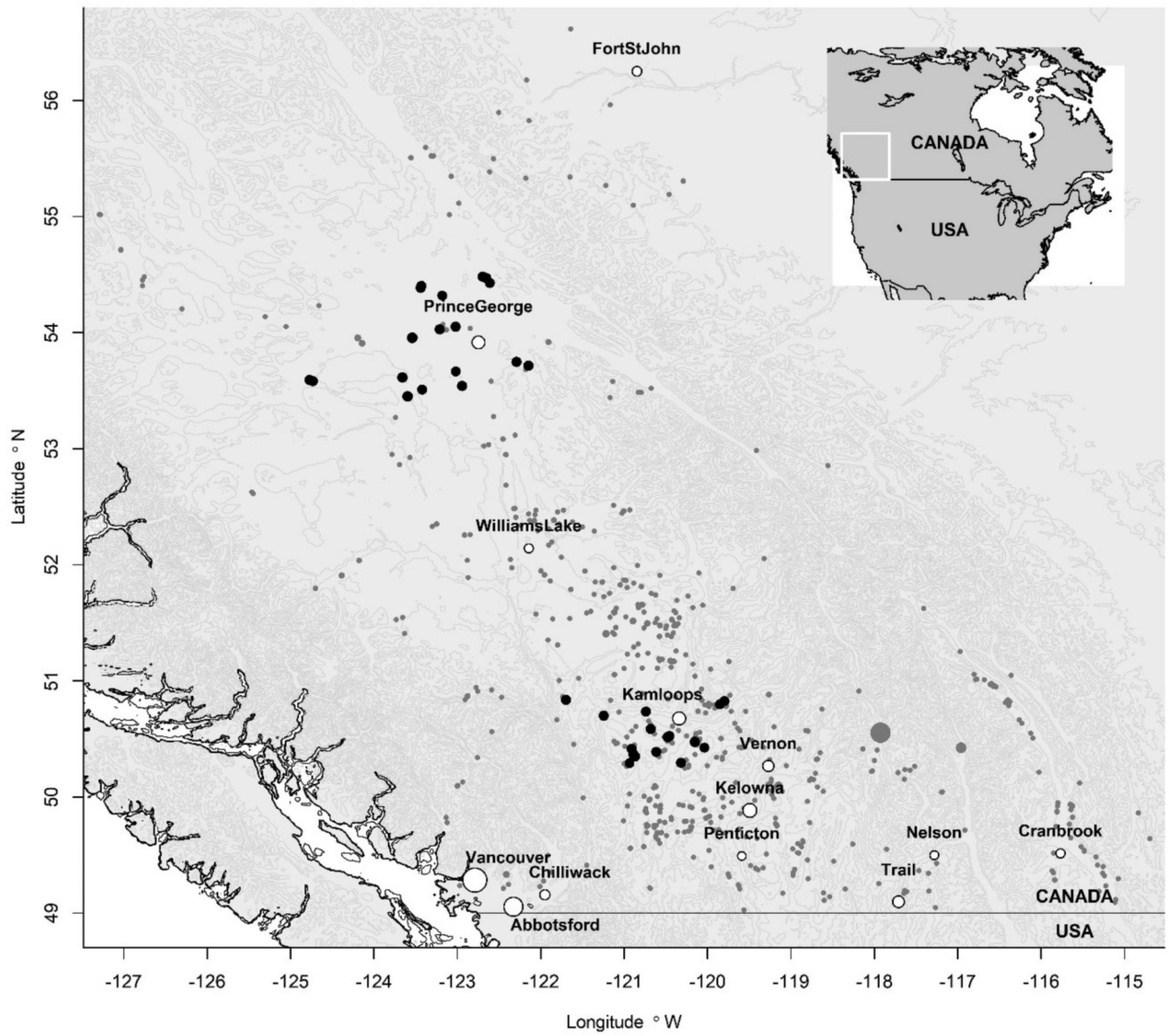

Figure 1.1 Map of the British Columbia recreational trout fishery. Solid circles on the map represent 584 lakes that are stocked with at least 200 trout per year and are over 5 hectares in surface area. The labelled white circles represent 8 of the 24 population centres that are large discrete towns or cities. The area of these circles is proportional to the number of license sales by population centre. (Image source: Carruthers et al. 2019).

As cold-water salmonids, rainbow and steelhead trout are sensitive to climate-linked hydrological changes such as increased water temperatures in summer, decreased water oxygen content, and increasing frequency of drought (Whitney et al. 2016) threatening the long-term sustainability of rainbow trout fisheries. The increased frequency of high summer temperatures and low flows have already resulted in several closures of rivers to recreational fishing in the province (Government of British Columbia 2015a, b, c, 2018, 2021), as the combined stress of angling (including catch-and-release) and exposure to high temperatures can be lethal for rainbow trout (Meka & McCormick 2005; Parkinson et al. 2016; Twardek et al. 2018). Further, more than 200 BC lakes are unable to support stocking programs for rainbow trout because of changes in water acidity (Freshwater Fisheries Society of BC internal monitoring data). Declines in dissolved oxygen in lakes is also widespread, 2.75 to 9.3 times greater than observed in the world's oceans (Jane et al. 2021). Forest clear-cutting is also a threat in BC reducing summertime streamflows, likely due to advance snowmelt, resulting in decreases in modelled rainbow trout habitat by up to 20-50% (Gronsdahl et al. 2019). Within the next twenty years models based in the United States project that approximately 20% of rainbow trout habitat will be lost due to climate change (O'Neal 2002; Wenger et al. 2011), increasing to almost 50% by the year 2100 (Jones et al. 2012).

1.6.4 Management of fish, fisheries, and wildlife in BC

Management of rainbow trout, fisheries and wildlife in BC is complex, involving both federal and provincial government agencies, as well as Indigenous communities and governments in specific territories. In addition, there are non-governmental stakeholders, such as academic researchers, non-profit organizations, private consultants, and resource user groups (e.g., anglers) that are also involved in management processes of rainbow trout in BC.

1.6.4.1 Parliamentary governments

Canada's fisheries are a "common property resource", belonging to all the people of Canada. Under the *Fisheries Act*, it is the Minister's duty to manage, conserve and develop the fishery on behalf of Canadians in the public interest (s. 43). However, in *practice*, jurisdictional authority is concurrently shared among federal and provincial agencies. In Canada's parliamentary governments, conservation and management of inland fisheries (lakes and rivers) is largely a provincial responsibility. The main agency responsible for management of freshwater populations of fish like rainbow trout and terrestrial wildlife is the British Columbia Ministry of Forests, Lands, and Natural Resource Operations and Rural Development (FLNRORD), the provincial natural resources ministry. Sport fishing and hunting occurs throughout the entire province of BC. Fisheries and wildlife management and conservation is divided into nine resource management regions that cover all areas of the province (Figure 1.2). Marine fish and tidal waters are a federal responsibility. The Federal Department of Fisheries and Oceans Canada (DFO) is the primary responsible agency for the management of steelhead trout. The conservation science section of the British Columbia Ministry of Environment and Climate Change Strategy (MOE) provides additional scientific and resource support to FLNRORD from specialized research biologists classified by their area of focus (species at risk, instream flows etc.).

Wildlife management decisions (e.g., fishing and hunting regulations, stocking hatchery fish) in BC are made by dedicated provincial natural resources ministry staff (statutory decision-makers; notably, Deputy Ministers, Directors, and Fish and Wildlife Section Heads) possessing statutory (compliance and permitting) decision-making authorities under legislation. Decisions by statutory decision makers are purportedly evidence-based on the best available science

(Government of British Columbia 2017), similar to other wildlife management agencies across North America (see Artelle et al. 2018a).

Figure 1.2 The nine different resource management regions in the province of British Columbia (Region 1: Vancouver Island, Region 2: Lower Mainland, Region 3: Thompson-Nicola, Region 4: Kootenay, Region 5: Cariboo, Region 6: Skeena, Region 7A: Omineca, Region 7B: Peace, Region 8: Okanagan) and their Fish and Wildlife regional office locations (Image source: Freshwater Fisheries Society of BC 2013).

1.6.4.2 Indigenous communities and governments

Indigenous communities and governments manage Indigenous and non-Indigenous recreational and subsistence fisheries that take place on reserve lands and (in some cases) on traditional territories. Throughout most of BC, colonization proceeded through direct land seizure in the absence of negotiated treaties, (although for some Indigenous nations formal treaty negotiations are underway). A system of geographically small reserves (slightly more than one-third of one percent of the land area in the province) was imposed by the Dominion of Canada with the province of BC between the 1850s and the 1920s for the many First Nations (Indigenous) communities (Harris 2008). The small reserve allotment process (only slightly more than one-third of one percent of the land areas in the province) was designed on the assumption that Indigenous peoples in the province were primarily fishing peoples and did not require a large land base to maintain their livelihoods. However, these reserves were generally too poor or small to provide adequate protection for the fisheries that were to be their primary means of food and economic support (Harris 2008). Since the early 1990s, the province of BC and Government of Canada have sought to negotiate modern treaties with First Nations to rectify this historical injustice, with varying degrees of success. Further, the British Columbia Assembly of First Nations (https://www.bcafn.ca/) and the First Nations Fisheries Council of British Columbia (https://www.fnfisheriescouncil.ca/) are striving towards reconciliation (restoring balance in the relationship between Indigenous peoples and non-Indigenous Canadians – McGregor 2018) that includes rights-based fishing opportunities and management on traditional territories including the negotiation and transfer of responsibility from crown lands back to First Nations.

Despite its millennia-long production and continued application by Indigenous peoples to environmental management, non-Indigenous "western" management have only recently considered Indigenous knowledge (Jessen et al. 2021), but this interest is growing substantially

(Reyes-García & Benyei 2019; Thompson et al. 2020; Wheeler & Root-Bernstein 2020). The extraction of Indigenous knowledge, in particular in Canada, for use by western decision-makers can and has led to the marginalization, appropriation, and commodification of Indigenous knowledge (Simpson 1999; Simpson 2001a,b). This may work to further settler colonialism, especially if subsequent decisions are made without the full involvement, collaboration and consent of the Indigenous and local communities themselves (Wong et al. 2020). Many Indigenous communities and governments may therefore be hesitant or reluctant to share knowledge out of fear that it could be used against them, i.e., reduced fisheries catch allocations, misused or taken out of context, or due to a lack of trust (Zeidler 2011; Steel et al. 2021).With interest in Indigenous data, information, and cultural knowledge on the rise, First Nations are asserting their authority over how this information is collected, used, and disseminated. As a response to research and data collection practices that have not always been beneficial to— or respectful of—First Nations' rights or interests the First Nations principles of OCAP® (standing for Ownership, Control, Access, and Possession) were developed in 1998 (https://fnigc.ca/ocap-training/). OCAP® establishes how First Nations data, information, and cultural knowledge should be collected, accessed, used, and shared to support strong information governance on the path to First Nations data sovereignty.

1.6.4.3 Nongovernmental stakeholder groups

The conservation and management of rainbow trout within BC is heavily influenced by various stakeholder groups. Specifically, a non-profit organization, the Freshwater Fisheries Society of BC (FFSBC; https://www.gofishbc.com), under contract from FLNRORD, is responsible for the province's stocking program, improving angler access, as well as various conservation services (including outreach and education). Under an agreement signed with the province of BC in 2015, 100% of the revenue generated from fishing licences goes to FFSBC. These programs are aimed at diverting recreational angler pressure to hatchery raised fish in efforts to protect wild fish such as rainbow trout. BC Hydro (https://www.bchydro.com), a provincially-owned electric utility monitors impacts associated with hydro dams to inform wildlife mitigation programs including habitat protection for spawning fish, nesting and migratory birds, as well as fish salvage. Local environmental non-governmental organizations (ENGO) such as the BC Wildlife Federation (https://bcwf.bc.ca) and BC Conservation Foundation (https://bccf.com) have broad goals aimed at ensuring the long-term sustainability of BC's fish, other wildlife, and outdoor recreational resources. The Habitat Conservation Trust Foundation (https://hctf.ca) receives 100% of the surcharge revenue collected from hunting, fishing, trapping, and guide-outfitter licenses per BC legislation and in turn funds conservation projects on freshwater fish, other wildlife, and the habitats in which they live. There are also end-user special-interest groups that advocate for fish conservation, long-term sustainability of fisheries, and quality of fishing opportunities (often advocating for particular angling gear, bait, or fish species): BC Federation of Fly Fishers https://www.bcfff.bc.ca, BC Fishing Resort & Outfitters Association http://bcfroa.ca, The British Columbia Federation of Drift Fishers https://www.bcfdf.com, Guide Outfitters Association of British Columbia https://www.goabc.org, North Coast Steelhead Alliance http://www.steelheadalliance.com,The Steelhead Society of British Columbia http://www.steelheadsociety.org. Various private environmental consultants and academic researchers throughout the province and North America also play important roles within the management of BC's fish and fisheries. They are often contracted throughout the province by Indigenous, federal, and provincial governments as well as FFSBC to carry out collaborative research on fish, fish habitat, or fisheries, or to provide advice. Finally, retired provincial government employees are also important actors as they often remain active within the realm of fish and fisheries issues, often as part of ENGOs described above, or as fishing guides, or informal government advisors or lobbyists.

1.6.4.3.1 Limitations

I contacted and heard from a diverse set of actors from Indigenous governments, parliamentary governments, and non-governmental stakeholders (Chapters 2-4; Tables 2.2, 3.2, 4.2). However, there was relatively less representation from natural resources branches of Indigenous governments (4 participants, 21 non-participants). I received several responses from Indigenous governments who declined to be interviewed because their primary focus is on salmon populations, rather than rainbow trout. Further, there was also relatively less representation from senior civil servants (3 FLNRORD Directors participants from 13 contacted; 0 FLNRORD Assistant Deputy Minister participants from 3 contacted), although I did hear from many Fish and Wildlife Section Heads (6 of 8 contacted). I received several responses from senior civil servants or their staff passing me onto more specialized or informed Directors or Fish and Wildlife Section Heads, whom I interviewed. In some cases, interviews planned with Assistant Deputy Ministers were cancelled due to busy schedules and last-minute ministerial meetings. The respondent skew is an artifact of response rates rather than research intent. It may have limited the interpretation of evidence use within the context of fish and wildlife decision making in BC specifically for Indigenous governments and parliamentary statutory decision makers/senior civil servants.

1.6.5 Government austerity and scientific integrity abuse

In Canada, there is some evidence that government agencies have recently been influenced by austerity, political distortion, and increased scientific integrity abuses – that when faced with politically controversial decisions, they often discount or ignore scientific information, whether from agency staff or nongovernmental scientists (Carroll et al. 2017; Westwood et al. 2017). Political influence is defined as "the achievement of (a part of) an actor's goal in political decision-making, which is either caused by one's own intervention or by the decision-makers' anticipation" (Arts & Verschuren 1999). Actors, for socio-economic or political reasons, may therefore modify the behaviour of decision-makers in a political arena, resulting in a modified decision. Scientific integrity as defined, for example, by the U.S. Department of Agriculture (USDA) is "the condition resulting from adherence to professional values and practices when conducting, reporting, and applying the results of scientific activities that ensures objectivity, clarity, and reproducibility, and that provides insulation from bias, fabrication, falsification, plagiarism, inappropriate influence, political interference, censorship, and inadequate procedural and information security" (USDA 2022).

Serendipitously, in 2017, a non-profit organization, Evidence for Democracy (E4D; https://evidencefordemocracy.ca), investigated the state of government science in BC (Smith et al. 2017). They found that in a survey of 403 provincial government scientists the majority (71%) said they had witnessed a decrease in research capacity in their ministry and/or branch over the course of their tenure in BC government; and 68% believed that there are insufficient resources to effectively fill their branch or ministerial mandate. Smith et al. (2017) also determined that 57% of government scientists believed that public service cuts compromise the government's ability to use the best available evidence in decision-making, and that 49% believed political interference has compromised their ability to develop laws, policies and programs based on evidence. In 2020, E4D updated this investigation with a survey of 1235 scientific professionals in the BC public service and found the outlook on science integrity had not improved (Heer & Girling 2020). The majority of scientists surveyed either thought there has been a moderate or substantial reduction in research capacity (38%) or saw no change (23%) since 2017. Further, 93% of the scientists Heer and Girling (2020) surveyed still believe that the public would benefit from greater professional capacity in the BC public service. Scientists identified hiring delays, lack of succession planning, and over reliance on professionals outside the government as core barriers to research capacity.

1.7 Summary

There is good reason to believe that management and policy decisions in the 'North American Model of Wildlife Conservation' are not as evidence-based as claimed. Despite the availability of diverse evidence to support wildlife management decisions, evidence complacency may arise due to a lack of accessible or actionable evidence, or political will or capacity to find, synthesize and then act (i.e., base decisions) on the relevant evidence. British Columbia makes for an interesting case study to investigate the role of evidence in conservation and environmental management decisions, policies, and practices. The province is experiencing rapid biophysical changes to its highly diverse ecosystems impacting tightly linked economies, human livelihoods, and well-being. I use the case of managed fish and wildlife resources in British Columbia, with particular emphasis on rainbow trout (*Oncorhynchus mykiss*) fish and fisheries to analyze how government employees, Indigenous rightsholders, and stakeholders perceive, evaluate, and use evidence. In doing so, this thesis reveals (a) barriers to evidence use, and (b) opportunities to enable effective knowledge exchange, that can facilitate the (re-)discovery of the missing hallmarks of evidence-informed wildlife management and conservation decisions in British Columbia, North America, and beyond (Artelle et al. 2018a).

1.8 Thesis roadmap and arc

In Chapter 2, mixed-methods data collection into how decision-makers and other potential knowledge users (a) perceive, evaluate and use western-based scientific, Indigenous and local knowledge and (b) the extent to which social, political and economic considerations challenge the integration of different forms of evidence into decision-making revealed that despite high (and relatively diverse) evidence use, more than 40% of respondents perceived a diminishing role for evidence in final decisions concerning wildlife management and conservation. They associated this with decreases in institutional resources and capacity and increases in socio-economic and political influence. Chapter 2 also revealed internal (i.e., institutional) evidence sources are used slightly more than external ones (i.e., peer-reviewed journals, management agencies in other jurisdictions) and that a lack of trust and hesitancy to share knowledge limit the use of Indigenous and local knowledge. These results revealed the need to dive deeper into particular topics: governance of wildlife resources through the case of managed rainbow trout fisheries and the role of evidence in such decisions (Chapter 3), and the use of a particular empirical evidence, using the example case study of conservation genomics (Chapter 4).

Genomics is the study of all genes of an organism (the genome), including interactions of those genes with each other and with the organism's environment. Conservation genomics is the use of new genomic techniques and genome-wide information to solve problems in conservation biology (i.e., preservation of biodiversity, species, and populations). In essence, genomics could be applied to identify conservation targets and threats and aid in the implementation and monitoring of conservation actions and manage threatened populations with greater precision. In a best-case scenario regarding application, conservation genomics would be seamlessly used in management of wildlife populations to estimate inbreeding, local adaptation, disease susceptibility, and outbreeding depression; and monitor genetic drift, population structure, and hybridization in wild and captive populations (Allendorf et al. 2010; McMahon et al. 2014; Grueber 2015). In a best-case scenario, genomic research would be informed by regular consultation with practitioners regarding their evidence needs (i.e., management objectives). Objectives-focused and practitioner-informed genomics research would provide valuable insights for management in conservation on what is important to preserve to curb the accelerating loss of biodiversity.

Chapters 3 and 4 revealed a lack of time and information overload were major barriers to external evidence use. They also revealed that despite an abundance of environmental evidence much of it may not be immediately ‘actionable’ and relevant to known problems faced by decision-makers due in part to poor communication and research dissemination between researchers and practitioners. Chapter 3 also revealed a lack of evidence-informed decision-making may be in part due to (1) shared jurisdictional authority between federal and provincial agencies over wildlife resources as well as, (2) the organizational structure of natural resource management agencies which are not autonomous from competing commercial and industrial objectives and directions.

The deep dives in Chapters 3 and 4 helped to expose the need for greater evidence exchange and mobilization which was accomplished using fuzzy cognitive maps to examine freshwater fisheries managers perceptions on the type, amount, rate, and reliability of evidence (i.e., information flows) influencing fish and fisheries decisions [Chapter 5]. Chapter 5 revealed decision-makers and practitioner thesis participants relied heavily on personal contacts with internal colleagues (and their intuition, personal experience, or opinion) and institutional information to inform decisions and practices. Thus, for the case study explored in this thesis, evidence which may influence wildlife management and conservation decisions is within a rather closed social network, centralized to a handful of individuals, groups or organizations either with decision-making powers (i.e., natural resource management agencies), or those closely partnered with such organizations. Chapter 6 summarizes these results in a conclusion, their implications for evidence-informed decision-making in the management and conservation of fish and wildlife, and provides future research directions.

Chapter 2: The role of western-based scientific, Indigenous, and local knowledge in wildlife management and conservation

2.1 Introduction

Managers of wildlife (free-ranging, non-domestic animals) are faced with decisions and issues that are increasingly complex (Arlinghaus et al. 2015; Powell 2020). This is especially true given the ecological crisis that is upon us, which includes pervasive and escalating threats to wildlife populations from a wide range of sources. For example, the UN body, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), has recently assessed the global extent of this crisis, finding that up to one million species of animals and plants are at risk of extinction in the short term (Díaz et al. 2019; IPBES 2019a,b; Balvanera et al. 2020). The cumulative and interacting drivers of these changes such as exploitation of organisms, climate change, pollution, invasion of alien species, etc., pose a particular challenge for already complex wildlife management and conservation.

Wildlife management and conservation involves managing wildlife, their habitat, and the people who engage and interact with animals and ecosystems. Such efforts require engagement with not only conventional user groups, such as hunters and anglers, but also anyone with a vested interest in a wildlife issue, program, action, or decision. This reflects the need to integrate human dimensions of wildlife into management (i.e., values, decisions, actions, preferences, attitudes) from an array of increasingly diversified actors (i.e., resource-user groups, industry, private landowners, farmers, policymakers, conservation organizations and other stakeholders and rightsholders) with high expectations for involvement in the process (Riley et al. 2002; Decker et al. 2012). Thus, wildlife managers must not only consider the complex biological and ecological context of the decisions they make, but also complex political, social, and economic circumstances and influences. This vast social and ecological complexity is key for understanding how wildlife managers use evidence and make decisions, and vice versa.

Evidence-based decision-making is seen by many as an important tool for managing social-ecological complexity (Pullin & Knight 2003; Sutherland et al. 2004; Addison et al. 2016). Evidence is important for both understanding complex interactions, and for politically justifying policy and management decisions (Pielke 2007; Adams & Sandbrook 2013). Moreover, the centrality of evidence to making and legitimizing decisions is prompting researchers and practitioners to consider multiple forms and sources of knowledge (Reed et al. 2013; Tengö et al. 2014; Salafsky et al. 2019). Specifically, in environmental management there is a growing interest and emphasis to incorporate a broad range of knowledge types including Indigenous and local knowledge (ILK) alongside the foundations of western-based science (Reyes-García & Benyei 2019; Thompson et al. 2020; Wheeler et al. 2020; Wheeler & Root-Bernstein 2020).

However, there are indications that the rhetorical popularity of evidence-based management is not matched in practice. For example, numerous studies have shown that environmental managers are far more likely to draw on intuition, past experience, or opinion to inform important decisions rather than evidence derived from western-based science (see review in Kadykalo et al. 2021a; and Pullin et al. 2004; Cook et al. 2010; Young & Van Aarde 2011; Matzek et al. 2014; Fabian et al. 2019;). This is described as 'evidence complacency' (Sutherland & Wordley 2017) in which despite the availability of evidence, it is not sought or used to make decisions. Even less is known about the use of more informal and tacit types of knowledge such as ILK. However, Lemieux et al. (2018) recently revealed that in Canada's protected areas organizations ILK is also valued and used less than personal and institutional experiential knowledge.

These studies suggest that the creation of knowledge and collection of evidence are necessary but not sufficient criteria for enacting evidence-informed decision-making. A growing research field, so-called 'knowledge exchange', has been focusing on how knowledge is exchanged and mobilized, and with whom it is exchanged (Fazey et al. 2012; Reed et al. 2014; Cvitanovic et al. 2016). This literature insistently emphasizes the need for knowledge and knowledge generators to be, or perceived as, salient (relevant and timely), credible, and legitimate to enable effective knowledge exchange (Cash et al. 2003; Cook et al. 2013). However, effective knowledge exchange requires determining, first and foremost, how (sometimes competing) knowledge is used, perceived, and evaluated by potential users. While this seems like a logical and obvious objective for those studying knowledge exchange, it has not often been explored empirically (Young et al. 2016b; Tengö et al. 2017).

The characteristics of knowledge and knowledge-holders notwithstanding, the use of knowledge is also dependent on the intense political, social, or economic considerations faced by potential knowledge users. Some of these considerations may constrain, compromise, and interfere with the ability of wildlife managers to make decisions based on evidence. Notably, limited financial resources, lack of staff, and inadequate timeframes are significant barriers to knowledge use in both western (Young et al. 2016a; Westwood et al. 2017; Lemieux et al. 2018) and Indigenous (Ban et al. 2018) environmental management agencies. Indeed, these challenges have already been well-documented in this study area, the province of BC in Canada. For example, a survey of 403 provincial government scientists found the majority (71%) said they had witnessed a decrease in research capacity in their ministry and/or branch over the course of their tenure in BC government; and 68% believe that there are insufficient resources to effectively fill their branch or ministerial mandate (Smith et al. 2017). It is also telling that 57% of government scientists believed that public service cuts compromise the government's ability to use the best available evidence in decision-making, and that 49% believed political interference has compromised their ability to develop laws, policies and programs based on evidence.

While I delineate, western-based scientific knowledge, Indigenous knowledge, and local knowledge for this chapter, I also recognize that the differences among these knowledge types fall along, at best, a fuzzy spectrum. This delineation is an artificial construct and risks oversimplifying knowledge systems that are diverse, complex, and increasingly intertwined. Indeed, ILK (Díaz et al. 2015; Tengö et al. 2017; Ban et al. 2018) shares many similarities with western-based scientific knowledge (i.e., learning by doing, building and organizing knowledge). However, delineations play a necessary role in facilitating evaluation of knowledge, which occurs primarily within, rather than across knowledge systems (Tengö et al. 2014; Alexander et al. 2019). It is important to consider the differences among these knowledges and their approaches may not be only related to the different data or information themselves, but also possibly with different understandings of how management should proceed. Overlooking these differences can hinder collaborative arrangements among western, Indigenous, and local governments and communities.

Using western-based scientific knowledge, ILK individually or synergistically can yield complementary insights that can enrich and enhance our collective understanding of the natural world (Tengö et al. 2014; Ban et al. 2018). ILK can provide valuable information from long-term ecological monitoring to inform conservation goals and adaptive management, especially in data-poor scenarios. For example, Indigenous knowledge such as current and historical estimates of fish body size and abundance extended baselines for data-poor species such as yelloweye rockfish in BC, Canada (Eckert et al. 2018). Local knowledge from recreational anglers and spear fishers in Galicia, Spain provided valuable data for management on the temporal declines of targeted species such as cephalopods and finfish stocks but also on non-target keystone species such as the poor status of kelp beds which support these coastal ecosystems (Pita et al. 2020).

Though there is an expanding interest from the western governments and institutions in engaging with ILK holders (Simpson 2004; Wheeler et al. 2020), there are significant barriers to meaningful inclusion of Indigenous and local views and knowledge. Such issues include for example, the perceived need to 'validate' ILK with western-based science; the low-level of knowledge-holder inclusiveness; the amount of time required to build relationships and gather knowledge; and the blatant disrespect or ignorance of Indigenous rights (Ban et al. 2018; Reyes-García & Benyei 2019; Wheeler et al. 2020; Wong et al. 2020). The extraction of Indigenous knowledge, in particular, for use by western decision-makers may be problematic and work to further settler colonialism, especially if subsequent decisions are made without the full involvement, collaboration and consent of the Indigenous and local communities themselves. This can lead to the marginalization, appropriation, and commodification of Indigenous knowledge (Simpson 1999; Simpson 2001a).

The mountainous province of BC, Canada makes for a relevant case to explore the role of well-informed decision-making to enhance social-ecological resilience. BC is rich in natural resources contributing substantially to the local and national economies. It is also home to ethnically and culturally diverse people (Indigenous peoples with traditional and constitutional rights, European and Asian immigrants, engaged resource-user groups). The province is experiencing rapid biophysical changes to its highly diverse ecosystems impacting tightly linked social-ecological systems. Climate-driven hydrological changes (e.g., increased summer freshwater temperatures, more hypoxic lakes; reduced snowpack; earlier onsets of spring snowmelt) are a primary concern (Healey 2011; Zwiers et al. 2011; Islam et al. 2017). Meanwhile, BC's boreal forests have suffered extreme wildfire seasons and a severe mountain pine beetle (*Dendroctonous ponderosae Hopkins*) outbreak (Dhar et al. 2016; Kirchmeier-Young et al. 2019). These vulnerable habitats support charismatic at-risk wildlife species of major significance to Indigenous and non-Indigenous people alike such as cutthroat (*Oncorhynchus clarkii*) and bull trout (*Salvelinus confluentus*), and mountain caribou (*Rangifer tarandus*). Moreover, they support social, cultural and economic well-being of BC's people in in the form of, for example, water supply, subsistence and recreational fisheries and hunting, wild foods, sense of place, cultural identity and heritage.

The goal of this chapter is to provide an initial assessment of the extent to which Indigenous, local, and western-based scientific knowledge are incorporated into wildlife management in BC. I used semi-structured interviews to assess how these different knowledges are (1) perceived, evaluated, and used by potential knowledge users – Indigenous governments, parliamentary governments, and stakeholders, and (2) the extent to which social, political, and economic considerations challenge the integration of evidence into decision-making. In (1), perceptions and evaluations apply to the knowledge generators (i.e., holders) by extension also. While I have attempted to have a representative dataset, I acknowledge my data are biased overwhelmingly to parliamentary government or NGO decision-makers and this assessment is therefore most reflective of how these different knowledges are used by non-Indigenous and non-local decision-makers. I explore this using the case of managed rainbow trout (*Oncorhynchus mykiss*) fisheries in BC. This effort to gain a better understanding of how knowledge is perceived, evaluated, and used will hopefully lead to a stronger and more diverse evidence base and in turn, more informed decision making based on multiple ways of knowing.

2.2 Methods

This research is exploratory, aimed at investigating and categorizing how decision-makers and other potential knowledge users involved in the conservation and management of wildlife within BC view and use various types of knowledge (i.e., Indigenous, local, and western-based scientific). As such, this research is intended to be primarily descriptive, and hypothesis-generating rather than hypothesis-testing.

Befitting exploratory research, I developed and employed an interview schedule using open-ended questions (Axinn & Pearce 2006; Creswell 2014; Young et al. 2018b). Open-ended questions allowed a wide range of respondents to explain their positions, priorities, and opinions freely. It also allows them to be precise in their answers, providing hard to obtain and sensitive information on evidence use and decision-making processes. The set of questions analyzed in this chapter are provided in Table 2.1. I did not provide a definition of key terms (e.g., Indigenous and local knowledge) because I was interested in interviewee open-ended interpretations thereof, put in their own words, for comparative analysis.

Table 2.2 Open-ended interview questions analyzed in Chapter 2.

Question	Audience
Does Indigenous, and/or local knowledge or information play a role in your work? If yes, how important are these different types of knowledge or information to your work? If yes, in what ways do you use these different types of knowledge or information in your work?	All
Does western scientific knowledge or information play a role in your work? If yes, how important is western scientific knowledge or information to your work? If yes, in what ways do you use western scientific knowledge or information in your work?	All
What role (if any) does western scientific knowledge or information or data play in your decision-making [in a typical fishing season]?	Parliamentary Governments
In your opinion, what role (if any) does western scientific knowledge or information or data play in current provincial fisheries decision-making [i.e., in the Ministry of Forest, Lands and Natural Resource Operations and Rural Development and Environment]?	Indigenous Governments, Stakeholders
Has the role of evidence-based management changed over time within the relevant provincial ministries? Do you think fisheries decisions are more likely to be influenced by social, political, and/or economic interests today than they were historically? If so, why?	All
Generally speaking, in your opinion what makes knowledge about rainbow trout "reliable" or "unreliable"? [What are the characteristics of "reliable" and "unreliable" knowledge?]	All

This study was conducted in accordance to the University of Ottawa Research Ethics Board (File Number: 02-18-08). All participants gave informed consent to participate in the study. I performed a pilot interview after ethical clearance that showed no issues. Qualitative data were transcribed from audio to text using Trint (https://trint.com) and analyzed using NVivo 12 software (QSR International Pty Ltd. 2018). For open-ended responses a three-step inductive coding process was applied to qualitative data (Thomas 2006). First, responses were read to identify key words, which became a list of potential codes. Similar potential codes were then grouped into themes. Responses were read a second time and sorted under these themes to provide a measure of their prevalence. A response may have multiple thematic codes if warranted. All coding was performed by the ANK. Because the coding task, in addition to transcription of data from audio to text, already consumed a significant amount of time and resources, using more than one coder was not viable in this chapter and thesis. Additionally, the coding system/frame *is* the collection instrument, not the coder, and should establish coding consistency. Multiple coders may have different theoretical biases and will organize codes into themes in different ways (Armstrong 1997) thus it is not always clear if using different coders reduces susceptibility to bias or errors in judgement. Although I acknowledge using multiple coders will reduce the risk of human error and may be a limitation in the present chapter. For details on the development of the interview population frame see Kadykalo et al. (2020). A total of N = 161 individuals or organizations were contacted to request an interview.

A total of 65 interviews (response rate of 40%) were conducted in-person (n = 43) and over the phone (n = 22) between April and November 2018 divided between three broad groups: members from natural resource management branches of Indigenous governments (n = 4), and parliamentary governments (n = 33), as well as representatives from non-governmental stakeholder groups (n = 28) involved in the management of recreational and subsistence rainbow trout fisheries in BC. The affiliations of respondents are provided in Table 2.2.

Table 2.2 Affiliations of the 65 participants and 96 non-participants (who were contacted but did not participate because they a) did not respond to my request, or b) declined to participate), grouped as members from natural resource management branches of Indigenous governments, and parliamentary governments, as well as stakeholders.

Indigenous Governments (FN)	n	Parliamentary Governments (GOV)	n	Stakeholders (STKH)	n	**TOTAL n**
Biologists	2	Biologists (FLNRORD)	17	Academia	6	
Fisheries Managers	2	Directors (FLNRORD)	3	BC Hydro	2	
		Fish & Wildlife Section Heads (FLNRORD)	6	Environmental non-governmental organization (ENGO)	5	
		Human Dimensions Specialist (FLNRORD)	1	Freshwater Fisheries Society of BC (FFSBC)	6	
		Policy Analysts (FLNRORD)	2	Private environmental consultants	6	
		Conservation Science Section (MOE)	3	Retired provincial government employees	3	
		Science Branch (DFO)	1			
Participant Sub-Total	(4)		(33)		(28)	**65**
Biologists	2	Assistant Deputy Minister (FLNRORD)	3	Academia	4	
Fisheries Managers	19	Biologists (FLNRORD)	31	BC Hydro	2	
		Directors (FLNRORD)	10	ENGO	2	
		Fish & Wildlife Section Heads (FLNRORD)	2	FFSBC	7	
		Fisheries Advisor	1	Private environmental consultants	1	
		Managers (FLNRORD)	2			
		Permit Clerks (FLNRORD)	3			
		Policy Analyst (FLNRORD)	1			
		Policy Leads (FLNRORD)	2			
		Regulations Officers (FLNRORD)	1			
		Regional Resource Manager (DFO)	1			
		Science Branch (DFO)	1			
		Provincial Fish Science Specialist (Government of Alberta)	1			
Non-Participant Sub-Total	(21)		(59)		(16)	**96**
TOTAL	25		92		44	**161**

While the focus of this research is recreational rainbow trout fisheries many of the respondents are involved in the conservation and management of fish and other wildlife populations. Therefore, the responses in this chapter are most specific to fisheries management but are described throughout under the broader term 'wildlife management and conservation'. Interviews lasted between 18 minutes and 2 hours, depending on the level of detail provided by the respondent.

2.3 Results

The results are organized by the order of questions in Table 2.1. Respondent sources and illustrative quotations which support out results are provided in Appendix C and linked as citations (end-noted superscripted numbers).

2.3.1 Indigenous and local knowledge

2.3.1.1 Indigenous knowledge

Indigenous knowledge plays a distinct role in the work for 51% of respondents[1] (i.e., they use it on a day-to-day basis), a minimal or limited role for 9% of respondents[2], and no distinct role for 22% of respondents[3] (Figure 2.1). For 23% of respondents, Indigenous knowledge was openly described as important, even critical, to their work[4].

The use of Indigenous knowledge was categorized in multiple different ways (Table 2.3). Many respondents cited statutory and legal (and funding agency) obligations to engage Indigenous peoples in decision-making and consider Indigenous knowledge more strongly[5]. Although, as some respondents noted, much of these obligations are just "paid lip service", lacking action – "it's very early days for us around that now".

Parliamentary government employees and stakeholders cited challenges and struggles in both *getting* and then *incorporating* Indigenous knowledge into decision-making[6]. The reason for these challenges were attributed to two issues, confidentiality of Indigenous knowledge and lack of trust. Examples for the former,

> “They like to protect it [Indigenous knowledge]. They often don't like to share it.” (Interview #58; male; provincial natural resources ministry affiliation).

> “There may be a reluctance on the First Nations part to provide it. First Nations are probably going to be more and more reluctant to divulge anything on net fisheries because they're going to be afraid that they're going to be cut back.” (Interview #59; male; ENGO affiliation).

Examples for the latter,

> “It's a process where we have to gain the trust of the First Nations before we get there. The First Nations [Indigenous knowledge]; that's probably the most important knowledge to gain because when we're dealing with accommodation, it'll be very important to gain the trust and to begin to work together, especially where they're beginning to say particular fisheries are now sustenance fisheries.” (Interview #14; male; provincial natural resources ministry affiliation).

> "I think we struggled sometimes understanding what was really important to First Nations and incorporating it. Sometimes it was the trust factor in terms of actually getting the particular traditional knowledge." (Interview #53; male; retired provincial government employee affiliation).

Confidentiality of Indigenous knowledge and a lack of trust may be a (by)-product of (perceived) insufficient legal protection of intellectual property[7]. It may also be due to a perceived concern of further losing constitutional (i.e., hunting and fishing) rights.

Several respondents (from the provincial natural resources ministry, ENGOs, the province-owned electric utility) acknowledged that the role of Indigenous knowledge is less than it should be, and a better job should be done in reflecting Indigenous values and knowledge in modern wildlife decision-making[8].

2.3.1.2 Local knowledge

Local knowledge plays a role in the work of 59% of respondents[9] and a minor or minimal role for 3% of respondents[10] (Figure 2.1). Twelve respondents (19%) were definitive on the importance of local knowledge to their work, relying heavily upon it[11].

Descriptions of local knowledge use by parliamentary government and stakeholder respondents overwhelmingly focused on the value of local knowledge from local communities (e.g., resource user groups) identifying blind spots (Table 2.3). That is, parliamentary government management agencies are limited by time and resources across (seemingly) endless territories ("we have so many lakes. I don't know a lot about all of them"), and therefore rely on local knowledge to "put up red flags". Moreover, like Indigenous knowledge, a sample of responses focused specifically on local knowledge signalling where and when environmental changes are occurring, and how local knowledge is used as a tool to inform and prioritize work and issues. For example,

> "It's sad to say but we're pretty reactionary in our work. I'd say for the changes we make, probably 50 percent of them are driven by initial comments from public or other user groups that trigger us to go and take a closer look. Then we can make an informed decision after we gather some data." (Interview #18; male; provincial natural resources ministry affiliation).

Some respondents noted that resource user groups – through sharing of local knowledge – have significant influences in prioritizing issues and projects or can be vital allies in conservation causes[12]. Conversely, some respondents left a cautionary note on incorporating stakeholder information[13]. It was remarked that anglers (and other local knowledge holders) may not be able to scale their individual observations and experiences to population-level understanding (i.e., unaware of the cumulative impacts of what they and others are doing to fish populations broadly – for example, mortality associated with catch-and-release fishing). Because local knowledge is frequently used for lobbying (i.e., politicized), it has the potential to steer management in wrong or self-interested directions[14]. Therefore, local knowledge may be weighted more heavily when it aligns with the core objectives of management[15] and can be confrontational if it conflicts with the core objectives of management[16].

2.3.2 The interface between Indigenous and local knowledge and management

ILK are grouped here not to conflate them, or to suggest they are interchangeable, but to best discuss the findings given these types of knowledge or information have not traditionally been the foundation or explicitly accounted for within the frameworks of western (i.e., parliamentary-governed) wildlife management.

Engaging ILK and then incorporating and reflecting it into modern wildlife management is being attempted or discussed[17] (by 45%), but actually doing it in practice is characterized as a challenge[18]. To summarize respondent perceptions, ILK is "not really straightforward" and is difficult to understand, translate, and assess. Additionally, while Indigenous governance systems are highly diverse – they may follow a very different decision-making process which may be very specific, consensus-driven and therefore prolonged (i.e., multigenerational) by western standards[19]. These struggles notwithstanding, ILK faces an additional uphill battle as western science generally carries more weight in decision-making[20]. However, ILK can lead to valuable insights[21] that could lead to better decisions, harnessed via collaborations and partnerships[22] which are projected to increase[23] especially given the provincial government has emphasized ILK as a key resource[24]. When it comes to reconciling ILK with wildlife management, two-way dialogue[25] focused on respectfully unpacking party interests and long-term goals was recommended for building trustful relationships[26].

2.3.3 The interface between Indigenous and local knowledge and western scientific knowledge

Fundamentally, the philosophies between ILK and western science may not differ substantially[27]. Successful integration (merging and bridging) or co-existence of ILK with western-based science was seen as partially dependent on being open to individual positions and values – "if you're open to it then it'll diffuse, but if you're not and close to it, it won't resonate"[28]. While collaborative approaches to combine knowledge types in decision-making are evolving, involved, and time-consuming, such approaches can reveal unique information[29]. Moreover, western science can complement ILK and add more weight to ILK, and vice versa.

2.3.4 Western scientific knowledge

Respondents were near-unanimous that western scientific knowledge plays a role in their work and decision-making[30] (98%) (Figure 2.1). The majority of respondents (65%) reported that western scientific knowledge plays a primary, central, and fundamentally critical role in their work[31], e.g.: "that's mainly what we do", "it's the foundation of our work", "it underpins all or our fisheries work in the province". As the core of many respondents' work, western scientific knowledge was considered as the *most* important source of information for their work (e.g., "the actual final decisions tend to be weighted around western science and all others feed into it"). However, two respondents (both Directors of Resource Management at the provincial natural resources ministry) were transparent that at their level of management, western scientific knowledge plays little role directly[32].

Western scientific knowledge is used by the majority of respondents (69%) to guide decisions, priorities, and management actions (Table 2.3); e.g., evaluating projects and programs[33], adjusting or setting regulations[34], especially stocking rate protocols[35]. Several respondents noted that in addition to the obvious use of natural science, that increasingly human dimensions research (e.g., creel and preference surveys) are being applied to inform decisions[36].

Western scientific knowledge used in decision-making is primarily sourced from "in-house" 'evidence-producers'[37] (49%) (e.g., stock and lake assessments[38], monitoring programs[39], long-term experiments, academic partnerships), and 'external' secondary sources[40] (39%) (e.g., peer-reviewed journals and publications, books, information from government management agencies in other jurisdictions). Several respondents clarified that they were not statutory decision-makers, and their roles were entirely about producing western scientific knowledge, and in cases, also providing advice (e.g., briefing notes) for decision-makers or stakeholders[41].

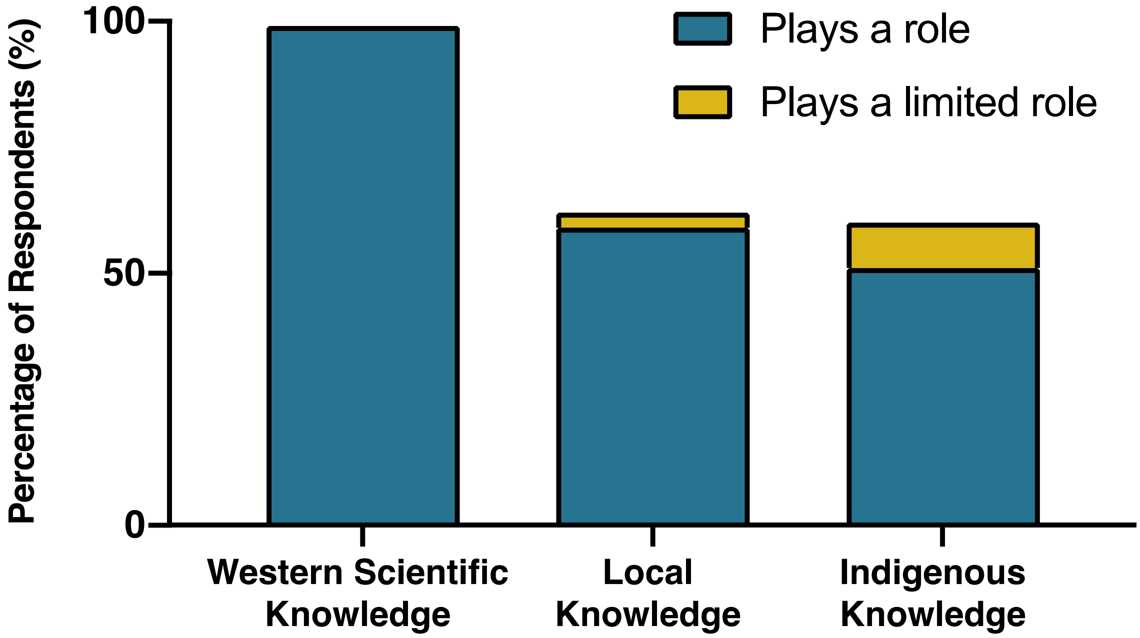

Figure 2.1 The role of western scientific, local, and Indigenous knowledge, as measured by percentage, in the work of n = 65 respondents.

Table 2.3 Indigenous, local, and western scientific knowledge used as evidence in the work of n = 65 respondents. Raw counts (and %) are number of respondents making a mention to the corresponding use of evidence. Respondent sources and illustrative quotations which support evidence use are provided in Appendix C and linked as citations (end-noted superscripted numbers).

Evidence Use	Examples	Indigenous Knowledge	Local Knowledge	Western Scientific Knowledge
Informing and re-fining work priorities and strategies Guide decisions, priorities, research and management actions	Where to prioritize enforcement, monitoring etc.; which projects (e.g., research questions), populations, objectives (protection, angling regulations) and issues (e.g., disease, invasive species) to prioritize	9 (14%)[1]	12 (19%)[10,11]	45 (69%)[20]
Historical information on fish and fisheries The distribution and extent of native fish populations	Abundance, distribution, habitat, fish size, population size, population trends, occupancy, range, spawning locations, species composition, threats etc.	24 (37%)[2]	10 (15%)[12]	
Identifying blind spots Issues or a sense of the quality or quantity of the resource people are seeing on the landscape	Angling pressure/over-fishing, disease, invasive species; population abundance/density		24 (37%)[13,14]	
Environmental change The value of knowledge in capturing *where* and *when* "inflection points" or changes occurred or might be occurring	Angling pressure, catch rates, climate, fish size, habitat and flows, overfishing, extinctions/extirpations	9 (14%)[3,4]	7 (11%)[15]	
Consideration of proposed regulation changes Adjusting or setting regulations	Stocking plans and decisions		5 (8%)[16]	11 (17%)[21]
To inform historical baselines Historical and contemporary "benchmarks"; what habitats *were* or *are* capable of in terms of fish and wildlife production	The ecological value or capacity of fish habitats prior to European colonialism or Post-World War II economic expansion	5 (8%)[5]	7 (11%)[17]	
Alternative Source of information	"Other data to substantiate" a knowledge claim	4 (6%)[6]	4 (6%)[18]	

Evidence Use	Examples	Indigenous Knowledge	Local Knowledge	Western Scientific Knowledge
A secondary source or perspective for comparison or supplementation of other knowledge types, "even if it's just to confirm my own observations"				
Local communities/stakeholder values and preferences Cultural and material values and importance tied to fish and fisheries, and how communities and stakeholders would like them to be managed	Harvest preferences, preferred spawning habitats, prioritizing populations, scenery		13 (20%)[19]	
First Nations traditional use, values, and preferences Cultural and material values and importance tied to fish and fisheries, and how First Nations would like them to be managed	Historic subsistence fisheries and practices	8 (12%)[7]		
Indigenous "stewardship values" Advocacy, protection, and restoration of fish populations and fish habitat	Protection of quantity and quality of fish	5 (8%)[8]		
Recovery plans and assessments	Historical abundance, historical distribution	2 (3%)[9]		

2.3.5 The diminishing role of evidence in the decision-making process

While evidence clearly has a considerable role in wildlife management and conservation – more than 40% of all respondents, namely, parliamentary government employees[42], those that at one time were in the employ of the provincial government[43], and those who work closely with parliamentary governments[44] provided accounts about what they perceived as the diminishing role of evidence (including ILK and western scientific knowledge) in decision-making. According to these accounts evidence in decision-making is limited by increased political and socio-economic influence (28%)[45], decreased institutional resources and capacity (9%)[46], and institutional knowledge (9%)[47], as well as (Figure 2.2).

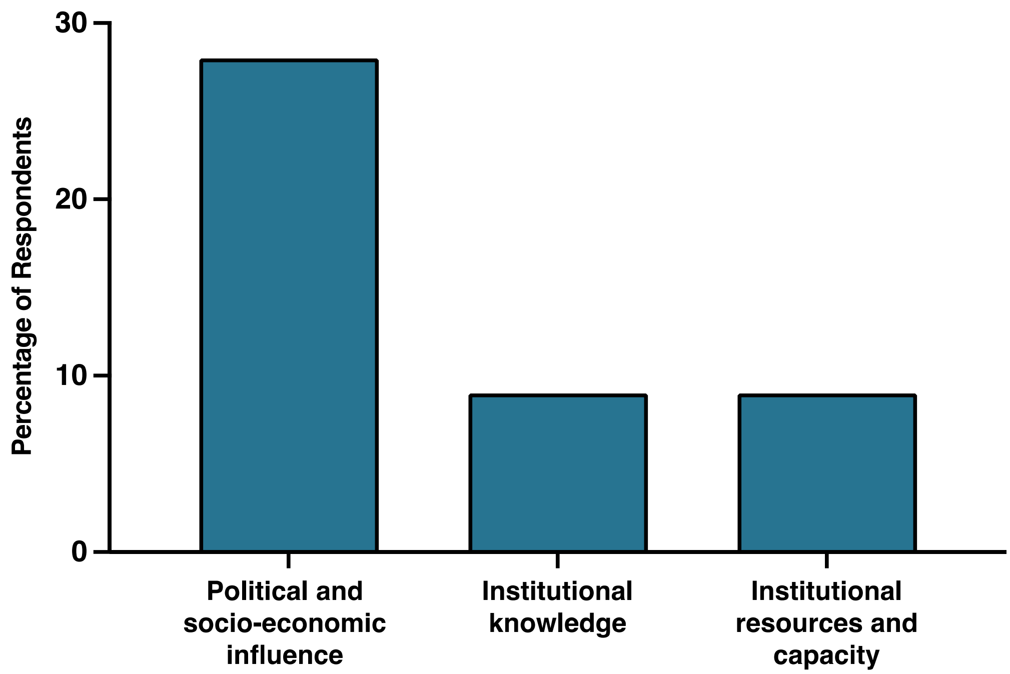

Figure 2.2 The diminishing role of evidence in provincial wildlife policy and practice due to increased political, and socio-economic influence; reduced institutional knowledge; and reduced institutional resources and capacity. Measured by percentage for n = 65 total respondents which specifically mentioned limitations to evidence-based decision-making.

2.3.5.1 Political and socio-economic influence

In the perspectives of many respondents, wildlife decisions may begin as evidence-based but are prone to becoming influenced by social, political, and economic factors (e.g., values, ideology). In other words, management actions and policy decisions may deviate from evidence. This is by no means a recent phenomenon but was described as more likely to occur today than it was some 10-25 years ago. Moreover, it was perceived that the higher within an organizational hierarchy evidence is considered in decision-making (e.g., at the Director or Deputy-Ministerial level), the more likely that evidence will be diluted. However, resource management decision-making was also frankly portrayed as a lot more complex today than yesteryear due to for example, a much more knowledgeable and better organized stakeholder base, especially around wildlife species which are targeted for recreation and harvest. This complexity may result in knowledge becoming politicized or exploited for social, political, or economic objectives (e.g., delaying actions and decisions over scientific uncertainty). In sum, provincial government decision-making may not be "purely science-based so much as its science-informed" (Interview #6; male; provincial natural resources ministry affiliation). Appendix D presents a sample of illustrative quotations which capture the issue of political and socio-economic interference to evidence-based decision-making.

2.3.5.2 Institutional resources and capacity

Respondents submitted that while decisions are made on the best available evidence available to them, they are challenged to deliver science (i.e., conduct research and/or use evidence) by limited resources. For example,

> "The provincial government that was in from 2001 to 2016 defunded the provincial natural resources ministry and de-staffed it by 50 percent. So, like a distillation column, when you de-staff, a lot of the bright people leave and what you're left with is people that are close to retirement, insanely committed that they'll stay there no matter what, or the idiots who are just happy to have a job." (Interview #57; male; academia affiliation).

The result being a shift from being less "research-driven" to more "management-driven" in which decisions rely more-heavily on anecdotal information, and "managing by feel". The resulting perception is that provincial ministries are no longer evidence producers (i.e., providers of western scientific knowledge) with academia fulfilling vacated parliamentary government science-based roles – for example,

> "I think the universities today play a greater role in providing information than the provincial government does unfortunately. I think their role is flipped. Mostly they're a regulatory body now, unfortunately. They used to provide science-based information of their own but not so much anymore." (Interview #45; male; private environmental consultant affiliation).

2.3.5.3 Institutional knowledge

The quality of parliamentary government western science was called into question by some respondents. When and where decisions are made by individuals (e.g., district managers) that lack experience and specific scientific education and training (e.g., statistics, social sciences, aquatic ecology) or there are few such qualified staff (that feed into the decision-making process), institutional scientific knowledge is perceived to suffer as decisions become based on feel and reaction opposed to analysis of data. The following example captures this limitation,

> "The institutional knowledge is just a fraction of what it used to be. We have fewer people with long-term experiences and a lot of new staff not from BC. They're usually smart people. They work hard. They're biologists. But they start at ground zero with the history, geography, and biology of the province." (Interview #42; male; provincial Ministry of Environment affiliation).

2.3.6 What is 'reliable' or 'unreliable' knowledge?

Appendix E presents the thematic codes—criteria—associated with "reliable" and "unreliable" knowledge along with the number of respondents making mention of each theme. Starting with reliability, a substantial minority of all groups mentioned the importance of factual corroboration of knowledge claims (e.g., by pictures, data etc.) (Table E.1). All groups also cited the importance of repeatability and reproducibility to demonstrate consistency, sound research design and methods, and peer-reviewed knowledge or information. Similar numbers across all groups also cite the scientific method, reputation—especially trustworthiness—of claimants, and quantifiable data as important indicators of reliable knowledge. Noticeable differences include a sizeable number of both parliamentary government employees and stakeholders citing the importance of acknowledging limitations (i.e., assumptions, uncertainty), as well as the expertise, skills, education, and training of claimants. This was not as frequently mentioned by members from natural resource management branches of Indigenous governments. Conversely, members from natural resource branches of Indigenous governments cited the importance of publicly available knowledge and information. Unsurprisingly, parliamentary government employees also focused more on the personal “hands-on” experience of claimants than other groups. Some respondents self-identified their own confirmation bias influencing perceptions of reliability, whereby knowledge claims which re-affirm previously existing experience and beliefs are given more weight.

Correspondingly, concerning unreliable knowledge, respondents frequently cited opinion, conjecture, or speculation without sufficient proof or evidence (Table E.2). Related to this, several responses described the ‘Dunning-Kruger effect’ (Dunning 2011), a cognitive bias in which people judge their cognitive ability to be greater than it is. Other key indicators of unreliable knowledge mentioned include: issue advocacy or self-interest of claimants; poor or non-transparent research design and methods (particularly for grey literature which is “not very well standardized, documented, or reported”); and anecdotes, hearsay, and inconsistency (i.e., conflicting reports, sampling bias). Stakeholders cited slightly fewer indicators of unreliable knowledge, while members from natural resource branches of Indigenous governments cited none specifically.

While ILK itself was explicitly cited by a few respondents as unreliable (Table E.2), several respondents indicated that reliability of Indigenous knowledge was especially difficult to assess[48]. This becomes an issue for application according to some respondents if Indigenous knowledge cannot be assessed for reliability under the same kind of criteria and scrutiny as western scientific knowledge[49]. Although people embedded in Indigenous knowledge systems might disagree with this assertion – that Indigenous knowledge cannot be assessed for reliability to the same extent as western scientific knowledge (though it might be difficult to assess within a western framework). Other respondents were optimistic about the reliability of Indigenous knowledge, especially if assessed under the criterion of sound research design and methods, repeatability, reproducibility, and consistency[50].

Several respondents cited "shifting baselines" (i.e., 'creeping normalcy' – Pauly 1995; Knowlton & Jackson 2008) as an important temporal interaction on determinations of reliable or unreliable knowledge[51]. Namely, the weight of historical knowledge may be diminished in contemporary contexts if major changes accepted as normal happen slowly through minor, often unnoticeable, increments of change[52]. Thus, reliability of knowledge may be dependent on the 'baseline condition', i.e., how far back in time one establishes the baseline.

2.4 Discussion

Contrary to studies that suggest evidence-based conservation and management decisions are rare (e.g., see examples in Section 2.1, and Cvitanovic et al. 2014; Koontz & Thomas 2018), respondents involved in wildlife management and conservation in BC described relying heavily on multiple forms of knowledge to inform their decisions. However, like Lemieux et al. (2018), where knowledge use in Canada's protected areas organizations was investigated, I found local knowledge, and especially Indigenous knowledge use to be much less than western scientific knowledge, or personal and institutional experience or opinion.

These results suggest that different types of knowledge are helpful in answering empirical and values-based management questions. For example, there is a clear indication that ILK, like western scientific knowledge, can help address purely empirical questions (e.g., How many fish in are there in this lake?). In this case, ILK is most often applied to extend and set historical baselines on wildlife and environmental change in data-poor scenarios. This confirms observations and results of other authors (e.g., Reed et al. 2013; Ban et al. 2018; Eckert et al. 2018; Pita et al. 2020). This knowledge then presumably helps wildlife managers oppose shifting baseline syndrome reducing the potential for overexploitation of nature. Clearly, questions that involve values (e.g., Should trout be introduced in this lake where they are currently and/or historically not present?) benefit from ILK. I found some evidence for management considering values such as harvest preferences and cultural importance. However, the extent to which management asks such questions to ILK holders is unclear from this data and should be an area of future work.

While respondents were generally willing and interested (and in some cases, required) to increase engagement with ILK, challenges pertaining to knowledge evaluation and use were observed. Namely, a lack of trust, hesitancy to share knowledge (particularly from Indigenous communities), difficulties in assessing reliability, and difficulties discerning knowledge from advocacy – i.e., "agency capture" (that is, undue influence on agency decision-making by special interest groups) (Artelle et al. 2018a).

Concerningly, regardless of knowledge type, these findings point to a diminishing role of evidence in final decisions concerning wildlife management and conservation. In other words, evidence appears to be an important consideration (as revealed by these results) but is often outweighed by other considerations, contrasting evidence-based decision-making. So, while respondents in these interviews rely heavily on multiple forms of knowledge to inform their decisions, their day-to-day decisions are generally at levels of governance that are not responsible for final decisions that concern wildlife management and conservation. In other words, the majority of participants are not at the top of the hierarchy of the organizations in which the work. I attempted to include statutory decision-makers (e.g., Deputy Ministers, Directors, and Section Heads – see Section 1.5 The Case) responsible for such final decisions as participants, though such people are few, as is the number of representatives of this group who participated in interviews. Hence, these results support the idea that evidence may form the basis of a decision but is often eclipsed by other, perhaps more economically or politically pressing, considerations (e.g., Morrison-Saunders & Bailey 2003; Artelle et al. 2018a). I find this in this case despite claims that decisions from statutory decision-makers in BC are grounded using an evidence-based standard (Government of British Columbia 2017; Artelle et al. 2018a). Like others have found (e.g., Smith et al. 2017; Nguyen et al. 2018; Kadykalo et al. 2020), mobilizing knowledge in support of wildlife management and conservation is, in parliamentary governments at least, limited by a decrease in research capacity (time, staff, and financial resources) and institutional knowledge. A recent history of austerity at the federal and provincial levels of government is in part, likely culpable (Smith et al. 2017; Westwood et al. 2017). This may partially explain why many parliamentary government respondents attributed the heavy use of local knowledge to identifying blind spots, providing warning signs of potential crises, thus informing adaptive management.

In this case study, increased socio-economic and political influence strongly corresponded to the diminishing role of evidence in wildlife management and conservation. It is tempting to associate the lack of evidence-based decision-making in wildlife management with the prevailing political climate. However, Artelle (2019) suggests these ‘cracks’ “run far deeper than ephemeral political cycles” and therefore should not be treated as a temporary phenomenon. Due to capacity, socio-economic, and political constraints, parliamentary (and perhaps Indigenous) government natural resource managers may not be empowered to use knowledge, regardless of type, even if it is available.

As I have found here, natural resource management agencies may be perceived as reactionary regulatory bodies, increasingly distanced from the generation and use of evidence.

For example, cuts to the public service in BC have resulted in much of the public interest science normally done by the province outsourced to “qualified professionals” hired by industry and project proponents with little to no oversight (Smith et al. 2017) – putting into question the role of evidence in the public’s interest. Concerning the evidence itself, it cannot be simply assumed that there is a dearth of knowledge and that generation of more knowledge, regardless of type is better, benefitting decision-makers in wildlife management and conservation. As recognized by Lemieux et al. (2018), in capacity-poor organizational settings (the case for many wildlife management agencies) information overload presents a paradox. Increases in information may further stress already limited human and financial capital as staff try to distill the relevant and credible information they need, thus overwhelming management and decision-making processes.

To overcome a lack of effective knowledge exchange, evidence synthesis (e.g., systematic reviews, systematic maps) is frequently endorsed as a logical solution to deliver relevant, accessible, and timely information to encumbered environmental decision-makers (see Pullin & Knight 2001; Dicks et al. 2014b; Pullin et al. 2016; Cook et al. 2017). I recognize that evidence synthesis alone is likely not enough to improve the use of knowledge, and that more is required (e.g., knowledge brokers; Segan et al. 2011) to develop the knowledge mediation sphere (Nguyen et al. 2017a). Yet, evidence synthesis is a tangible step to amplify and foster multiple forms and sources of knowledge, as well as strengthen partnerships between knowledge producers and decision-makers.

In theory, a benefit of evidence synthesis is that it can draw upon diverse knowledge sources and disciplines in a cohesive manner to comprehensively inform issues on a given matter. However, evidence synthesis has traditionally focused on knowledge from western-based, especially natural sciences (Wheeler & Root-Bernstein 2020). This suggests that individuals and organizations that compile and review environmental evidence (e.g., The Collaboration for Environmental Evidence and Conservation Evidence, Conservation Evidence) ought to increase efforts to include other sources of knowledge such as from Indigenous and local communities. The good news is that there are many useful ILK publications and case studies (Collier-Robinson et al. 2019; Wyllie de Echeverria & Thornton 2019) to draw upon. This is further illustrated by the 'Bridging Indigenous and Science-Based Knowledge Initiative' under the auspices of Fisheries and Oceans Canada (DFO), a department of the Government of Canada. In the process of producing systematic evidence maps, they have found 71 studies for coastal-marine systems and 74 for freshwater in Canada alone (personal communication; Alexander et al. 2019). In practice, both western science and ILK could be synthesized and shared using a web portal containing a geospatial map, as DFO are planning. Furthermore, synthesists, like primary researchers should move beyond consultation toward building meaningful relationships in collating and synthesizing evidence. While this will involve making calls for evidence to Indigenous and local knowledge holders, it should also involve utilizing existing Indigenous and local led knowledge platforms such as SIKU – the Indigenous Knowledge Social Network and Exchange for Local Organizations and Knowledge of the Arctic (ELOKA) which retain ownership, control, access, and sovereignty of the data to knowledge holders.

Indigenous and local knowledge is place-based knowledge accumulated intergenerationally by close and continuous observation within specific cultural contexts, belief systems, epistemologies, and worldviews (Díaz et al. 2015; Tengö et al. 2017; Ban et al. 2018). Thus, ILK is nuanced and integrates understandings of observations within the system and environmental context within which it was generated. In other words, Indigenous and local information may not, cannot, and perhaps *should* not be separated from the value system and worldview which its placed. For example, in defining the quality of a fishery, Indigenous knowledge may include attributes that are also valued by western scientific knowledge (run-timing, size and abundance of a stock), as well as those that are not, such as attributes of kinship to fish (markings on fish, flavour, colour and texture) and emphasis on place of capture (Interview #22; male; Indigenous government natural resource branch affiliation). These can be considered relational values, broader than instrumental and intrinsic values, which encompass preferences, principles, and elements about human relationships that involve more than just human beings (e.g., Gould et al. 2019). Hence, extracting ILK and placing it within a western-based framing as might occur in evidence synthesis risks reducing ILK systems to a collection of mere factual data and losing the full benefit of the holistic nature of these knowledge systems. ILK which generally takes a holistic approach may directly oppose western-based science and frameworks which generally takes a reductionist approach. Importantly then, standards, guidelines, and practices for ILK generation, synthesis, and weaving them with western science should be (co-)developed by ILK holders themselves, not western scientific primary researchers or synthesists. This will involve moving away from knowledge integration and knowledge co-production to a knowledge coevolution framework (Chapman & Schott 2020). In such a framework, distinct knowledge systems are bridged and strengthened to generate new understandings while considering the normative impacts of western science and empowering local knowledge holders.

Challenges related to assessing the reliability of ILK from western decision-makers suggest a deep tension about ILK use in western frameworks. This might however be expected for non-Indigenous people given Indigenous knowledge is outside of their own knowledge system. The prevailing perception is that ILK needs to be validated or verified by western scientific knowledge to be useful (Needham et al. 2020; Wheeler et al. 2020; Wheeler & Root-Bernstein 2020). In addition to extracting ILK without the full involvement, collaboration, and consent of Indigenous and local knowledge holders the desire to validate ILK furthers a lack of trust. It may also lead to the marginalization, appropriation, and commodification of knowledge.

As revealed here and elsewhere (see Huntington 2000; Reed et al. 2013; Ban et al. 2018; Ainsworth et al. 2020; Wheeler & Root-Bernstein 2020), ILK use can yield significant benefits for environmental management. The question is no longer whether to engage ILK but how best to do this. Western decision-makers may be overly cautious in doing so, given the complicated knowledge-action space presented above. This reveals a need for training for western-based scientists and decision-makers on how to avoid bias from misunderstanding ILK and to overcome misconception*s* such as the need to validate it (Wheeler et al. 2020).

Fundamentally, these results further suggest Indigenous and local peoples should be directly involved in wildlife management—using and interpreting their own knowledge as appropriate. Thus, ILK should be evaluated in reference to the knowledge system in which it is situated. Under a fair and equitable system, the salience, legitimacy, and credibility of ILK would then be evaluated by knowledge holders from that knowledge system (Tengö et al. 2017; Wheeler & Root-Bernstein 2020).

Co-existence, complementarity, and alignment of western-based and ILK systems in management necessitates supporting autonomous knowledge. Practically this means, “have them side by side so you can see the value of each, to see them for what they are” – otherwise there is a risk that “you water each of them down” (Interview #54; female; provincial natural resources ministry affiliation). Two related concepts recently introduced in western literature may help achieve this: co-assessment of existing knowledge (Sutherland et al. 2017) and ‘Two-Eyed Seeing’ (Mi'kmaq principle of Etuaptmumk) (Rayne et al. 2020; Reid et al. 2020). In the former, western decision-makers collaborate with ILK actors to assess the validity and relevance of external knowledge which may lead to Indigenous and locally informed knowledge synthesis and decisions. The latter brings together multiple knowledge systems side by side in which both ‘eyes’ view the world for the benefit of all, rather than making one ‘eye’ conform to the rules and assumptions of the other.

This study population was highly biased to provincial and ENGO decision-makers. This was not intentional as I attempted to have a representative dataset covering stakeholders, Indigenous and parliamentary governments. Nonetheless, this limits our ability to infer the use of knowledge beyond primarily western decision-makers. Representatives from natural resource branches of Indigenous governments were few, as many of those contacted for requests for interviews expressed little or no interest or expertise in rainbow trout, citing identities linked primarily to salmon. So, for example, it is likely that Indigenous knowledge may indeed play a much greater role on the ground by Indigenous governments and communities, but this would not be captured by these data. Inherently, the methods employed, open-ended questions in interviews also presents limitations. The interviewer, consciously or otherwise, may influence the direction of interviewee responses through underlying personal biases or preconceptions. However, the benefits in enabling me to collect sensitive data from a wide range of practitioners and providing flexible space for interviewees to explain their positions, priorities, and opinions freely and precisely was why this method was chosen over, a survey questionnaire, for example (see Young et al. 2018b).

2.4.1 Conclusion

Wildlife management decisions are highly meaningful, supporting the conservation of biodiversity, habitats, and ecosystem services but they are extremely complex. Evidence is an important source for informing decisions under such extreme social-ecological complexity. These results suggest that gaps between generated knowledge and knowledge users (Toomey et al. 2017; Bertuol-Garcia et al. 2018) may not be as pervasive or expansive as described in some contexts. In this case, Indigenous governments, parliamentary governments, and stakeholders use multiple forms of knowledge in decision-making but rely heavily on internal (institutional) knowledge. However, despite agreement that local knowledge, and especially Indigenous knowledge, can yield significant benefits for wildlife management and conservation, it is generally under-utilized in comparison to western scientific knowledge, or personal and institutional experience or opinion. Concerningly, underlying the use of knowledge is a perception of the diminishing role of evidence in decisions concerning wildlife management and conservation. Interview respondents associated this move away from evidence-informed decision-making with decreases in institutional resources and capacity, but especially with increases in socio-economic and political influence which outweigh evidence.

This research generates further questions. I have assessed how wildlife managers evaluate knowledge, but how they procure it in organizational cultures with capacity shortages and information overload is also important. Whether potential knowledge users perceive claims as more knowledge-based or more advocacy-based and the factors which predict this outcome would benefit evidence-based management and conservation. It would be important in any follow-up work to distinguish how different types of knowledge might be more or less helpful in answering questions that mix empirical data and values (e.g., what is the sustainable level of fish harvest for this lake?), what that information would be, and how it would be used. This was a particular gap observed in this work. Further, empirical investigations of co-assessing knowledge and applying the ‘Two-Eyed Seeing’ approach are needed to assess their effectiveness and limitations in wildlife management contexts (Sutherland et al. 2017; Reid et al. 2020).

For wildlife management to be truly adaptive and effective, drawing on the full complement of evidence to develop a holistic and collective understanding of the natural world seems desirable. Thus, more is needed to improve the use of evidence. Particularly I emphasize the need for knowledge brokers; standards, guidelines, and practices for ILK generation and synthesis developed by knowledge holders; and collaborations and partnerships between and within western science, Indigenous, and local communities which embrace knowledge coevolution (Chapman & Schott 2020). I encourage transformative changes in wildlife management towards direct involvement of knowledge holders, co-assessment of knowledge, and transparency in how (multiple forms of) evidence contribute to decision-making. These changes also pertain to organizational cultures so that wildlife managers are motivated and enabled to apply multiple forms of knowing to advance decisions that yield co-beneficial management and conservation outcomes for both people and nature. I believe this can help overcome a lack of trust, hesitancy to share knowledge, difficulties in assessing reliability, and difficulties discerning knowledge from advocacy.

Chapter 3: Uncertainty, anxiety, and optimism: Views of stakeholders, Indigenous rightsholders, and regulators on the past, present, and future status of Rainbow and Steelhead Trout fisheries governance in British Columbia

3.1 Introduction

Inland fisheries are complex social-ecological systems that provide important nutritional, economic, cultural, and recreational benefits to people from fish in nature (Arlinghaus et al. 2013; Lynch et al. 2016). These fisheries are essential to the sustainability and well-being of many communities and regions across Canada. Fisheries within inland waters—lakes, rivers, streams, canals, and reservoirs—are diverse. They include commercial, moderate livelihood, subsistence, ceremonial, and recreational fisheries, which often maintain a common interest in the same fish. Responsible fisheries management is essential to ensuring fish species and the communities they support are sustainable and thriving for generations to come.

Yet, the biophysical environment of inland fisheries is increasingly threatened by rapid environmental change. Fish are among the most endangered organisms globally, especially within freshwaters (Cooke et al. 2013; Reid et al. 2019). Globally, populations of freshwater species have declined by an average of 83% since 1970 (Harrison et al. 2018; WWF 2018), while migratory fish which depend on freshwaters have declined by an average of 76% since 1970 (Deinet et al. 2020), a far steeper drop than for terrestrial or marine-exclusive species. Extinction rates for freshwater species are exceptionally high in Canada, the proportion of fish species classified as 'Extinct' in Canada is over four times higher (1.96% of 204 identified freshwater-dependent fish species) than that observed worldwide by WWF (0.44% of 18075 identified species) (WWF 2021). Declines in fish diversity and abundance are inextricably connected to converging social-ecological crises (Dudgeon 2019) whereby humans have altered biogeochemical cycles, climate processes, and ecosystem functions (Steffen et al. 2015). Threats to the biophysical environment of fish are thus made further complex due to the link with the human environment, a defining feature of the Anthropocene. Habitat alteration, pollution, invasive species are all specific human-driven threats which are putting pressure on inland fish populations. Fish are also threatened by fish farm aquaculture borne disease, over-exploitation from harvest – and often overlooked – injury and mortality from catch-and-release fishing and the spread of non-native genotypes through stoking programs. These threats to the biophysical environment of fisheries are pervasive and are projected to increase in the future. Ensuring the sustainability of fish populations and fish habitat in natural or semi-natural biophysical environments is but one major challenge to fisheries management.

Effective fisheries management is also challenged with the human dimension, tasked with providing a rational basis for decisions in the face of conflicting objectives, such as improving angling opportunities or conserving wild populations while controlling costs (Smith et al. 1999; Riley et al. 2002; Varkey et al. 2016). The North American Model of Wildlife Conservation, the prevailing model of state, provincial, and federal agencies based on regulated management, science-based policies and equitable access and public ownership (Organ et al. 2012; Krausman & Cain 2013; Ryder 2018; Mahoney & Geist 2019), like the biophysical environment, is thus also changing rapidly. Fisheries management in Canada today involves engagement with not only conventional user groups, such as anglers, but also stakeholders and rightsholders with a vested interest in a fish or fisheries issue, program, action, or decision. There are high expectations of fisheries managers to include all fisheries actors in management processes, and high expectations of these diverse fisheries actors for involvement in those management processes (Endter-Wada et al. 1998; Decker et al. 2012; Krausman & Cain 2013).

In terms of governance, fish and fisheries are seen by some as too complex to be governed by a single agency, opening calls for co-management – joint action of multiple parties (Berkes 2009). Anglers and other fisheries actors have dedicated significant human and economic stewardship resources to protect the fish upon which they depend. Even when hierarchical institutional regimes are efficient, effective management is dependent on stakeholder support and perceptions of legitimacy associated with trust in governing bodies (Turner et al. 2016). Fisheries management in Canada is also further complicated by institutional challenges – transboundary governance of fish, overlaps in governance between federal and state (i.e., province, territorial) level governments, and confusion over who has jurisdictional authority (Temby et al. 2015; Jeanson et al. 2021b).

Unpacking this vast social-ecological complexity is key to unlocking responsible fisheries management in Canada and beyond. Yet, the complex feedbacks and interactions between individual fish and populations, resource users and other stakeholders, and regional and state level fisheries managers are poorly understood (Ward et al. 2016). In shaping a sustainable future for fish and the people that depend on them, it is argued that fisheries policies and practices integrate evidence derived from the social sciences (Hunt et al. 2013; Hicks et al. 2016) and to better understand and address this social-ecological complexity (Clay & McGoodwin 1995; Arlinghaus 2006; Hunt et al. 2013). Ultimately also, it is humans who dictate how species are managed, what impacts are acceptable, and how management is designed and funded. Perceptions such as values, beliefs, preferences, and attitudes are evidence that can be elicited from social science studies, and they can be either positive or negative (Bennett 2016). Positive perceptions, not just natural science evidence, can ensure the support of fisheries actors, enabling responsible fisheries management, ultimately shaping policy and practice directions. Perceptions of local people can provide important insights into observations, understandings, and interpretation of the social and ecological impacts of fisheries management and conservation, the legitimacy of fisheries governance, how people value fish, how people are affected by fish and fish management decisions, and the social acceptability of fisheries management (Bennett 2016). Regarding inland fisheries, this may include perceptions of management measures, fish population dynamics and angler preferences. Conservation and management narratives which do not account for local values, beliefs, and interests risk upholding a narrative of disconnected fish and wildlife government agencies. Incorporating perceptions alongside natural science evidence will provide a more complete picture on which to base fisheries conservation decisions and management, especially as fisheries governance and management adapt to rapidly changing social and biophysical conditions.

In BC, the most westerly province in Canada, rainbow trout (*Oncorhynchus mykiss*) are a native cold-water salmonid fish which support social, cultural, and economic well-being of BC's diverse population, including Indigenous peoples with deep connections to lands and waters. Rainbow trout include freshwater residents and an anadromous form called 'steelhead' trout, which migrate from marine to freshwaters to spawn. The long-term sustainability of these fish populations and their dependent fisheries by increased water temperatures (Meka & McCormick 2005; Parkinson et al. 2016; Twardek et al. 2018), declines in dissolved oxygen in lakes (Jane et al. 2021), drought and low water conditions (Whitney et al. 2016; Gronsdahl et al. 2019). Within the next twenty years models based in the United States project that approximately 20% of rainbow trout habitat will be lost due to climate change effects (O'Neal 2002; Wenger et al.

2011), increasing to almost 50% by the year 2100 (Jones et al. 2012). The increased frequency of high summer temperatures and low flows have already resulted in several closures of rivers to recreational fishing in the province (Government of British Columbia 2015a, b, c, 2018, 2021), as the combined stress of fishing (including catch-and-release) and exposure to high temperatures can bet lethal for rainbow trout (Meka & McCormick 2005; Parkinson et al. 2016; Twardek et al. 2018). In BC rainbow trout populations (when and where thriving) support recreational, subsistence, and ceremonial fisheries, which contribute $957 million CAD (e.g., licence sales, accommodations, packages sales of equipment, boats, fuel etc.) to local and national economies and translates into the employment of 5,000 persons (Bailey & Sumaila 2012; Freshwater Fisheries Society of BC 2013). The most preferred species in terms of total 2010 catch in BC are rainbow trout (58%) while are the 8th most preferred species (2%) (Freshwater Fisheries Society of BC 2013).

Here, I examine the perceptions of stakeholder, Indigenous rightsholder, and regulatory groups on the current and future status of rainbow and steelhead trout (*Oncorhynchus mykiss*) populations and fisheries in BC, Canada. This research is exploratory in nature and is intended to be primarily descriptive, and hypothesis-generating rather than hypothesis-testing. I use qualitative data from in-depth interviews and quantitative data from surveys to analyze how these different rainbow and steelhead trout fisheries actors view fisheries decisions, policies, and practices; and the factors which govern the long-term sustainability of these fisheries in BC. These perceptions can inform fisheries management and conservation decisions, policies and practices that are more salient, robust, legitimate, and effective (Bennett et al. 2017).

3.2 Methods

3.2.1 Interviews

A qualitative approach based on open-ended semi-structured interview questions (Axinn & Pearce 2006; Creswell 2014; Young et al. 2018b) was used to gather opinions and perspectives of actors connected to rainbow trout science and management. The interview questions (see Table 3.1) were designed to encourage open-ended discussion about rainbow trout management from a wide range of respondents. This study was conducted in accordance with the University of Ottawa Research Ethics Board (File Number: 02-18-08). I performed a pilot interview after ethical clearance that showed no issues. All participants gave informed consent to participate in the study. Although some interviewees granted permission to use their names, all quotes shared in this chapter are attributed anonymously in order to protect everyone's identities. I developed the initial population frame for interviews by searching the BC Government Directory (https://dir.gov.bc.ca/) for government employees who work in fisheries management using the keywords "fish" or "fisheries". The population frame was then further developed in consultation with two senior managers in the provincial government and a senior scientist/officer with FFSBC to ensure that key government employees, stakeholders, and rightsholders were identified. The population frame was then supplemented by snowball sampling from voluntary referrals by respondents.

Interviews were conducted in person and over the phone between April and November 2018. A total of 65 interviews were conducted (response rate of 40%) with participants from natural resource management branches of Indigenous governments (n = 4), parliamentary governments (n = 33), as well as representatives from FFSBC (n = 7) and nongovernmental stakeholder groups (n = 22) who have been involved in the management of recreational and subsistence rainbow trout fisheries (Table 3.2). An additional 96 individuals were contacted but did not participate because they a) did not respond to my request or b) declined to participate due to little interest or no expertise in rainbow trout (affiliations of these individuals are provided in Appendix F). Each of the 9 different resource management regions in BC had at least one representative interview participant, covering all areas of the province. Interviews lasted between 18 minutes and 2 hours, depending on the level of detail provided by the respondent. Anadromous wild steelhead trout were discussed by interview participants opportunistically and voluntarily (i.e., there were no steelhead-specific questions).

3.2.1.1 Data analysis

Interview transcripts were transcribed from audio to text using Trint (https://trint.com) and then coded and analyzed using NVivo 12 software (QSR International Pty Ltd. 2018). The coding process involved two steps. In the first step responses were categorized according to the original interview questions (Table 3.1) in order to isolate relevant content. In the second step inductive coding was conducted, for which the coded responses were re-read for emergent themes (Thomas 2006; Charmaz & Belgrave 2012). Responses were read a third time to identify any additional themes and were then sorted under final themes to provide a measure of their prevalence. A response may have multiple thematic codes if warranted. All coding was performed by ANK. Because the coding task, in addition to transcription of data from audio to text, already consumed a significant amount of time and resources, using more than one coder was not viable in this chapter and thesis. Additionally, the coding system/frame *is* the collection instrument, not the coder, and should establish coding consistency. Multiple coders may have different theoretical biases and will organize codes into themes in different ways (Armstrong 1997) thus it is not always clear if using different coders reduces susceptibility to bias or errors in judgement. Although I acknowledge using multiple coders will reduce the risk of human error and may be a limitation in the present chapter. Figures were produced in GraphPad Prism version 9.2.0 (www.graphpad.com).

3.2.2 Survey

Interview data was supplemented with an online survey of BC rainbow trout anglers, titled "*Threats to Rainbow Trout and Steelhead in British* Columbia" (see Jeanson et al. 2021a), also part of the Genome Canada project described above. For several themes for which there is overlap between interview questions and questions in the online survey (see Table 3.1), interview results are augmented with results from the online survey to provide complimentary insights on the views of rainbow trout angler stakeholders.

The online survey was conducted in accordance with the Carleton University Research Ethics Board (#10733). Participants were required to give informed consent via the online consent form at the beginning of the survey. The survey consisted of multiple choice, Likert-style, and free-answer questions. The survey mechanism was built and operated using the online Qualtrics software. The survey was pre-tested by three anglers with experience fishing for rainbow trout in BC. Pre-testing indicated a completion time of approximately 15 minutes. The survey was available for approximately 6 months from the beginning of April to mid-October 2018 and was distributed using a non-random, non-stratified broadcast sampling method to reach BC rainbow trout anglers. The survey was distributed through recruitment posts to personal social media accounts (Twitter and Facebook), paid targeted advertising (Facebook), and links in email newsletters of FFSBC and Anglers Atlas.

A total of 1171 individuals opened the survey link and viewed the survey but after removing individuals who did not: i) continue the survey after reviewing the consent form (n =

47), ii) fish for rainbow trout in BC (n = 6), and iii) did not respond to any question in Table 3.1 or Appendix G (n = 89) a total of 1029 surveys from rainbow trout anglers were retained. At the beginning of the survey, anglers were asked to select which subpopulation of rainbow trout they target most (rainbow trout in streams/rivers, large lakes, and small lakes, steelhead in streams/rivers,) and answer all survey questions with that response in mind to account for differences in fishing experiences. I grouped rainbow trout anglers to facilitate comparison with interviewee responses but recognize anglers in this case are not homogenous and grouping angler subpopulations risks losing some nuance. Statistical differences in responses between rainbow and steelhead trout anglers were compared with a two-sample Mann-Whitney U (Wilcoxon rank-sum) significance test.

Table 3.1 Open-ended interview questions analyzed in this chapter and to which interviewee group they were directed: Natural resource management branches of Indigenous governments (FN); parliamentary governments (GOV); representatives from Freshwater Fisheries Society of BC (FFSBC) and nongovernmental stakeholder groups (STKH) (Table 3.2). Also included are relevant survey questions analyzed in this chapter which were directed to n = 1029 rainbow trout and steelhead anglers. n/a = not applicable.

Interview Question	Interviewee Group	Survey Question
Conservation status assessment of rainbow and steelhead trout populations		
In your opinion, do you think that wild rainbow trout populations are currently threatened [under threat]? [*If yes*] What do you think are the primary causes of these threats? Why do you think that? [*If no*] Why do you think that?	ALL (n = 65)	Please indicate your level of agreement or disagreement with the following statements: - I believe that [previously selected fish] populations in British Columbia are currently at risk of decline due to environmental changes
		In your opinion, how much of a threat do the following factors pose to [previously selected fish] populations? – Agriculture, Climate change, Commercial bycatch, Dams, First Nations fishing, Fish diseases, Fish farming/Aquaculture, Forestry, Habitat alterations, Invasive species, Mining, Predation, Recreational fishing, Residential & commercial development. Water quality
		In your opinion, over the past ten years, water temperatures of the waters you regularly fish in British Columbia...
		In your opinion, over the next ten years, water temperatures of the waters you regularly fish in British Columbia...
		In your opinion, climate change in British Columbia is...
		Please indicate your level of agreement or disagreement with the following statements: - I believe that climate change will not harm [previously selected fish] populations in British Columbia for many years
		Please indicate your level of agreement or disagreement with the following statements: - I believe that climate change will never harm [previously selected fish] populations in British Columbia
Praise and criticisms of parliamentary governments managing the rainbow and steelhead trout fishery		
In your opinion, what are governments doing right in managing the rainbow trout fishery? Doing wrong?	FN, FFSBC, STKH (n = 32)	In your opinion, how much of a threat do the following factors pose to [previously selected fish] populations? - Poor management
		Please indicate your level of agreement or disagreement with the following statements: - I believe that the provincial government has provided sufficient resources to successfully manage fish populations in British Columbia

Interview Question	Interviewee Group	Survey Question
		Please indicate your level of agreement or disagreement with the following statements: - I believe that the provincial government has implemented the necessary regulations to successfully manage fish populations in British Columbia
		Do you believe that the federal government ought to be involved in the management of fish populations in British Columbia?
Fishery actors		
Do you have direct contact with stakeholders in the course of a fishing season? *[If yes]* Which ones? How frequently? In what ways? How important is stakeholder input/feedback/consultations in your decision-making? How do you balance the different demands/interests of stakeholders in your decision-making? How do you prioritize these competing demands/interests?	GOV, FFSBC (n = 39)	n/a
Prioritizing conservation concerns in decision-making		
In your opinion, at what point do stakeholder interests or demands override potential conservation concerns?	GOV, FFSBC (n = 39)	n/a
Criticisms of decisions made with respect to fisheries management of rainbow trout populations		
As you know, some people are critical of the decisions made with respect to fisheries management of rainbow trout populations. What are the most common criticisms that you hear? What do you personally think of these criticisms? [In your opinion, are these criticisms valid?]	GOV, FFSBC (n = 39)	n/a

Table 3.2 Affiliations of the 65 interview participants, grouped as members from natural resource management branches of Indigenous governments, and parliamentary governments, the Freshwater Fisheries Society of BC as well as non-governmental stakeholders.

Indigenous Governments (FN)	**n**	**Parliamentary Governments (GOV)**	**n**	**Freshwater Fisheries Society of BC (FFSBC)**	**n**	**Stakeholders (STKH)**	**n**	**TOTAL n**
Biologists	2	Biologists (FLNRORD)	17	Biologists	2	Academia	6	
Fisheries Managers	2	Directors (FLNRORD)	3	Officers and Executives	4	BC Hydro	2	
		Fish & Wildlife Section Heads (FLNRORD)	6			Environmental non-governmental organization (ENGO)	5	
		Human Dimensions Specialist (FLNRORD)	1			Private environmental consultants	6	
		Policy Analysts (FLNRORD)	2			Retired provincial government employees	3	
		Conservation Science Section (MOE)	3					
		Science Branch (DFO)	1					
Participant Sub-Total	(4)		(33)		(6)		(22)	**65**

3.3 Results

Additional results on the conservation status of rainbow and steelhead trout populations; ensuring the long-term sustainability of rainbow and steelhead trout fisheries in BC; managing wild populations versus stocked populations; rainbow trout management plan; the most challenging aspects of rainbow trout management and conservation; contact with stakeholders; stakeholder input, feedback, consultation in decision-making; balancing different demands and interests of stakeholders in decision-making; and prioritizing conservation concerns in decision-making are provided in Appendix G.

3.3.1 Conservation status assessment of rainbow and steelhead trout populations

Regarding non-anadromous resident wild rainbow trout, interviewees generally provided a nuanced answer to whether wild rainbow trout populations are currently threatened, rarely taking an extreme position (28% not at risk, 55% neither threatened nor not at risk, 8% threatened) (Figure 3.1). The following quotations capture the majority sentiment of interviewees, “at the provincial level no, at a population-specific level, yes some are at risk” (Interview #1, FFSBC); “it seems unlikely that the whole species is threatened but there certainly are certain populations that are threatened, and I would say certain types of populations are much more threatened than other ones” (Interview #55, academia affiliation). The reasons interviewees did not think that resident populations are threatened, cited from highest to lowest frequency are: adaptability, robustness, resilience; stocking programs which divert recreational angler pressure from wild to hatchery-raised fish; stable stocks and populations (based on monitoring and stock assessments); high abundance; wide provincial distribution; a vast province with many unsettled and unimpacted areas; high diversity of populations; and conservative regulations focused on sustainable harvest. Most interviewees qualified their responses, acknowledging that some rare populations of resident rainbow trout (e.g., ecotypes, ecomorphs) may be threatened. Particularly, wild river and stream populations such as those in the Kettle and Horsefly rivers, as well as recreationally prized, large-bodied piscivorous rainbow trout like the Gerrard rainbow trout of Arrow, Quesnel, Kamloops, Shuswap, and Kootenay Lakes. Angler survey respondents took more extreme positions, with 58% of rainbow trout angler responses believing non-anadromous resident wild rainbow trout are currently threatened (Figure 3.1).

Regarding steelhead, 96% of interviewees were definitive in assessing the anadromous form of rainbow trout in BC as threatened (Figure 3.1). For example, “and on the anadromous side it’s a train wreck. It couldn’t be worse” (Interview #46, retired provincial government employee), "they're on death's doorstep right now it seems" (Interview #59, retired provincial government employee), "Steelhead are critically imperiled. Their stock numbers have continued to decline precipitously" (Interview #48, FLNRORD). Interviewees particularly underscored declining steelhead populations on Vancouver Island and the southern interior Fraser populations (e.g., Thompson and Chilcotin river steelhead). Most steelhead angler survey respondents (90%) also believed that steelhead populations are threatened in BC.

Nearly half, 49% of rainbow trout anglers agree that resident rainbow trout are currently declining due to environmental changes, while 86% of steelhead anglers believe steelhead are currently declining due to environmental changes ($p < 0.001$).

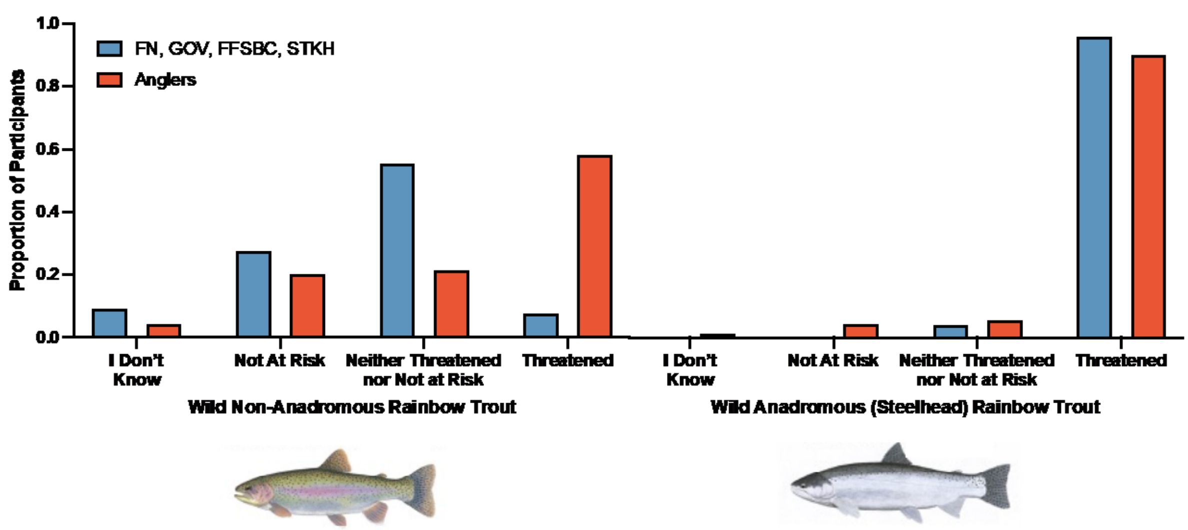

Figure 3.1 Perceived threat level of rainbow and steelhead trout in British Columbia by members from natural resource management branches of Indigenous governments (FN), parliamentary governments (GOV), Freshwater Fisheries Society of BC (FFSBC), non-governmental stakeholders (STKH), and anglers. Rainbow trout: FN, GOV, FFSBC, STKH interviews n = 65, angler surveys n = 871; steelhead trout: FN, GOV, FFSBC, STKH interviews n = 65, angler surveys n = 143.

Loss or degradation of habitat, residential and commercial development, water temperature extremes (particularly high summer water temperatures affecting river and stream populations), climate change, recreational fishing pressure, and abstraction of water were the primary threats to wild rainbow trout identified by interviewees (Figure 3.2A). A unique threat to interior populations of wild rainbow trout mentioned by several interview respondents is the outbreak of mountain pine beetle (*Dendroctonus ponderosae*) in BC, which has altered freshwater and riparian habitats and hydrology through the subsequent timber salvage and forest cover loss (see illustrative interview excerpts in Appendix H).

Bycatch in commercial fisheries, habitat alterations, climate change, increased predation pressure from pinnipeds and marine mammals, water temperature extremes, and water quality (particularly decline in coastal oceanic condition and productivity) were the most frequently referenced threats to wild steelhead by interviewees (Figure 3.2B).

Like interviewees, angler survey respondents identified habitat alterations and water quality as key threats to wild rainbow trout populations in BC (Figure 3.2C). Rainbow trout anglers also aligned their opinions with interviewees around water temperature extremes: 59% are of the opinion that over the past ten years, water temperatures of the waters they regular fish in BC have increased (i.e., have become warmer), and 74% are of the opinion that over the next ten years, water temperatures of the waters they regular fish in BC will increase (i.e., will become warmer). However, in contrast to interviewees, resident rainbow trout angler survey respondents also emphasized the threats posed by invasive species, fish farming/aquaculture, commercial bycatch, and did not take as extreme positions on the threats posed by climate change or residential and commercial development.

Angler survey responses for steelhead were similar to interviewees with commercial bycatch, habitat alterations, climate change, and water quality identified as key threats (Figure 3.2D). As rainbow trout anglers did, steelhead anglers also agreed with interviewees around water temperature extremes: 71% are of the opinion that over the past ten years, water temperatures of the waters they regular fish in BC have increased (i.e., have become warmer), and 78% are of the opinion that over the next ten years, water temperatures of the waters they regular fish in BC will increase (i.e., will become warmer). Resident rainbow and anadromous steelhead anglers did not differ in their perception of water temperature extremes ($p > 0.05$). However, steelhead angler survey respondents again in contrast to interviewees, like for resident rainbow trout, emphasized the threat of fish farming/aquaculture. Uniquely, steelhead anglers were also of the belief that First Nations fisheries are a large threat to steelhead populations. Steelhead anglers did not seem to identify pinniped and marine mammal predation as much of a threat as interviewees did.

Both resident rainbow and anadromous steelhead trout anglers did not perceive recreational fishing pressure as a key threat in contrast to interviewees. This was one of the few threats where there were no detected statistical differences in responses between the two angler groups along with agriculture, fish diseases, mining, and water quality. The latter, a key identified threat by both angler groups to their targeted or preferred form of rainbow trout, anadromous or non-anadromous. Steelhead anglers perceived climate change as a much greater threat to their preferred fished populations than resident rainbow trout anglers: 52% of steelhead anglers expressed that climate change in BC is a very serious problem in contrast to 35% of resident rainbow trout anglers ($p < 0.001$); 76% of steelhead anglers strongly disagree or disagree that climate change will not harm fish populations in BC for many years in contrast to

59% of resident rainbow trout anglers ($p < 0.001$); 90% of steelhead anglers strongly disagree or disagree that climate change will never harm fish populations in BC in contrast to 79% of resident rainbow trout anglers ($p < 0.05$).

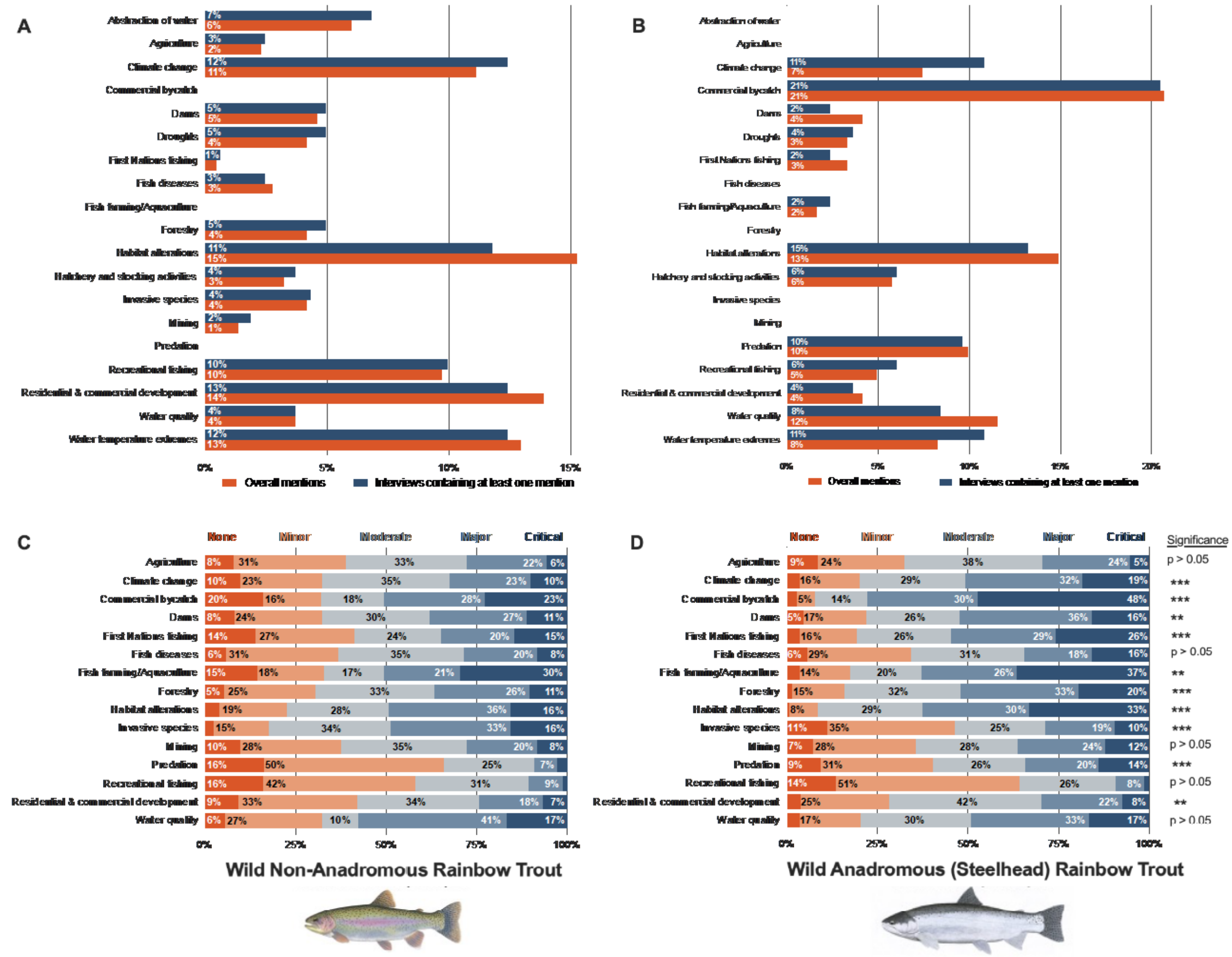

Figure 3.2 Perceived threat factors of (A) rainbow and (B) steelhead trout in British Columbia by members from natural resource management branches of Indigenous governments (FN), parliamentary governments (GOV), Freshwater Fisheries Society of BC (FFSBC), and non-governmental stakeholders (STKH) represented as a fraction of the total mentioned threats (n = 65 interviews); and of (C) rainbow trout (n = 883 survey responses) and (D) steelhead trout anglers in British Columbia (n = 146 survey responses). Statistical significance tests differences

in survey responses between rainbow and steelhead trout anglers * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$.

3.3.2 Praise and criticisms of parliamentary governments managing the rainbow and steelhead trout fishery

FLNRORD in partnership with the FFSBC were praised by interviewees for their stocking programs which supplement and take pressure off wild fish populations in addition to generating economic revenue. They were also commended for their stocking of indigenous (wild) strains and deliberate attempts to separate wild populations from hatchery populations to prevent introgression between populations. Interviewees recognized the role of governments and FFSBC in providing a mix of recreational angling opportunities and received specific compliment of interior small lakes fisheries (e.g., "I think they're managed well. They've got the reputation of being some of the best, if not the best in the world" Interview #59, retired provincial government employee). FLNRORD was also commended for their working relationships with First Nations and fulfilling their legal duty to engage in "meaningful consultation" (Newman 2009) and their receptiveness to reconciliation. From a regulatory perspective, FLNRORD were complimented for being increasingly conservative, prioritizing habitat protection, and being reactive to threats. Examples included harvest regulations; implementing temperature closures when rivers exceed a certain threshold; gear and bait restrictions such as the prohibition of live fish for bait.

On the flip side, many interviewees including previous employees of the provincial government (34%), were highly critical of governments, indicating that governments are not doing enough in the management and conservation of rainbow trout. Responses focused on letting politics influence management instead of science (e.g., "the best science in the world is no use if you can't implement any of it. That seems to be the dilemma we face now", Interview #63, retired provincial government employee), a lack of accountability or government oversight over professional industry, unwillingness to confront or challenge First Nations (e.g., "governments seem to be falling all over themselves to deal with First Nations, according to the United Nations Declaration on the Rights of Indigenous Peoples and it just seems like that pendulum has swung too far to one side. A lot of stuff is being done Nation to Nation without the rest of society having any input which is very troubling", Interview #59, retired provincial government employee) and unwillingness to confront or challenge commercial fisheries (e.g., "the federal government are not managing commercial interception fisheries that are catching steelhead as bycatch", Interview #61, BC Hydro). Steelhead were often specifically discussed (e.g., "we've non-managed them into the ground. There's so few of them it's ridiculous that [the Thompson River steelhead fishery] is even considered to be opening. The federal government continues to just do enough except extirpate the last one", Interview #46, retired provincial government employee). Most angler survey respondents believe poor management is a major or critical threat to *Oncorhynchus mykiss* populations, with this opinion stronger amongst steelhead anglers ($p < 0.001$) (Figure 3.3A); and disagree that the provincial government has implemented the necessary regulations to successfully manage *Oncorhynchus mykiss* populations, with this opinion also stronger amongst steelhead anglers ($p < 0.001$) (Figure 3.3B). Slightly more than half of steelhead anglers believe that the federal government (DFO) ought to be involved in the management of steelhead populations in BC; while most rainbow trout anglers do not believe that DFO ought to be involved in the management of rainbow trout populations ($p < 0.001$) (Figure 3.3C).

Aside from a handful of high-profile fisheries, across all interviewee groups (29% of participants) governments were also criticized for their general lack of stock assessments, monitoring and information on rainbow trout populations, especially those in rivers and large lakes. A lack of government oversight of industry and enforcement (e.g., conservation officers) were additional criticisms. Many interviewees admitted that there are insufficient resources for government management agencies. Namely, that governments are constrained by a lack of funding, depending on external funding to maintain their responsibilities; and are experiencing reduced staff levels, and reduced scientific capacity and knowledge. The following quotations captures the sentiment of many, “I guess in some ways they're always reactive, because they have to be. There’s one fisheries biologist for a really large region. How on earth are we going to effectively manage the resource when we're so limited? During government budget cuts, first thing to go when you're trying to pinch pennies is all the environment people” (Interview #15, academia affiliation). Angler survey respondents expressed the same beliefs – generally disagreeing that provincial governments have been provided sufficient resources to successfully manage populations, with this opinion stronger amongst steelhead anglers ($p < 0.001$) (Figure 3.3D).

Poor governmental organizational structure and strategic direction was a cross-cutting criticism. FLNRORD was described as not very well set up to support fish and wildlife issues. Their mandate was questioned, citing a focus on resource extraction, with a lack of management plans or reference to fisheries management in service plans. For example, “I don't know to what extent your average statutory decision maker considers wild rainbow trout in making a decision about timber allocation or any of that stuff. Most of those decisions are made by district managers of forests that probably have no training in aquatic ecology and fisheries management and I'm not even sure that they get any input from the few staff that are. So, to me the main thing the province in my estimation, is doing wrong, is failing to adequately consider the values that you need in those watersheds to sustain those populations of wild rainbow trout" (Interview #39, ENGO affiliation). Confusion between who has jurisdiction for management of anadromous fish was also a cross-cutting criticism. For example, "the Feds [DFO] do have jurisdiction, but I think the province has jurisdiction over some aspects of different types of fisheries and I think it's easier for governments to pass blame to each other and try to appease stakeholder groups than meet the primary objective of recovery. As soon as you start talking about habitat it gets blurry. Who's responsible for what? And conflicting objectives and municipal versus provincial versus federal and now First Nations are a part of that too. And it becomes exceedingly challenging." (Interviews #35 & 36, FFSBC). Poor coordination between the nine FLNRORD resource management regions was also cited, for example, "…you can have two regions side by side doing a totally different thing. Often, they don't know what the region next to them is doing. They're not allowed to travel between regions unless they get a director's approval" (Interview #57, academia affiliation).

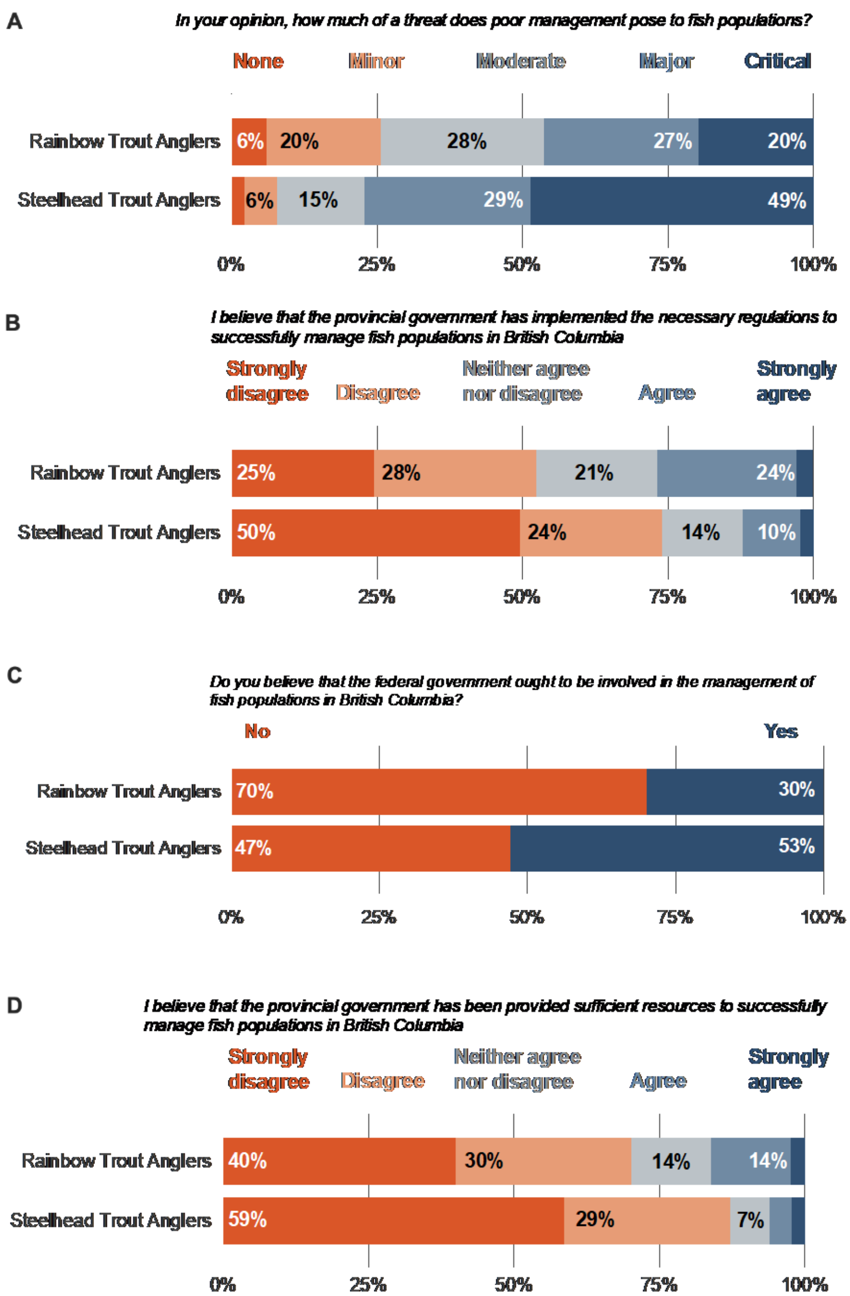

Figure 3.3 Stacked bar plot of angler responses to online survey questions. A: rainbow trout (RBT) anglers, n = 761; steelhead trout (ST) anglers, n = 140; B: RBT anglers, n = 729; ST anglers, n = 133; C: RBT anglers, n = 737; ST anglers, n = 131; D: RBT anglers, n = 655; ST anglers, n = 119.

3.3.2.1 Freshwater Fisheries Society of BC

FFSBC was specifically referenced by interviewees for their unique role in the governance and management of rainbow and steelhead trout. For example, “I think the creation of the Freshwater Fisheries Society and giving them the mandate that the government never really exercised, which is to actually promote and develop the fishery, was a great idea” (Interview #53, retired provincial government employee). The illustrative quotation in Appendix I provides more context to the formation and role of FFSBC and how that has altered the perception of government agencies like FLNRORD.

However, not all were supportive of FFSBC with one respondent particularly critical: “And then the final straw. They did what was called the core review and spun off and created the Freshwater Fisheries Society and that used to be within government, it was called The Fish Culture section. And so now that that's outside of government being run on contract. That took that role and that oversight away from the government and now it's being run essentially by a contractor. There are a few good people in there, but basically, it's more like a pizza delivery process now. If you want pepperoni pizza, you order x-type of rainbow trout. They deliver them. Minimal follow-up. Disconnected from the management. Not accountable to the public. Full on train wreck in my opinion.” (Interview #57, retired provincial government employee).

3.4 Fishery actors

3.4.1 First Nations versus recreational interests

Fisheries managers described the difficulty in balancing intersections between recreational angling groups and First Nations, which often have different values and views. Interviewees discussed the challenges of the differing value propositions of harvesting fish for food and security versus recreational interests in catching and releasing fish and how those might be at odds with one another.

> "When it comes to recreationally focused species like rainbow trout, that's where the disconnect is. A lot of times First Nations have more of a tie to the value for food and ceremonial purposes. The recreational element is part of the disconnect." (Interview #44, FLNRORD)

> "For the most part, Indigenous peoples in BC have a fundamental disconnect with sport fishing. It is viewed as playing with their food. And one of the underpinning principles for sport fishing BC, the use of catch and release as a management tool, fundamentally puts us into conflict with Indigenous peoples, especially with rainbow trout. So, it has led to a disconnect in many cases, especially on the steelhead side, where we're talking about their traditional knowledge, Indigenous knowledge, we can't get there because they're too hung up on the fact that we seem to be playing with their food or advocating for playing with their food." (Interview #51, FFSBC)

These differences can result in issues becoming political, for example, a Burbot fishery that has been closed for stock recovery, now at healthy levels, is being considered for re-opening by the provincial government but the First Nations which have maintained an active subsistence fishery throughout don't want it open to recreational fishing. These issues become elevated when a conservation concern is present, for example, when First Nations are advised they can no longer maintain a food source fishery but catch and release fishing (which has a potentially much smaller percent mortality rate) is maintained.

3.4.2 Indigenous people's subsistence harvesting of rainbow trout

First Nations have a unique history in BC that is strongly tied to salmon and are perceived to have less interest in rainbow trout.

> "First Nations in this area are much more salmon centric" (Interview #4, FLNRORD)

And where and when rainbow trout or steelhead are harvested, it is often out of necessity and not preference.

> "Where we have anadromous fish and fisheries, Indigenous people are focused on salmon and rainbow trout are seen to be an afterthought. Rainbow trout just don't contribute to the harvest cycle for First Nations, where they would nomadically migrate through various camps to harvest moose, harvest caribou, harvest salmon, harvest berries when they're seasonally available. They never talked about the seasonal harvest of rainbow trout. It just doesn't register for them, because the protein you get from rainbow trout and their availability... A chinook or a sockeye salmon that show up in super abundance can be dried and stored for the winter have so much more value than rainbow trout, which are only there in the spring and they're very small, and the return per work unit invested in it just never made it worthwhile. They don't really see it in the same way as salmon." (Interview #51, FFSBC)

"In the wintertime when their salmon resources are depleted, they will go out and harvest steelhead, but many First Nations have said their preferred sustenance is salmon over steelhead, that they will eat a steelhead, but they much prefer salmon. They use steelhead as a last resort." (Interview #58, FLNRORD)

3.4.3 Emerging interest of Indigenous peoples in rainbow trout

Some respondents forecasted an emerging interest of Indigenous peoples in rainbow trout due to environmental changes affecting their preferred food sources, salmon, and due to economic opportunities, that are potentially afforded by rainbow trout fisheries.

"There's a renewed interest, I think, from First Nations because of climate change because some of those [salmon] populations are going to be a little bit more difficult to meet their sustenance needs and rainbow trout might be the one that they're able to fill the gap with because of the regeneration times and potentially their ability to be managed quicker and more effectively." (Interview #14, FLNRORD)

"The more progressive First Nations are seeing it as: what is the economic interest in rainbow trout? Are there some benefits rather than the traditional food, social, and ceremonial consumptive uses of rainbow trout? So, that is new and it's starting to appear more frequently across British Columbia, especially in the south, where economic opportunities are the driver now for First Nations interest in sport fishing. So, some of them are putting aside their fundamental dislike for sport fishing, if there's an economic interest in it." (Interview #51, FFSBC)

This emerging interest in rainbow trout and freshwater fisheries from not only Indigenous fishers, but also other salmon fishers, raises concerns of added pressures to these systems.

> "As salmon stocks and saltwater and freshwater salmon fishing opportunities decline there's going to be more and more pressure put on large lakes, small lakes, inland ricers and non-anadromous fishing opportunities" (Interview #46, retired provincial government employee)

3.4.4 Interest in co-management of rainbow trout

Given the interests of some Indigenous peoples in ownership of economic fisheries, some First Nations are either in the process of developing or discussing co-managed or collaborative freshwater fisheries with the provincial government.

> "In small lakes with rainbow trout fisheries, up until now we haven't had a lot of First Nations involvement as they're so focused on salmon. With salmon stocks really declining we've been told by First Nations that they are going to start pursuing rainbow trout as a protein source. And so now they are actively looking to co-manage some of our fisheries. So that is changing so that's going to be a really big impact our stocking program." (Interview #18, FLNRORD)

> "There are some that are very interested in becoming part of the stocking program and running it as an economic venture. And then there's others that just want to have absolutely nothing to do with it and think that it's something that nobody should do

> because they don't understand and don't value and just think that it's weird to play with your food." (Interview #54, FLNRORD)

However, co-managed or collaborative fisheries can prove to be difficult if provincial and First Nation government mandates don't align clarified some interviewees. For example, the Okanagan Nation Alliance, a First Nations Tribal Council with tremendous fisheries capacity in terms of staff and resources, reintroduced Sockeye into the Okanagan region starting in 2004, but the provincial government did not approve. At the time, the provincial government was concerned from a science perspective about what the impacts of this re-introduction might be and suggested that the re-introduction should follow provincial policies for stocking. Today, the relationship is admittedly relatively collaborative. Scientific oversight in the form of a monitoring and evaluation plan, and binding thresholds determine if, and when, the Sockeye enumeration program should be stopped due to negative environmental impacts.

3.5 Prioritizing conservation concerns in decision-making

Consistent with the provincial government's allocation framework (see Appendix G.6.3 Section 'Balancing different demands and interests of stakeholders in decision-making'), conservation is claimed as the first and foremost priority of government employees and FFSBC.

> "Well, pretty much everything we do in BC, fundamentally conservation comes first. If we can't account for the conservation of the population, being able to maintain its stability looking forward, then there really isn't any other options for us in terms of managing a fishery." (Interview #6, FLNRORD)

> “We want to make sure that we're not jeopardizing the population based on our management decisions. That's the goal. Sustainable populations. Fisheries can occur but if we're getting to a place where we're threatening the population, we shouldn't be fishing anymore.” (Interview #43, FLNRORD)

While conservation is of highest priority there are certain scenarios where governments are often not prepared (or able) to fully intervene and implement conservation actions. “I actually don't think conservation in this province always comes first” (Interview #21, FLNRORD).

3.5.1 First Nations

“If there’s a defined conservation risk, I think that the province has shown they will institute a conservation value. I think where that breaks down are situations where First Nations are involved.” (Interview #35, FFSBC). First Nation communities are at times told they are no longer able to maintain a food source fishery and to stop fishing when there is a conservation concern, which becomes contentious when First Nations invoke their traditional and constitutional rights to fish. When these scenarios occur, by admission, most of the Indigenous community is compliant and only a few are non-compliant. If there is a conservation issue, government employees aspire to deeply engage and consult with the community, sharing information back and forth to develop a conservation-based approach.

3.5.2 Economic factors

“Often, I think the economic drivers outweigh conservation elements” (Interview #14, FLNRORD). Decisions that generate economic benefits exert weight on fisheries management decisions and may ultimately tip in favour of economic value. “For conservation, we don’t usually get a lot of pushback from the recreational angler. But if there’s guides who are making money, if there is a commercial fishery that bycatches them, that's when you run into problems." (Interview #42, MOE). The influence of economic drivers precluding conversation may be subtle. For instance, in steelhead hatchery augmentation, which "…has a positive net output or outcome, in terms of fitness and abundance over the longer term. But it's going to ramp up the fisheries which then have a negative consequence or impact on the underlying wild stock. So, that's a good example I think where we can easily rationalize deriving benefits from these populations. Squeezing them a little bit. However, if asked from a purely conservation perspective whether that's the right outcome, we'd say well absolutely not. We'd prefer just to have no fisheries and have no hatchery augmentation. That would be a best outcome for these populations." (Interview #33, FLNRORD).

3.5.3 Social and political factors

"Sometimes it's a political decision made at a higher level regardless of what maybe the science is saying" (Interview #18, FLNRORD). "At the biologist level or the lowest manager's level, I really try to focus on the conservation aspect. However, once an issue goes up the line, decisions tend to become more political. So quite often we recommend something that may be based on conservation and then we get told that from a political level you can't do that, or we have to find a balance somewhere. So, we try to be focused on conservation as much as we can but there's always a political aspect that plays into things which is what makes the job difficult at times" (Interview #26, FLNRORD). Political and social resistance was described in examples of stakeholder pushback to closing or limiting rainbow trout fisheries to deal with invasive species or to prevent hybridization with Westslope cutthroat trout. The political strength of stakeholder groups is also demonstrated in the following example, "Our Premier a couple of years ago, Christy Clark overturned a small regulation that we were going to change in Kamloops. We wanted to change the age and access regulations on this lake to allow for more children to be able to access it because on too many lakes these old guys were going every day and fishing and taking up all the access points. Everybody agreed, it seemed like a simple slam dunk. We got the Director to sign off on it and it went to the Premier's office and because it was an election and there were twelve disgruntled old guys that she might lose twelve votes on, she canned it." (Interview #40, FLNRORD).

> "I think decisions and information gathered by regional biologist nowadays is significantly affected by the politics. Their management decision or proposals are undermined by outside influences. Best management practices don't rule the day. There's interference. Social interference. A particular stakeholder can influence politicians who direct Ministry (FLNRORD) staff to do something that's not in the interest of the resource and it happens regularly and it happens on all habitat, including stocked lakes where I've seen examples where residents on a lake are unhappy and they think they know how to manage the fishery and they go political because they don't agree with the provincial regional biologist management program and the biologists are just told to stand down or make a management change that isn't the right thing to be doing. I think that happens a lot. I know it happens." (Interview #46, retired provincial government employee)

3.5.4 Interior Fraser River steelhead

The case of interior Fraser River steelhead is a prime example where all these economic, social, and political factors converge in rainbow trout fisheries. The stock is below conservation levels. It has been emergency listed by COSEWIC – The Committee on the Status of Endangered

Wildlife in Canada, an independent watchdog committee of wildlife experts and scientists, but the listing recommendation has not been adopted into legislation in Canada's *Species at Risk Act*. Reducing anthropogenic mortality is the only recovery action available. That would likely mean fishery closures and changes in water use (licenses), which would have drastic economic affects for wide range of groups, most noticeably, non-selective and gill-net commercial fisheries.

> "There's no appetite to do that because of the social and economic and cultural issues. So, you just kind of put up your hands in the air and say so if we can't do it for this stock when are we going to do it ever? and that is the question that I always have on the back of my mind" (Interview #37, FLNRORD)

> "DFO [the federal Department of Fisheries and Oceans Canada] isn't willing to close fisheries down that they know are harming a threatened stock. In fact, they won't even allow them to be listed on the *Species at Risk Act* even if COSEWIC recommends it" (Interview #35, FFSBC)

> "It seems like governments these days utilized processes to stall for time and hope that the issue will go away. This Species at Risk process that's underway now, we don't have a lot of faith that in the end we will see interior Fraser steelhead listed. The societal impacts of doing that will be so great the governments will be reluctant or afraid to go full hog if they're listed. You don't see the government in the end making the decision to list interior Fraser steelhead. It would be great if they did. We are rather pessimistic but that's borne

of banging our heads against a brick wall of government" (Interview #59, retired provincial government employee)

3.6 Criticisms of decisions made with respect to fisheries management of rainbow trout populations

"We don't get a lot of criticism to be honest" was repeated by many fisheries managers (i.e., FLNRORD government and FFSBC employees). Most criticisms of fisheries management that are received are steelhead-specific, clarified interviewees. Table 3.3 presents the most common criticisms of decisions made with respect to fisheries management of rainbow trout populations. Overall, Table 3.3 shows that many stakeholders and actors have completely opposing viewpoints (i.e., many feel that there should be more stocking, while others feel there should be less; many want to harvest more fish, while others want all fish to be released). Overall, these findings suggest people want more, and bigger fish, and they want more fishery access opportunities, but have very different opinions about how to achieve this (e.g., stock more, or restrict fisheries more so that fish grow larger). Some respondents described that often the most vocal critics are past fisheries managers: "The BC Wildlife Federation likes to criticize everything we do and they're often the past managers who are the ones who poisoned all the lakes 60 years ago. Stocked not native feral populations. Yet they're still trying to manage us." (Interview #21, FLNRORD); "Ex biologists. They're probably our biggest critic of all" (Interview #35, FFSBC); "Yeah. All the retired biologists in the province have nothing better to do than to criticize what's going on" (Interview #36, FFSBC).

Fisheries managers agreed that most criticisms were valid or warranted, "except the we're fresh out of university one". Fisheries managers described reviewing criticisms, information, and the source critically parsing issue advocates from honest brokers. According to some interviewees stakeholders are often not informed nor understand the complexity of government and making decisions in government. Fisheries managers described challenges in facilitating engagement that leads to a level of understanding of a particular fish management issue amongst critics. The diversity and contradiction in criticisms was often reconciled by fisheries managers who emphasized that they value and try to manage for diversity and quality of fishing opportunities (i.e., there is a room for all gear-types and fisheries).

Table 3.3 Criticisms of decisions made with respect to fisheries management of rainbow trout populations. Interviews containing at least one mention is the total number of interviewees who discussed this topic. Overall mentions are the total number of times a topic was discussed and coded. Code occurrence is a rough proxy of relative importance of each topic (parliamentary government [GOV] and FFSBC employees (n = 39).

Criticism	**Interviews containing at least one mention**	**Overall mentions**
Not doing enough; Don't know enough; Doesn't get out in the field enough; Aren't experienced enough	15	19
Not enough fish – stock more fish	15	17
Regulations are too conservative – a lack of harvest opportunity (e.g., bag limits are too low)/management is overly risk adverse	10	13
Stock too many fish – lakes are overstocked and overpopulated	6	9
Fish aren't big enough	5	6
Regulations favour a particular gear-type (e.g., fly fishing over others) or fishery (e.g., trophy fisheries over others)	5	6
Regulations should be more restrictive (e.g., more closures, more catch-and-release, smaller bag limits)	5	6
Lack of government investment in managing/enhancing fisheries (resources, staff)	5	5
Lack of fishing access and opportunity	4	6
Poor communication with stakeholders/governments aren't listening	4	6
Regulations are too complicated	4	5
Not enough enforcement of regulations	4	4
Lack of communication between federal and provincial government/lack of communication between regions	2	2
Prioritize other species (i.e., Kokanee *Oncorhynchus nerka*, Westslope cutthroat trout *Oncorhynchus clarkii lewisi*)	2	2
Too many anglers	1	1

3.7 Discussion

My results show that non-anadromous rainbow trout are perceived as not at risk at the provincial level, but some rare populations (e.g., ecotypes, ecomorphs) may be. Conversely, anadromous steelhead trout are definitively perceived as threatened by every category of study participant. Key threats identified by participants to both anadromous and non-anadromous *Oncorhynchus mykiss* populations were similar: habitat alterations, water quality, water temperature extremes, climate change, residential and commercial development, and abstraction of water. Predation pressure from pinnipeds (i.e., seals and sea lions) and bycatch in commercial fisheries were identified threats more specific to steelhead. Fisheries managers received praise for hatchery stocking programs and interior lakes fisheries (like Rosenberger et al. 2004) but criticized for a lack of information on fish populations and being too passive in prioritizing conservation. Interestingly, retired employees of the provincial government were often the most outspoken critics of current management efforts suggesting an intergenerational disconnect and opposition. In this case, effective fisheries management is limited by insufficient resources (funding, staff, time), confusion in jurisdictional authority between provincial and federal governments, and poor organizational structure and strategic direction. I found evidence that political and economic influence may supersede conservation actions despite clear organizational mandates and policies of conservation as top priority. These results also reveal that anglers may have similar values and objectives of preferred fish populations, but conflicting opinions about which actions could be taken to support these (e.g., stock less or stock more). While this study packages a lot of information and data, I focus the remaining discussion on the main contributions relevant for inland fisheries research, conservation, and management.

First, anglers generally believe that resident wild rainbow trout are more threatened than interviewees (i.e., fisheries managers) do (Figure 3.1). This suggests disagreements regarding the magnitude of threats to wild rainbow trout or perhaps, systematic differences in social science instruments. Anglers may be subject to an emotional and enthusiasm bias, a closeness and connection to fish populations, perceiving the threats to favoured fish populations as greater than they are (Organ et al. 2010; Heffelfinger et al. 2013; Love-Nichols 2020). My interpretation of these findings is that both anglers and interviewees believe rainbow trout are not threatened at the species or provincial level, but certain isolated and vulnerable populations (e.g., wild river and stream, large-bodied piscivores) likely are. The implications of such a consensus warrants future natural and social science research into the diversity and characterization of vulnerable rainbow trout populations and eco-types – the focus of conservation genomics; and into the social, economic, and cultural values of such populations and eco-types.

I obtained evidence that both rainbow and steelhead trout anglers did not perceive recreational fishing pressure as a key threat. This is largely consistent with other human dimensions empirical research in the recreational fishing sector that demonstrates anglers perceive sportfishing as one of the lowest impacts on fish populations and that anglers appear to be more critical of other user groups (see Lynch et al. 2010; Gallagher et al. 2015; Nguyen et al. 2016; Danylchuk et al. 2017). However, recreational fishing has the potential to negatively affect fish and fisheries and may contribute up to 12% of global fish harvest (reviewed in Cooke & Cowx 2004), and in most inland fisheries in developed countries recreational fishing is the dominant user of freshwater fisheries resources (Arlinghaus et al. 2002; FAO 2012). These findings then suggest that anglers are unaware of potential angling threats and conservation solutions, or that anglers and trying to deflect blame, or choosing to respond in a way that least impacts their recreational activities (if more conservative management regulations were established). This may hint at tensions in recreational anglers complying with fishing regulations such as bag limits. However, this finding and others discussed below (i.e., pinniped predation, climate change) may also present a starting point for future conversations about the potential contribution of recreational fishing to not only fishery declines, but also human induced habitat degradations and alterations.

These results have several implications for the management of anadromous steelhead trout. Steelhead anglers as well as some interviewees were highly critical, identifying poor management as a major and critical threat to steelhead populations. They also believed that the federal government (DFO) ought to be more involved in the management of steelhead populations in BC. This suggests that the DFO has not fulfilled its duty to manage, conserve and develop the steelhead fishery on behalf of Canadians and ought to be more actively involved in the management of steelhead. Steelhead anglers thus place little trust and confidence in the governance of DFO affecting their perceptions of DFO's governance legitimacy (Turner et al. 2016). Just as for freshwater biodiversity generally, the actions taken to address the steelhead conservation challenge have been "grossly inadequate" (Harrison et al. 2018). These results also suggest shared jurisdictional authority between federal and provincial agencies over anadromous fisheries enables mismanagement, inaction, and decision paralysis. Alternatively, this also supports the idea that fisheries management agencies in this case are organizationally structured in such a way that is not autonomous from competing commercial and industrial objectives and directions like forestry and commercial fishing. For instance, DFO was frequently criticized for their unwillingness to confront or challenge commercial fisheries. These findings imply a possible need for transformative institutional reform ensuring fish, fish habitat, aquatics research and management are all within the same department or ministry and uncompromised by other competing mandates. It also suggests for stronger cohesion, communication, and coordination amongst management agencies in transboundary or overlapping jurisdictions, even amongst adjacent regions. Lastly, given the magnitude of threats to steelhead trout, many study participants are in favour of adopting COSEWIC's recommendation and listing Thompson River and Chilcotin River populations of steelhead under the federal *Species at Risk Act* (Government of Canada 2018).

Interestingly, steelhead anglers did not identify pinniped predation pressure as a large threat to steelhead populations in contrast to interviewees. However, in DFO's recent recovery potential assessment for Chilcotin River and Thompson River steelhead trout (2018), inshore predation from seals, especially harbour seals (*Phoca vitulina*), was identified as the single largest predictor of steelhead declines (see also Melnychuk et al. 2014; Berejikian et al. 2016; Sobocinski et al. 2020). Seal abundance has steadily increased due to marine mammal protection and DFO (2018) extrapolated seal consumption estimates from Thomas et al. (2017) for 2012 and 2013 estimating 360,000 steelhead smolts were consumed per year. This builds on work from Kendall et al. (2017) on spatial patterns in steelhead decline that suggests mechanisms of decline are taking place early in marine life, close to inshore areas (where seal predation pressure is highest). Anglers are thus unaware of the magnitude of this threat. The interview data in this chapter support the magnitude of this threat and potential intervention implications for steelhead recovery. Management levers for steelhead recovery are limited but survival between smolt and adult is needed for recovery regardless of fishing efforts. Work from DFO (2018) suggests that reducing steelhead fishing mortality to zero or freshwater range expansion will not be nearly enough to recover steelhead. The management lever of a pinniped reduction (cull) holds the greatest promise in steelhead recovery, a possible 5-fold increase in spawner abundance, and should be investigated further. This could be explored by subjecting a system to seal reduction through adaptative management to observe the impacts to steelhead. Of course, this raises ethical dilemmas of the roles of humans in altering these systems to begin with and the capacity of humans to reverse negative impacts.

Steelhead anglers perceived First Nation fisheries as a large threat to steelhead populations. As this was inconsistent with interviewees, it is difficult to surmise the true magnitude of this threat. Perhaps interviewees were hesitant in pointing fingers at Indigenous communities they are attempting to establish more harmonious relationships with. This pattern of results is also consistent with previous literature which points to conflict between First Nation and recreational fishers, and particularly, complaints about First Nation fisheries use of nets for fishing (Nguyen et al. 2016). Transparently acknowledging situations when First Nations fisheries lead to steelhead mortality and bycatch and taking future preventative measures to reduce it may defuse conflict.

Pointedly, I obtained considerable evidence, in the form of perceptions, that FLNRORD and/or DFO is unwilling to confront or challenge First Nations fishing rights. Of course, these relationships are budding and delicate after centuries of western exploitation and expropriation making any western parliamentary government intervention likely seem authoritarian. However, I heard cases of collaboration on conservation issues like Interior Fraser River steelhead fisheries where a First Nation leader (Chief) recognized some members of their community were part of the problem and worked closely together with parliamentary governments to close the fishery and enforce the closure. Much work remains to be done to build true and lasting reconciliation, but these findings suggest that relationships in the pursuit of conservation are possible if trust and respect are placed at the core of interactions. This will be ever more important as these results suggest an emerging interest of Indigenous peoples in rainbow and steelhead trout for subsistence due to declines in salmon of for local economies as a source of income. Co-managed or collaborative inland fisheries between parliamentary governments and First Nations may be difficult, but co-management (sharing of power and responsibility between government and local resource users) can deliver positive ecological and social outcomes and improvements in governance (Berkes 2009; d'Armengol et al. 2018). Co-managed and collaborative fisheries are likely to be more successful if they're mindful of power and equity asymmetries and embrace adaptive management principles as the Okanagan Nation Alliance and FLNRORD did in their partnership over sockeye and kokanee re-introduction. Trust, respect, mutual learning, and open mindedness are crucial elements for collaborative and co-managed fisheries (Chapman & Schott 2020) especially given the differing value propositions of harvesting fish for food and security versus recreational interests in catching and releasing fish.

These findings highlight the difference in rainbow and steelhead trout anglers in their perception of climate change to their preferred angled fish populations. Steelhead anglers perceived climate change as a much greater threat than resident rainbow trout anglers which is the opposite pattern presented by interviewees. Climate change is impacting freshwater habitats and hydrological processes at an alarming rate and is unequivocally a prime threat to resident rainbow trout (Wenger et al. 2011; Whitney et al. 2016). This implies there is a need for FLNRORD and FFSBC to educate and inform resident rainbow trout anglers on the magnitude of this threat and how it contributes to fisheries closures. Like Litt et al. (2021), this work suggests big gaps in angler awareness of threats, especially in this case of recreational angling for both rainbow and steelhead trout, pinniped predation for steelhead trout, and climate change for rainbow trout. If resident rainbow trout anglers appreciate the extent that climate change threatens beloved fish populations, this could promote climate activism and reform benefitting fish habitat (Love-Nichols 2020).

Taken together, these findings indicate there is a need for a consistent management plan and framework for rainbow and steelhead trout with clear provincial and regional objectives linked to management actions (see also Appendix Sections G.2 – 'Ensuring the long-term sustainability of rainbow and steelhead trout fisheries in BC' and G.4 – 'Rainbow trout management plan'). There is evidence that such plans are effective in impacting information flows among fisheries management social networks and affecting decision-making processes (Leonard et al. 2011). There was support for a management plan which included rainbow trout to be integrated into a wider holistic framework of ecosystem management including things like habitat, non-angling values and Indigenous-led conservation (see Arlinghaus & Cowx 2008; Beard et al. 2011; Hessami et al. 2021). However, study participants realized that a management plan and other practices to ensure the long-terms sustainability of rainbow and steelhead trout and their fisheries ultimately depend on political will. Relatedly, some interviewees desired more consistent and clearer policy guidance for complex issues ranging from dealing with aquatic invasive species or working with and establishing relations with First Nations. Issues perhaps that could be considered within a broader aquatic ecosystem plan in which inland fisheries is placed.

These findings point to a concerning trend of economic, social, and political considerations increasingly influencing fisheries management and overriding conservation despite it being purported as the highest priority amongst fisheries managers. These results support previous literature which have found management and conservation decisions eclipsed by influencing economic or political considerations (e.g., Morrison-Saunders & Bailey 2003; Carroll et al. 2017; Artelle et al. 2018a). One trend that warrants highlighting is the lack of accountability of government oversight over professional industry. After years of cuts to the public service, the BC government is reviewing its "professional reliance" model which risks conflict of interest when professionals are employed by the same industry the government regulates (Smith et al. 2017; Heer & Girling 2020). As these results also indicate, that science normally done by the province, and then outsourced to "qualified professionals" hired by industry and project proponents, has had little to no oversight (e.g., Appendix H illustrative extract 2). "By allowing professional reliance to run wild, I think the industry really had free will and range in the province of British Columbia" [Interview #45, private environmental consultant]. Overturning this model, and the austerity of governments investment in fisheries management (time, staff, and financial resources), would surely open pathways to more evidence and conservation-based decisions.

This work reveals several interesting trends in relationships between fisheries managers and stakeholders. FLNRORD government and FFSBC employees recognized the potential for 'agency capture' by stakeholder groups (i.e., undue influence on agency decision-making by special interest groups which lobby or advocate for personal interests; Artelle et al. 2018a). In this case, fisheries managers exercise caution in weighting any one individual or groups interests over others, given that the most vocal angling clubs and associations represent a very small proportion of the full angling community. These participants suggested memory recall and avidity biases may compromise angler perceptions (e.g., van Poorten et al. 2011; Howarth et al. 2021). These results further indicate managers place greater emphasis on natural science evidence (e.g., stock assessment information), when it is available, than stakeholder information or preferences. Also interesting is that these results suggest angler stakeholders may often have the same fishery objectives – larger and more fish, and more fishery access opportunities – but completely opposing views on how to achieve that, e.g., whether to stock more or restrict fisheries more. Implying that further research, education, and outreach is needed to inform anglers on the best practices to achieve shared objectives of better angling opportunities. Lastly, with the average age of angling participants increasing (see Brownscombe et al. 2014) these results imply this will have profound effects for angler-derived license revenue for FFSBC and HCTF and their programs and investments in fisheries and habitat conservation (see Appendix G Section G.5 – 'The most challenging aspects of rainbow trout management and conservation'). This implies that FFSCBC and HCTF will need to maintain efficiency in the reduction of license revenue or conversely, seek alternative funding sources or inflationary increases in license prices for seniors.

This study population was highly biased to non-Indigenous fisheries actors. This was not intentional as I attempted to have a representative dataset. Nonetheless, this limits our ability to infer perceptions beyond primarily western decision-makers and resource users. Representatives from natural resource branches of Indigenous governments were few, as many of those contacted for requests for interviews expressed little or no interest or expertise in rainbow trout, citing identities linked primarily to salmon. The methods employed also presents limitations. In grouping rainbow trout angler subpopulations and interviewees to facilitate comparison I recognize these groups are not homogenous and grouping risks losing some nuance and difference in perceptions (e.g., by region, position within organization, fishery targeted). The interviewer, survey developer, and data analyst consciously or otherwise, may influence the direction of participant responses, or the coded emergent themes, through underlying personal biases or preconceptions. Errors in inference may also arise through measurement error and translation validity – the degree to which I accurately translated the construct of what interview and survey participants were saying. Poor quality audio in recording and errors in transcription from audio to text, and errors in interpreting and coding participant constructs are inherent limitations to this study; limitations that cannot be controlled by the use of software (e.g., NVivo). Admittedly, the magnitude of such methodological biases is quite low. I also note that perceptions do not always translate into behaviour and may not provide an accurate assessment of the current and future status of rainbow trout populations and fisheries (Nilsson et al. 2020).

3.7.1 Conclusion

Inland fisheries are complex interconnected social-ecological systems that need to be explored further to enable effective fisheries management realizing long-term sustainability and resilience. This chapter examined the perceptions of stakeholder, Indigenous rightsholder, and government employees on the current and future status of rainbow and steelhead trout populations and fisheries in BC, Canada. There was little concern for the conservation status of resident rainbow trout, but anadromous steelhead trout were perceived as threatened. Recreational anglers underestimated their effects on fish populations relative to other participants. Fisheries managers were praised for hatchery stocking programs and small lakes fisheries but criticized for a lack of information on fish populations and for an unwillingness to stand up to commercial and Indigenous interests which infringe on the conservation of fish populations. Insufficient resources (funding, staff, time), confusion in jurisdictional authority between provincial and federal governments, and poor organizational structure and strategic direction are perceived to further limit effective fisheries management. I found that despite conservation being purported as the highest priority of fisheries managers, economic, social, and political drivers are increasingly superseding conservation decisions and actions. I hope these perceptions inform effective fisheries management and conservation as rainbow trout governance and management approaches adapt to changing social and ecological conditions.

Chapter 4: Conservation genomics from a practitioner lens: Evaluating the research-implementation gap in a managed freshwater fishery

4.1 Introduction

Fish and wildlife populations are increasingly threatened by rapid environmental change and thus require informed conservation and management decisions, policies, and practices based on the best available knowledge (Nguyen et al. 2017a). However, investments in new science often fail to result in actionable biological conservation and natural resource management outcomes; something well-documented by the emerging literatures on "knowledge exchange" and "knowledge mobilization" (e.g., Fazey et al. 2012; Cvitanovic et al. 2015; Nguyen et al. 2017a). This results in management decisions that are often made without the best quality evidence, thus increasing the probability of inappropriate conservation and management actions (Pullin & Knight 2003).

Genomics research – a relatively new field of scientific knowledge – is often promoted as a beneficial management tool for the preservation of biodiversity, species, and populations (i.e., conservation genomics) (Shafer et al. 2015; Garner et al. 2016). Genomics is the study of all genes of an organism (the genome), including interactions of those genes with each other and with the organism's environment. Whereas, for decades, molecular markers (fragments of DNA) have been used in traditional conservation genetics, conservation genomics uses genome-wide information (complete systematic mapping of DNA) to conserve biodiversity and manage species and populations, which in principle, improves genetic precision and inferences between genotype and phenotype (Shafer et al. 2015). For example, cutting-edge genomics research on salmonids, the key model species for applying conservation genomics, is (finally) providing insight on the heritable basis of ecologically relevant traits – the adaptive genomic variation associated with specific phenotypes (e.g., Aykanat et al. 2015; Barson et al. 2015; Pearse 2016). However, like other new research, conservation genomics may be difficult to translate into evidence-based conservation and management. This is especially true when there is uncertainty or disagreement amongst the different actors about the value, relevance, and utility of the scientific knowledge (Roux et al. 2006; Cook et al. 2013; Young et al. 2018a); when there are different expectations and preferences of new knowledge (Young et al. 2016b); when organizational structures and culture limit communication (Soomai 2017); and when conflict exists between scientists and elements of broader society about the ownership of new knowledge (i.e. what knowledge is privately held vs. in the public domain or in the public interest) (Salter & Salter 2017).

Conservation genomics, in general, has made little advancement towards routine application in conservation practice (McMahon et al. 2014; Grueber 2015; Shafer et al. 2015; Garner et al. 2016; Shafer et al. 2016). This is likely in part due to a "credibility crisis" as genomics ran into difficulties of political buy-in during the 2000s (Salter & Salter 2017), to public concern and fear about genetically modified animals (i.e., transgenics) (Check 2002), and to an implementation 'gap' between fundamental research and applicable solutions for conservation practitioners (Shafer et al. 2015; Taylor et al. 2017). The "conservation genomics gap" is also a result of challenges in generating and interpreting genomic data, tasks that have to date been largely confined to academic researchers (Shafer et al. 2015). Each of these problems is connected to a major barrier identified in successfully mobilizing academic science more generally – the failure of scientists to understand the behaviours, preferences, and viewpoints of potential users of their knowledge, and to also effectively translate their science to potential knowledge users (Young et al. 2016b). Another compounding factor may be, as Shafer et al.

(2015) argue, that the core problem is not a lack of knowledge about conservation issues but rather a lack of political will to act appropriately on this knowledge. It is also important to recognize the tension between reducing uncertainty through gaining knowledge from scientific research versus the very urgent concerns faced by practitioners of biodiversity conservation (Wiens 2008). Conservation genomics of salmonids serve as an excellent example to explore this (Piccolo 2016).

For genomics to have meaningful impact on fish and wildlife conservation and management, suitable ways to remove or overcome general barriers limiting the use of new scientific knowledge are required (Gibbons et al. 2008; Shafer et al. 2015; Shafer et al. 2016; Nguyen et al. 2018; Young et al. 2018a). This is especially the case where the new scientific knowledge is technical in nature and prone to using jargon which may alienate those external to the scientific process (Hoban et al. 2013). We analyze how potential knowledge users (government employees and stakeholders [fish and wildlife managers and decision-makers]) perceive and evaluate new claims of conservation genomics knowledge using the case of managed rainbow trout (*Oncorhynchus mykiss*) fish and fisheries in BC.

Fish and wildlife managers are thus important potential users of new science and represent an important interface for science and action (Young et al. 2013). It is therefore important to understand the perspectives of potential knowledge users and understand the challenges that may impede the movement of new knowledge into action. Along with Taylor et al. (2017) this research is one of the first contributions to navigating the conservation genomics gap or ‘space’ (Toomey et al. 2017) by directly identifying preferences, experiences, knowledge of, and viewpoints of potential conservation genomics knowledge users (practitioners). However, like Taylor et al. (2017), this case study represents only one context, but provides further knowledge to the factors that could perpetuate a "conservation genomics gap", the perceived barriers of integrating new genomics knowledge into conservation practice, and potential solutions to bridge or navigate the gap. I conclude by providing recommendations to improve communication between genomics research scientists and potential knowledge users with a focus on increased genomics education and awareness.

4.2 Methods

This research was exploratory, aimed at investigating and categorizing a set of perceptions and behaviours among knowledge users that were unknown at the outset of the study. As such, this research is intended to be primarily descriptive, and hypothesis-generating rather than hypothesis-testing.

Befitting exploratory research, I developed and employed an interview schedule using a mixed-methods approach with both closed- and open- ended questions (Axinn & Pearce 2006). The closed-ended questions involved a series of Likert-style opinion statements about genomics research (which I define as the use of high-throughput sequencing of genome-wide information (Shafer et al. 2015; Garner et al. 2016)) for which respondents were asked to indicate their level of agreement on a five-point scale (strongly disagree, disagree, neither agree nor disagree, agree, and strongly agree), with the option of answering "I don't know". Open-ended questions allowed respondents to explain their positions and opinions freely. The set of questions analyzed in this chapter are provided in Table 4.1.

Table 4.1 Interview questions analyzed in Chapter 4.

Question	Type
Are you familiar with genomics research?	Open-ended
What do you think of genomics research?	Open-ended
What are the upsides of genomics research (if any)?	Open-ended
What are the downsides of genomics research (if any)?	Open-ended
Do you see genomics research deriving more benefits (being more valuable) for fish stocking programs or for the management and conservation of wild fish populations?	Open-ended
Please indicate the degree to which you agree or disagree with the following statements about genomics research	Closed-ended (Likert-style) with open-ended follow up

Respondents were not presented with a definition of genomics, its distinguishing characteristics between "traditional" (conservation) genetics, nor the costs or benefits of genomics research. I did not provide a definition of key terms (e.g., genomics) because I was interested in interviewee open-ended interpretations thereof, put in their own words, for comparative analysis. Qualitative data were analyzed using NVivo 12 software (QSR International Pty Ltd. 2018). Quantitative (Likert) data were analyzed using the 'likert' (Bryer & Speerschneider 2016) and 'psych' packages in R version 3.4.4 (R Core Team 2018). For open-ended responses a three-step inductive coding process was applied to qualitative data (Thomas 2006). First, responses were read to identify key words (Appendix J, Figure J.1), which became a list of potential codes. Similar potential codes were then grouped into themes. Responses were read a second time and sorted under these themes to provide a measure of their prevalence. A response may have multiple thematic codes if warranted. All coding was performed by ANK. Because the coding task, in addition to transcription of data from audio to text, already consumed a significant amount of time and resources, using more than one coder was not viable in this chapter and thesis. Additionally, the coding system/frame *is* the collection instrument, not the coder, and should establish coding consistency. Multiple coders may have different theoretical biases and will organize codes into themes in different ways (Armstrong 1997) thus it is not always clear if using different coders reduces susceptibility to bias or errors in judgement. Although I acknowledge using multiple coders will reduce the risk of human error and may be a limitation in the present chapter.

I developed the initial population frame for the interviews based on a review of the ‘grey’ (government) literature on fish policy and regulations and the BC Government Directory (https://dir.gov.bc.ca/) searching for: “fish” or “fisheries”. The population frame was then further developed in consultation with three senior managers at FLNRORD, MOE, and FFSBC to ensure that key government employees and stakeholders were identified. The population frame was then supplemented by snowball sampling from voluntary referrals by respondents. A total of n = 163 individuals or organizations were contacted to request an interview. This study was conducted in accordance to the University of Ottawa Research Ethics Board (File Number: 02-18-08).

A total of 65 interviews (response rate of 40%) were conducted in-person (n = 43) and over the phone (n = 22) between April and November 2018 divided between two broad groups: government employees (n = 33), and representatives from non-governmental stakeholder groups (n = 32) involved in the management of recreational and subsistence rainbow trout fisheries in BC. The two-sample Mann-Whitney U (Wilcoxon rank-sum) significance test was used to compare quantitative (Likert) responses between these two affiliation groups. The government employees group includes a large number of FLNRORD individuals involved in fisheries management (i.e., directors, resource managers, fish and wildlife section heads, and biologists), as these are the employees most directly involved in freshwater fisheries management with stakeholders and in-season decision-making. It also included employees in the MOE Conservation Science Section who were identified by the organization as working closely with fisheries managers and stakeholder groups. A few employees from the DFO Science Branch were identified for their expertise in genomic applications to fish conservation. The stakeholder group includes representatives of recreational and subsistence fisheries, BC Hydro (the province-owned electricity utility that has a major water and land footprint in BC), academia, First Nations communities, ENGOs, and environmental consultants who are hired by stakeholders and play a role in management processes. The affiliations of respondents are provided in Table 4.2. I recognize that the term stakeholder does not comprehensively describe the diversity and nuances of all individuals involved shown in Table 4.2. For example, First Nations communities are grouped as stakeholders (those with vested interests in managing freshwater fish and recreational and subsistence fisheries), but it is important to note that under BC legislation they are in truth 'rightsholders' given the special legal status of Indigenous rights and territorial claims. Each stakeholder has distinct interests, values, identities, and perspectives. This group is, however, distinct from government employees occupying similar roles in that they are all involved in the management of BC rainbow trout but external to government (see Young et al. 2016a; Young et al. 2016b; Nguyen et al. 2018; Young et al. 2018a) so stakeholders is an imperfect term that I employ with this important caveat.

Table 4.2 Affiliations of the 65 respondents, grouped as government employees and stakeholders.

Government Employees	n	Stakeholders	n
Biologists (FLNRORD)	17	First Nations fishery	4
Fish & Wildlife Section Heads (FLNRORD)	6	Private environmental consultants	6
Directors (FLNRORD)	3	Academia	6
Policy Analysts (FLNRORD)	2	ENGO	5
Human Dimensions Specialist (FLNRORD)	1	Retired Government Employees	3
Conservation Science Section (MOE)	3	Freshwater Fisheries Society of BC	6
Science Branch (DFO)	1	BC Hydro	2
Total	33		32

While the focus of this research is recreational rainbow trout fisheries, it is important to recognize that the term 'fisheries management' may be limiting in this research-context as several of the respondents manage fish (and not anglers) while others manage both fish and wildlife populations. Therefore, the responses in this chapter are most specific to fisheries management but are described throughout under the broader term 'fish and wildlife management'. Among the respondents, 56 were male and 9 were female. Government employee respondents covered each of the 9 different resource management regions in BC (Region 1: Vancouver Island, Region 2: Lower Mainland, Region 3: Thompson-Nicola, Region 4: Kootenay, Region 5: Cariboo, Region 6: Skeena, Region 7A: Omineca, Region 7B: Peace, Region 8: Okanagan). Some respondents elected to remain anonymous while others released their identities. Interviews lasted between 18 minutes and 2 hours, depending on the level of detail provided by the respondent.

4.3 Results

4.3.1 Familiarity with genomics research (understanding of genomics)

As mentioned previously, a lack of familiarity with genomics research among potential users is a major barrier to uptake. Consistent with this, only 26% of respondents in this study stated that they are familiar with genomics research, while 42% were vaguely familiar and 32% were unfamiliar. Of those that were vaguely familiar, very few understood the difference between genetics and genomics so overall, the vast majority (~74%) were not familiar with genomics nor understood the difference between genomics and genetics.

Table 4.3 presents findings from the twelve Likert-style opinion statements about genomics research that were read to or shared with respondents during interviews. The results are presented below linked to these twelve statements.

Table 4.3 Mean responses to twelve Likert-style opinion statements about genomics research (0 = strongly disagree, 1 = disagree, neither agree nor disagree = 2, agree = 3, strongly agree = 4).

	Government Employees		Stakeholders		Significance
	Mean	SD	Mean	SD	
1. Genomics research provides reliable information about rainbow trout populations	3.07	0.62	3.21	0.68	0.422
2. Genomics research about rainbow trout would help me make better decisions	2.83	0.71	2.88	0.98	0.488
3. Genomics research is worth the monetary cost	2.57	0.84	3.04	0.76	0.043*
4. Genomics research provides us with information we wouldn't otherwise have from other sources or studies	3.30	0.53	3.35	0.88	0.319
5. Genomics should play a more central role in rainbow trout management than it currently does	2.57	0.69	2.71	0.81	0.305
6. The benefits of genomics research for trout management are over-stated	1.76	0.83	1.48	0.80	0.188
7. Genomics data should be freely available to anyone who wants it	3.26	0.68	3.16	0.97	1
8. I have ethical concerns about genomics research on trout	1.03	0.98	0.71	0.86	0.169
9. I am worried about incorporating genomic technologies into rainbow trout populations	-	-	1.16	0.99	-
10. I am worried that stakeholders will think that genomics research on rainbow trout means incorporating genomic technologies (transgenics/genetic modification) into rainbow trout populations	1.70	1.17	1.38	1.19	0.494
11. I am worried that stakeholders will think genomics research on rainbow trout may eventually lead to incorporating genomic technologies (transgenics/genetic modification) into rainbow trout populations	2.10	1.14	1.50	1.20	0.245
12. I am worried about genomics research on rainbow trout populations	-	-	0.82	0.81	-
n	33		32		

n = 65; *p < 0.05, based on Wilcoxon rank-sum test for ordinal data (Mann-Whitney two-sample significance test).

4.3.2 Benefits of conservation genomics research

Despite low overall familiarity with genomics, government employee and stakeholder respondents overwhelmingly saw genomics research as a valuable endeavor (n = 60), providing both reliable and novel information and knowledge about rainbow trout populations (Table 4.3, #1 & #4) that generally would help improve their conservation decision-making (Table 4.3, #2) (see Table 4.4-1 for illustrative quotations). Positive responses included descriptions of genomic science as “robust”, “accurate”, “enormously-detailed”, “fast-paced”, and the “future for molecular-based research”.

Table 4.4 Illustrative quotations from government employee and stakeholder respondents about the benefits, the uncertainty and relevance, and barriers to implementation of conservation genomics.

1. BENEFITS OF CONSERVATION GENOMICS RESEARCH

I think it's a fundamental tool now in a manager's toolbox. Like, I've seen it in the last 5 years working here, we've used it to inform management decisions. Maybe not even inform management decisions in some cases but used as a tool to help us understand more about the population in a way that helps guide further monitoring work or helped us determine a certain question around what the underlying biology of the population is. (Interview #27; male; First Nations fishery affiliation).

1.1 Identifying threats and threatened populations

In the summer of 2015, the drought year, stream levels receded. Temperatures increased. And all of a sudden, we were faced with making decisions on which streams to close to protect fish. And there's a lack of information about temperature thresholds. So, I guess if we had some information like this strain will be ok up to 22 (°C), while this one suffers at 18 (°C) it might help us manage stream-flows, seasonal openings, and closures. (Interview #28; male; FLNRORD affiliation).

I think looking at some of these different things, we're going to have to find Rainbow Trout strains that are more tolerant to pH or temperature and if we don't, people are putting Bass and Perch in these lakes. So, what we'll see is that if we can't keep Rainbow Trout alive in some of our lakes – I mean this area is known for Rainbow Trout, this is a mecca in North America for Rainbow Trout – but if we can't sustain those populations people will move other fish in; non-native fish that we have to then deal with. (Interview #18; male; FLNRORD affiliation).

1.2 Identifying genetically distinct unique populations

We're really able to understand the genetic architecture and how particular phenotypes arise and whether they're worthy or not of special consideration when it comes to management. So, for example, the genes that produce summer-run fish opposed to winter-run fish. Knowing exactly where that is, understanding the likelihood of those re-evolving quickly or slowly has important practical consequences. I mean even the way we split up conservation units, plays directly into and elevates the importance of say conserving a particular population; closing a certain fishery right down to direct economic impacts to a particular stakeholder group. So, it helps to clarify what's important and what's not. (Interview #19; male; FLNRORD affiliation).

1.3 Assessing and monitoring populations

I think it's a super helpful tool to identify related groups of fish, for example. Any kind of plant or animal actually. But once you know that you have some discrete conservation unit – and genomics can help to inform that – you can do a better job of conservation if you have a notion of what the geographic focus is and also then the relative abundance of that particular unit might be and whether it's of concern or not. (Interview #24; male; FLNRORD affiliation).

1.4 Characterizing meaningful genetic diversity

Shore-spawning and stream-spawning kokanee: you know, are the shore-spawners just stream-spawners that are too lazy to go into the stream? But actually, they seem to have different genomes. The DNA is different. So, that corroborates phenotypic observations of behaviour. (Interview #24; male; FLNRORD affiliation).

The relationship between Steelhead and Rainbow Trout – that's not something we clearly know. It appears like they can switch between Rainbow Trout and Steelhead even though there are differences genetically. But I don't think we fully know that yet. So, some of those questions are huge because for example, the Thompson River-Steelhead, we're down to less than 200 fish. And it's a very unique world class fishery that we can't even open anymore. And so, there's some thought that we still have this genetic bank of Rainbow Trout that at some point can turn into Steelhead. So, understanding some of those relationships I think is pretty important for sure. (Interview #18; male; FLNRORD affiliation).

1.5 Understanding genomic diversity and linking it to phenotypic diversity

We used genomics to actually look at the structure of early-time spawners and average-time spawners in tributaries and they're basically all one big population. So, it's a benefit to us. It's helped us effectively manage what our mitigation responses are to potential impacts. (Interview #61; male; BC Hydro affiliation).

2. TENSION BETWEEN CONSERVATION GENOMICS AND CONSERVATION PRACTICE

2.1 Questioning the relevance of genomics to management and conservation

I think we already know a lot of that, in terms of climate change, impacts of fishing and land use. It's just actually making and implementing the decisions to address those types of conservation concerns, is the challenge. (Interview #5; male; FLNRORD affiliation).

Are we going to be deriving information which is going to allow us to be more specific than the general knowledge out there? And I would probably imagine that no – we probably already know what we need to know in order to manage 99% of what we would do in the steelhead realm, for instance. And again, it's unclear to me as we drill right down to that level of individual program management how any level of additional information is going to help inform that. I might be wrong there but I'm not sure that we see a bunch of specific management outcomes proliferate from this work. (Interview #33; male; FLNRORD affiliation).

On the conservation side, my experience is that it is generally not a data deficiency issue. It's usually pretty clear what's causing the conservation concern and its more just the difficulty of implementation. There's not – I don't think – a data shortage in genomics that's going to help the conservation part. I could be wrong. (Interview #20; male; FFSBC affiliation).

2.2 Discrete and limited conservation and management levers

We mostly think about fishing regulations as the thing that we control but when it comes to things like temperature tolerance or sensitivity, we're talking about water use, we're talking about forestry, we're talking about other things. So, if I think a bit more globally, I could imagine maybe ways in which genomics information gets incorporated or could be incorporated into population management at a level that's beyond our fish section here. (Interview #32; male; FLNRORD affiliation).

3. BARRIERS TO IMPLEMENTATION OF CONSERVATION GENOMICS

3.1 Communication disconnects between researchers and knowledge users

I've heard of the genome project. I don't know much about it. We haven't had much involvement, right? So, I think there's a little bit of a disconnect – there always is – between research and how that research can be applied for management. We're management, there's research – and there's a bit of a gap in between. And so, I think maybe within the Ministry we should be better at pursuing some of that research. But I think there must be a mechanism for management and research to meet in the middle. We often work with universities and describe the management goals we hope the research will inform and often what we get back is great information, but it's not applicable to management. So, how is this research going to actually help us with decisions? And that seems to be the disconnect sometimes, because researchers love to do research and then they get off on a tangent and that's great. It's interesting information. But from my perspective, it's how can we can use that information to make more informed management decisions? (Interview #18; male; FLNRORD affiliation).

I have seen the downsides of some research here in BC in that the process takes so long, and we aren't actually given the tools or the application in the end. It gets published in some journal and we're not even told about it. And then all of a sudden you come across this piece of published research.

Oh, that's my colleagues and this isn't even something that was sent out to us. To be honest these models are so complicated and amazing and they're really neat but then giving us (the managers) the tools, there's a real gap in the middle. I'm kind of waiting, waiting, waiting. So that would be the downside is just that gap between these really, really complex models and then giving us something to manage by. Or maybe even convincing us to use it. (Interview #25; female; FLNRORD affiliation).

3.2 Practitioner misunderstanding and confusion leading to potential misuse and misapplication

There's a lot of unfamiliarity with the techniques and a lot of times people may not understand it. I mean, I think it can be intimidating to a lot of people because they don't have the background in the science behind the tool. So, a lot of times it's a tool that seems like it has a lot of black magic behind it. So, people are maybe intimidated by it or don't trust it. I've definitely seen too, where there's less uptake on the use of the tool because people don't really understand what it can be used for and the science behind it. So, that's definitely a downside. It's just a suspicion that it's not being used to its full potential. (Interview #27; male; First Nations fishery affiliation).

I'm optimistic around some of the new technologies but I'm very limited – I have a limited understanding of it. Because they [fish populations] somehow seem different or better, realistically, I'm totally unclear how much better or different they might be. (Interview #33; male; FLNRORD affiliation).

3.3 Misunderstanding genomics research as genetic modification

I would say that I agree with both of the statements based on the feedback we get on our work with triploid rainbow trout and kokanee. There is a small but vocal minority of our angler stakeholders that equate what we're doing (pressure shocking eggs to render them subsequently sterile) with inserting genes and making transgenic fish (which we don't do and have no interest in). So, based on that, I think that some stakeholders could be confused by the term genomics and interpret is as something else. (Interview #1; male; FFSBC affiliation).

I'd have to 'neither agree nor disagree' to these questions. On one hand I've had anglers who I thought were quite knowledgeable express concern over these same issues. On the other hand, most knowledgeable anglers who I talk to are aware and understand. This is quite clearly an education issue which needs some resources dedicated to it. (Interview #50; male; FFSBC affiliation).

We get the question all the time – not just about triploid fish – are these genetically modified? People are very leery about genetically choosing a specific fish. And that's a really big concern for the public. So that's something that could be a negative perception of doing any – not that we're modifying – but even just selecting for certain genetics, that scares people, I think. There are probably some dangers involved with that. (Interview #18; male; FLNRORD affiliation).

3.4 Differences in data and results interpretations

I guess one generalized comment is that some researchers are able to find with some incredible accuracy and precision interesting things around lineage and diversity and similarities or differences in populations and population structure. Whereas others are able to not infer almost anything at all given large datasets and it's unclear to me how we can have such resolution on one hand and such opacity on the other given the same technique used for two different populations. So, in some cases I'm not even in a position to really critically review or understand. I mean, it's kind of looking at a binary code, a series of 1's and 0's. I'm certainly not in a place to be as critical as I think I'd like to be. (Interview #33; male; FLNRORD affiliation).

3.5 Uncertainty over whether differences or variation have any meaningful or demonstrable value, or ecological relevance

Someone did some kokanee work for us on the west-arm of Kootenay Lake analyzing Single Nucleotide Polymorphisms (SNPs), and they determined that shoal-spawning kokanee were different than tributary-spawning kokanee in the west-arm. So, I guess the downside of it is, what does that actually mean, right? Where's the phenotypic difference – is it the pH? O_2? is it they can live in lower O_2? So, we can get the difference, but we don't know what it means. So, I think that's one of the downsides of it, is you can find the difference but actually linking it to something is maybe difficult. (Interview #62; male; BC Hydro affiliation).

3.6 Cost

Well, that comes down to the cost change on a sliding scale – how much you do and what kinds of SNPs you develop right. So, it can come down. But in general, we are confined to these funding pots that we use and so you're talking about sometimes taking up a large portion of a typical project fund to put into that. So, I think it is worth it in very specified situations definitely, but the costs have to come down for it to be used as a general tool. So, if the costs come down then yeah it could end up becoming a standard practice for us for a lot of different projects. If it's making up the majority of the expense, then you really want to make sure it's providing you some target information you're specifically after. (Interview #20; male; FFSBC affiliation).

3.7 Potential to misspend limited resources

As facetiously described: Why bother cutting back on forestry and buffers around streams when you can just introduce fish that are more adaptable to increased turbidity and temperatures? (Interview #31; male; FLNRORD affiliation).

3.8 Temporal mismatches between the supply of genomics and the demands of conservation practitioners

And then of course, operationalizing the results of finding a stock of rainbow trout that are tolerant to low or lower oxygen or high pH or whatever it is that we're seeking – making it an operational reality just seems so far off right now. It truly is an academic undertaking and climate change, environmental change, is happening at a much faster pace than perhaps our research is getting done. (Interview #51; male; FFSBC affiliation).

Respondents recognized the value of genomics research for: understanding disease outbreaks or prevalence to diseases, identifying and helping prevent hybridization, and identifying introgression of domestic and wild genotypes (risks associated with wild and hatchery fish interactions). However, the benefits respondents most-often identified and discussed were: identifying threats and threatened populations, identifying genetically distinct unique populations, and understanding genomic diversity and linking it to phenotypic diversity.

With respect to BC freshwater fisheries, respondents consistently mentioned the threats of high pH (alkalinity) and water temperatures. Thus, respondents were able to identify the value in genomics research exploring resilience, adaptation, and sensitivity (i.e., tolerance and limitation thresholds in strains, stocks, or individual fish to temperature, pH, oxygen) (see Table 4.4-1.1).

Identifying fish that might be better locally adapted to drought conditions or water quality changes was seen as a significant benefit, especially given – as many respondents indicated – that these are expected to be increasing threats down the road, threatening intraspecific (within-species) biodiversity. Other mentioned threats which could be addressed by genomics research include the role of hatchery stock in the fitness of wild stock, the impact of invasive species on fitness, and impacts to habitat quality.

Respondents recognized the benefits of genomics research in identifying the source of genetic uniqueness, distinctness, and relatedness (i.e., defining populations) (see Table 4.4-1.2). These benefits may extend to identifying completely isolated populations or genetically distinct populations. There was strong agreement this knowledge would help in conserving unique or distinct populations and stocks of rainbow trout by identifying which stocks to protect and which stocks management could be more or less risk adverse with. To this goal, several respondents acknowledged genomics would help in providing data on historical fish-stocking (i.e., on the lineage and population history [trends, decline, expansion] of domesticated strains in BC and their possible origins) for which records were poorly kept, if at all; identifying the distribution (*where* and *when*) of feral (historically-domesticated) versus wild fish populations; and how that information might correspond with, for example, Indigenous and local knowledge.

Moreover, government employees identified the value of genomics research to efficiently assess populations through population or stock monitoring, especially in mixed-composition fisheries and *when* and *where* stock identification is difficult or impossible to do visually (see Table 4.4-1.3).

There was common support that genomics research could benefit fish and wildlife management by characterizing meaningful genetic diversity. Respondents provided numerous examples where genomics could help in understanding the levels of biodiversity within fish which might have implications for the way in which fish are managed. For example, the benefits of genomics research were referenced with respect to triggering or differentiating: stream- versus shore-spawning fish; resident (e.g., rainbow trout or kokanee) versus anadromous (e.g., steelhead or sockeye) fish; run-timing (i.e., migration composition, strength, and competition); life-history stages and characteristics; ecotypes (i.e., distinct form of a species occupying a particular habitat); local adaptations; fidelity (see Table 4.4-1.4).

The ability to get detailed genomic information to then compare to phenotypic variation and attributes – being able to link genotype and phenotype (i.e., the genetic basis of physical characteristics and traits) – was seen as highly informative to understand within-species and population-type diversity so that conservation efforts could be managed to protect and maintain sufficient genetic diversity and to enhance the resilience of populations (see Table 4.4-1.5).

4.3.3 Tension between conservation genomics and conservation practice

While, in general, genomics research was viewed favorably, the exact role of genomics in rainbow trout management was less clear (Table 4.3, #5). Some respondents noted that use of genomics research in decision-making depends on management objectives and the ability to use genomics in support. Others noted that species other than rainbow trout (i.e., those with greater conservation concerns) would benefit more from genomics research. A substantial number (n = 25) of respondents questioned the relevance of genomics to fish and wildlife management. Most of these questions centred around *whether* or *how* genomics research could influence management outcomes and change the way that management levers could be pulled (see Table 4.4-2.1). These opinions mostly align with the description from Shafer et al. (2015) of the disconnect between conservation genomics research and conservation practice as being associated with political rather than knowledge limitations.

Others noted an important limitation -specifically, there are only a discrete number of levers most fish and wildlife managers have at their disposal (see Table 4.4-2.2). In other words, the use of genomics knowledge to inform management decisions may be limited by organizational structure and processes that implicate other facets of decision-making beyond those traditionally associated with fish and wildlife management.

4.3.4 Barriers to implementation of conservation genomics

A substantial number of respondents (n = 44) provided feedback on what they perceive to be downsides, risks, or barriers of genomics research, while seven respondents explicitly stated they do not see any. Among those with concerns, key issues included: that enormous amounts of information make it too difficult to integrate; overwhelming researchers and users searching for a signal in ample noise; focusing on economically important resources; contributing to increased handling of already sensitive or endangered organisms; and diverting interest and attention from more basic and broad biological questions which may be more relevant for conservation. Other barriers described in more detail include: communication disconnects between researchers and knowledge users; practitioner misunderstanding and confusion; differences in data and results interpretations; linking genomics to something meaningful; cost; potential to misspend resources; and the applied-genomics process being too slow for conservation and management.

There was general agreement that the benefits of genomics research for trout management are not over-stated (Table 4.3, #6). However, this result was not unanimous, suggesting communication disconnects between researchers and knowledge users. The implementation space between genomics research scientists and knowledge users was described as disconnected on account of poor engagement and communication (see Table 4.4-3.1). Upon completion of some partnered genomics projects, government employees indicated with concern, that they were never informed about and actually given genomics applications and management recommendations (see Table 4.4-3.1).

A considerable number of responses described genomics as overly-technical and complex – especially for when engaging directly with stakeholders. There was some worry that knowledge users may take genomics findings at face-value, over-estimating the potential of the science to solve problems and answer questions. If true, respondents recognized that this may potentially open doors for the science to be misused or misapplied (e.g., putting more pressure on fish stocks, misuse of the designatable conservation unit concept). These responses further explained a potential loss of engagement with any knowledge user not interested in the technical details. Genomics was even analogized as a “bit of a black art” (see Table 4.4-3.2).

Government employees and stakeholders described a (rare) concern that some knowledge users, including the general public, may misunderstand genomics as genetic modification (Table 4.3, #9-11) (i.e., transgenics, genetic modifications); misunderstandings or assumptions that some respondents suggested could be addressed by clear communication (see Table 4.4-3.3). Ethical concern over applying genomic technologies to fish, however, was generally not the prevailing opinion held by the government and stakeholder respondents interviewed in this chapter (Table 4.3, #8, 9, & 12).

The confusion and complexity of genomics science may be compounded by differences in the interpretation of data and results according to some government employees and stakeholders. Several respondents claim that differing results and conclusions between genomics research scientists may alienate or mislead potential knowledge users who have no way themselves of validating the accuracy and precision of results (see Table 4.4-3.4). Thus, genomics research and its scientists may cultivate skepticism and may be perceived as arrogant or audacious by knowledge users.

Respondents also expressed concerns about the implications of detecting the presence or absence of genomic differences or variation and what this means in practice (i.e., the ability to translate genomics results to conservation and management decisions, polices, and practices). There was uncertainty as to whether differences or variation that genomics research scientists find have any meaningful or demonstrable value, or ecological relevance (see Table 4.4-3.5).

In the absence of meaningful differences or variation respondents expressed uncertainty and questioned whether that is a product of failed or false detection (perhaps due to poor study design), or whether conclusions are indeed biologically significant. There were also concerns that genomics results could potentially either confuse, over-sell, or under-sell the environmental factors that regulate gene expression (i.e., a lack of genomic understanding of the genetic basis of phenotypic variation). It was suggested by respondents that genomics research scientists should communicate genomics results in an objective way that is accessible to knowledge users; clearly focusing on and communicating the limitations, possibilities, and advantages of genomics science (i.e., what it can and cannot do).

There was general agreement that genomics research is worth the monetary cost (Table 4.3, #3) but like #5 & #6 (Table 4.3) these results were not unanimous, suggesting practitioners may not be educated on the costs or benefits of genomics. This is the only opinion statement on which government employees and stakeholders significantly differed in their responses. Stakeholders tended to agree with the statement more than government employees; although the statistical significance or clarity (Dushoff et al. 2019) is marginal when measured along a continuum of statistical significance. Given that this was the only statistical difference, and it was only marginally clear at best, I present findings of the responses to opinion statements in Figure 4.1 pooled for stakeholders and government employees. Some responses supported the idea that genomics research is an expensive and time-consuming pursuit, especially for large geographical ranges or regions such as rainbow trout in BC, where comprehensive spatial coverage for sample-collection is required (see Table 4.4-3.6).

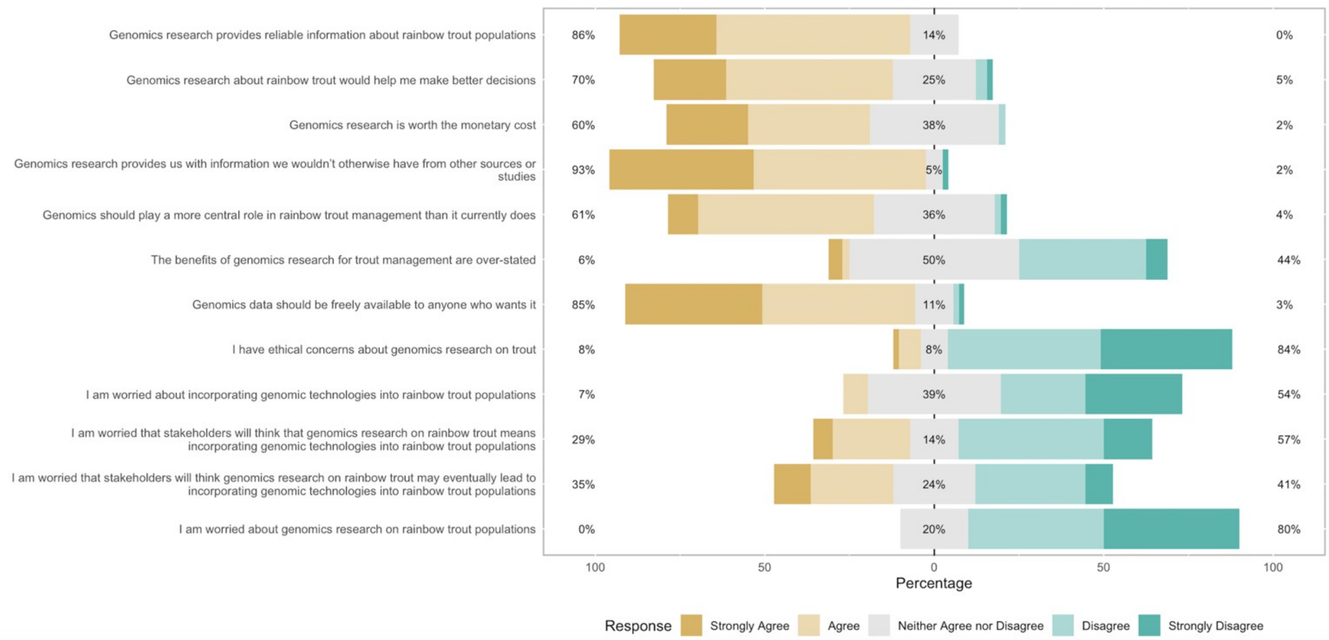

Figure 4.1 Likert-bar plot of the responses to twelve Likert-style opinion statement about genomics research pooled by respondents (n = 33 government employees, n =32 stakeholders).

There was a strong consensus that genomics data should be freely available to those who want it (Table 4.3, #7). However, a respondent expressed concern that freely available genomic data would influence angler preferences while another acknowledged the 'double-edged sword' between sharing data and protecting data for publication

There may be a risk that investments of (limited) resources in genomics science may be poorly spent if investments elsewhere may yield higher beneficial returns for conservation, identified some respondents. Particularly, spending on genomics could limit funding to other forms of (e.g., small-scale, rudimentary) research or to clear conservation concerns whereby investments could instead be made into preserving and protecting those populations by, for example, habitat restoration; habitat enhancement; monitoring of fish and fisheries; and enforcement. If money spent on genomics could be better spent on direct conservation measures or practices, genomics could undermine or undervalue these measures or practices and instead promote or unintentionally-facilitate “worst practices”, noted some respondents (see Table 4.4-3.7).

Several respondents made statements based on their own experiences, that the applied-genomics process of collecting and reporting back data for monitoring and management purposes takes too long (i.e., is too slow to inform management dealing with environmental changes that are happening at faster paces) (see Table 4.4-3.8).

4.4 Discussion

The potential for research-implementation “gaps” or “spaces” (Roux et al. 2006; Arlettaz et al. 2010; Cook et al. 2013; Toomey et al. 2017) between conservation science and evidence-based management in conservation practice have been well documented. If conservation practitioners aspire to make conservation and management decisions informed by the best-available science (Dicks et al. 2014a; Dicks et al. 2014b), and conservation scientists aspire to produce conservation and management-relevant science (Liu et al. 2008; Cook et al. 2013), implementation and integration spaces between these two complementary goals suggest real (or perceived) barriers. I explored the role of conservation practitioners in the “conservation genomics gap” (Shafer et al. 2015; Garner et al. 2016; Taylor et al. 2017) by consulting directly with potential genomics knowledge users using a specific case of a recreational and subsistence freshwater fishery. Overall, respondents were largely unfamiliar with genomics yet highly receptive to embracing genomics as a science to inform conservation and management decisions, policies, and practices; similar to results found in New Zealand (Taylor et al. 2017). By revealing preferences, demands, experiences, knowledge of, and viewpoints of conservation practitioners I highlight some of the barriers that they perceive to conservation genomics knowledge transfer (i.e., knowledge mobilization and exchange) into conservation practice. The interviews also revealed opportunities (potential solutions) to overcome barriers in the translation of genomics research into conservation practice in this case study.

There was rather low familiarity of genomics (i.e., the complete genome-wide high-throughput sampling and sequencing of nucleic acids of organisms) science held by conservation practitioners, representing an opportunity to increase genomics education and outreach targeting conservation practitioners. Like practitioner respondents in Taylor et al. (2017), in this case, practitioners were also aware of their lack of knowledge in genomics (and genetics) and were keen to receive more information, presenting an opportunity for genomics researchers to communicate the relevance of their science. However, many of the benefits identified by the smaller proportion of respondents familiar with genomics were management-specific. Conservation practitioners were therefore able to recognize – despite in cases, low familiarity with the science – precise conservation-relevant benefits. This should be encouraging for genomics scientists for two reasons. First, the majority of identified benefits are prevalent issues in conservation practice and can be disseminated to contexts beyond this specific case. Second, conservation practitioners have a good understanding of what specific knowledge they need and want to inform conservation and management. If genomics researchers hope to produce salient science that will be translated into practice, they need to focus on these benefits and address management-relevant questions (Fazey et al. 2005), and appreciate the practical demands of conservation practitioners. For example, respondents were very focused on resilience, interested in the capacity of genomics to inform the sensitivity and adaptation potential of the populations they manage – both wild and hatchery (stocked) fish populations – to environmental threats particularly linked to climate change. Respondents were also very interested in genetic distinctness and uniqueness to inform management by the delineation of discrete populations (e.g., management or conservation units - Bradbury et al. 2013; Flanagan et al. 2018); linking genomic diversity to phenotypic diversity; prevalence and susceptibility to disease; fitness consequences from introgression between domestic and wild genotypes; monitoring populations; assessing gene flow; detecting local adaptation; and species hybridization – real-world issues prevalent across conservation and management, which could potentially be informed by genomics (Allendorf et al. 2010; McMahon et al. 2014; Grueber 2015; Shafer et al. 2015; Garner et al. 2016). For rainbow trout specifically, interest from practitioners in the heritable basis of ecologically relevant traits should be encouraging as salmonids are among the key model species for applying conservation genomics.

These findings also help in identifying and understanding the barriers and challenges that exist in the implementation of conservation science. It is important to recognize from the perspective of a researcher, a substantial number of conservation challenges may be limited by political or social will, and not by scientific knowledge. All of the 'knowledge to action' barriers mentioned by respondents, especially a lack of genomics expertise, are characterized by a communication disconnect between researchers and practitioners, implying an obvious need for clearer communication, echoing calls for better communication between genomics researchers and practitioners (Shafer et al. 2015; Garner et al. 2016). Effective communication is imperative to bridge the gap between research and conservation (Cook et al. 2013). The perceived lack of genomics expertise in Canada is also worrying given it too is a country with an active conservation genomics community (see Taylor et al. 2017). In my experience, I believe a) external genomic scientists are not proactively engaging with practitioners, *and* b) external genomic scientists have very few main contacts at FLNRORD, MOE, or nongovernmental stakeholder groups.

This study reveals that like conservation genetics (Taylor et al. 2017), conservation genomics is particularly susceptible to misunderstanding and potential of mis-application due to a lack of technical expertise. This is likely not exclusive of genetics or genomics, with similar findings attributed to biotelemetry science (e.g., Nguyen et al. 2017b). To many practitioners, the difference between genomics, traditional genetic approaches, and genetic modifications (i.e., transgenics) may be ambiguous which could potentially widen both the "conservation genomics gap" and the broader "conservation genetics gap". This result is congruent with results found by Taylor et al. (2017). In relation to salmonid management and in particular for *O. mykiss* the difference between genetics and genomics is no small issue as for example, rainbow trout and steelhead trout, different forms of the species, are ecologically very different and are managed as such. Genetics is more likely to result in "false negatives", for example, in interpreting the genetic basis for ecologically relevant traits (see Piccolo 2016). Different interpretations of genomics data and how these relate to meaningful conservation-outcomes prompts skepticism – relating to potential linguistic and epistemic uncertainty (see Regan et al. 2002). Major barriers that were also mentioned included the expensive start-up and large-scale data-management costs of genomics (see Chow-White & Green Jr. 2013; Shafer et al. 2015) and a lack of funds to pursue this research (see Taylor et al. 2017). Another perceived barrier is the return on investment (i.e., cumulative benefits) and the time taken to produce conservation genomics results. In the case of cost, it is well-understood that conservation practitioners are limited in funding and human-resource power and reducing both of these costs to practitioners would likely improve science-implementation. In the case of time, applications from a science like genomics may be delivered too slowly to address management concerns that are happening at a faster rate on-the-ground and in-the-water – indicating potential mismatches in demand and supply in conservation science (Nguyen et al. 2017b; Taylor et al. 2017; Nguyen et al. 2018). In contrast to biotelemetry science (Young et al. 2018a), there was not a clear desire or signal for genomics to play a greater role in rainbow trout management perhaps due to the uncertainty of how and where genomics can translate into conservation applications. In general, it was not clear to practitioners what the costs of genomics research are, and to most, what the precise benefits are, and what management applications or recommendations it would produce. If the limitations to the science itself, limitations to interpretations or understanding of the science, and explanations of *how* and *where* the science could inform conservation and management go unaddressed (i.e., not communicated clearly), this can potentially alienate and erode the trust of conservation practitioners who feel they have no potential way of validating the accuracy and precision of the scientific claims that are made. A perceived lack of transparency in science communication might suggest an important role for science translators and knowledge-brokers to decrease conservation practitioner credulity. Access to research data was also recognized as a potential barrier which may suggest strong competing interests between research for academic publication and management-relevancy which may widen the "conservation genomics gap".

In contrast to Taylor et al. (2017) very few respondents had collaborated with external conservation genomics researchers and when they had, their experiences were mixed. The collaborations generally started out positive with clear communication and robust science. However, the final management applications (tools), and recommendations were often provided in a form that was not useable for management. Practitioners in collaborations thus perceived genomics as too focused on fundamental science goals rather in generating mission-oriented findings relevant to end users. Clearly, when practitioners find the results of their collaborative genomics research in academic journal articles and only after it has been published, there are communication or incentive issues to producing and sharing genomics research.

As I have revealed here, there is positive evidence that genomics has considerable potential to help in directing priorities and informing decisions, policies, and practices in conservation and management. Like other fields of conservation science, it is important to recognize that genomics represents exploratory frontier-research (Shafer et al. 2015; Shafer et al. 2016) for which the benefits of research are most likely to be realized in the future, especially as threats to biodiversity increase or become increasingly complex to manage. It should also be recognized that genomics knowledge may be unique in that it may help inform the conservation and management of species by providing valuable information and knowledge on the processes and functions at the genetic-, and ecosystem-levels which underpin species-level biodiversity (McMahon et al. 2014; Grueber 2015). Ultimately, genomics should be recognized and utilized as one conservation knowledge-source among many (i.e., one tool in the conservation practitioner’s toolbox).

I conclude with a set of guidelines informed by this research which I feel will improve knowledge mobilization and exchange in the implementation of conservation genomics into conservation practice emphasized by clearer communication between genomics researchers and conservation practitioners. These are potential solutions to overcome barriers to the use of conservation genomics by practitioners focused on improving conservation genomics expertise among practitioners. Overcoming these barriers could lead to better integration of genomics into conservation in a meaningful way that truly benefit fish and wildlife populations and their stewards and users.

4.4.1 Guidelines for improving the implementation of conservation genomics research into conservation practice

1. Conservation science research institutions (and their funding agencies) in collaboration with conservation practitioners should instate a knowledge and sharing interface or platform (Roux et al. 2006) to facilitate increased communication, information flow, and personal agency-academic and cross-cultural relationships and collaborations (Pullin & Knight 2003; Gibbons et al. 2008; Shafer et al. 2015; Garner et al. 2016) between conservation research scientists and conservation practitioners around conservation projects, if one does not exist. Potential interfaces include a "national conservation genetics hub", sabbaticals for researchers and practitioners to exchange information and ideas, and networking events where conservation genomics scientists visit government and stakeholder offices and are introduced to staff (see Taylor et al. 2017).
   Conservation practitioners should engage with conservation research scientists to communicate clearly what sorts of data or information could be applicable in affecting a management lever (i.e., informing a conservation or management decision, policy, or practice). For example, focusing on genetic uniqueness and distinctness to inform discrete conservation units or for differentiating resident and anadromous fish, ecotypes, spatial separation at spawning. I recommend genomics scientists target practitioners: working with threatened species, interested in mapping genetically distinct populations, or interested in linking genomic variation to ecological traits.

2. Conservation genomics scientists, perhaps aided by 'science-advisors' (i.e., knowledge-brokers, science-translators) need to improve science-communication about conservation

genomics by helping enhance practitioner knowledge and familiarity of genomics concepts. Specifically, education campaigns should clearly focus on objectively communicating the limitations, possibilities, and advantages of conservation genomics in lay language. This could include for example, one day workshops, three-minute videos covering genomics concepts using Canadian case studies, or an online self-guided conservation genomics course (e.g., Taylor et al. 2017). In the case of workshops or other researcher-practitioner interfaces, it is necessary that many practitioners are identified and engaged, not just a few representatives of practitioner groups. For conservation genomics, communication should also focus on the advantages and contributions of genomics versus traditional genetics (i.e., that it can address a broader range of questions, Shafer et al. 2015) and the differences between genomics research and genetic modification (i.e., transgenics). Again, these results show that practitioners are keen to engage with researchers and improve their genomics knowledge. They are, in this case, generally willing to use new conservation genomics insights to improve management (see Piccolo 2016).

3. Conservation research scientists should promote to practitioners that genomic costs are decreasing and should provide realistic cost estimates when possible. Conservation genomics scientists should also promote their ability to attract external funding and when possible look to secure alternative (additional) funding to aid collaborators (i.e., practitioners) in collecting data (Shafer et al. 2016). In certain cases, it should be communicated transparently that conservation genomics research may not be a worthwhile use of resources (Flanagan et al. 2018). More on-the-ground examples

disseminated to conservation practitioners will build momentum for navigating the conservation implementation space and 'bridging the gap' (Shafer et al. 2015; Garner et al. 2016).

4. Conservation research scientists should promote that research on economically important fish or wildlife populations produces benefits that spill-over to other species and organisms of lesser economic-importance. Examples should be provided and communicated when and where possible (e.g., genomics research on rainbow trout provides the genetic basis and infrastructure to learn about other salmonids and freshwater fish).

5. Conservation research scientists should aspire to share their data openly (if a project is in the public interest) unless there are ethical concerns for not doing so (e.g., potential of resource exploitation, risk of potential harm). Academic journals and funding agencies in turn, should mandate conservation research articles to publish or deposit the associated data openly for further use in conservation science and practice. Collaborative agreements between researchers and practitioners should clearly describe how and when management applications and recommendations will be provided to practitioners.

6. Conservation research scientists should engage more practitioners rather than the targets (e.g., fish and wildlife practitioners). For example, genomics information could be relevant to and incorporated into management levels beyond what is traditionally targeted (e.g., to forestry, water use, land use planning).

7. Conservation science funding agencies and schemes need to provide creative incentives for academic researchers to engage fully in conservation. Performance indicators that measure rigour of conservation impact are needed to move away from “publish or perish” models in conservation science. Admittedly, this is an issue that is much broader than conservation genomics.

Chapter 5: Conceptualizing evidence exchange and mobilization in freshwater fisheries management decisions using fuzzy cognitive maps

5.1 Introduction

Despite a biodiversity and nature crisis in which we are losing species and ecosystems faster than at any other time in human history (Díaz et al. 2019; IPBES 2019b; WWF 2020), environmental managers are far more likely to draw on intuition, past experience or opinion to inform important decisions rather than evidence (Pullin et al. 2004; Cook et al. 2010; Kadykalo et al. 2021a). Evidence in this decision-making context can be broadly defined as: "relevant information used to inform a question or decision of interest" (drawing from Salafsky et al. 2019). A culture of 'evidence complacency' remains in many areas of policy and practice (Sutherland & Wordley 2017), in which despite the availability of plentiful and varied evidence (Kareiva & Marvier 2012; Salafsky et al. 2019), it is not sought or used to make environmental decisions. Accordingly, this divide between available environmental evidence and its implementation in practice and policy may perpetuate ineffective and detrimental management actions while squandering limited resources (Walsh et al. 2015; Jarvis et al. 2020; Ford et al. 2021).

Significant barriers hinder the effective use of evidence in decision-making (Rose et al. 2018a; Walsh et al. 2019) preventing the long-held goal of conservation and environmental management decisions to be more evidence-based and yield better outcomes (Pullin & Knight 2003; Sutherland et al. 2004; Salafsky et al. 2019). These barriers are the focus of a growing research field in environmental management, so-called 'knowledge exchange' aimed at exploring how evidence is exchanged and mobilized, and with whom it is exchanged (Fazey et al. 2012; Reed et al. 2014; Cvitanovic et al. 2016). This literature emphasizes that to enable effective knowledge exchange, evidence and evidence producers need to be, or be perceived as, salient (relevant and timely), credible and legitimate (Cash et al. 2003; Cook et al. 2013), free from bias and trustworthy (Turner et al. 2016; Cvitanovic et al. 2021). Evidence must therefore generally meet the conditions of being relevant, timely and useable for environmental managers to make informed decisions about pressing issues which require urgent action (Fazey et al. 2005; Laurance et al. 2012; Rose 2015; Stephenson et al. 2017; Kadykalo et al. 2020). Scientists are not free of value judgements (Pielke 2007; Adams & Sandbrook 2013), and the perceived characteristics of evidence and evidence producers as politicized, distorted, or biased may also foster low trust and skepticism in the evidence-base or that the information is communicated faithfully (Pielke 2002; Roux et al. 2006; Young et al. 2016b; Nguyen et al. 2018). The linear "information-deficit" model of knowledge transfer from evidence producers to decision maker assumes the availability of abundant evidence should enact evidence-informed decision-making (see reviews in Cvitanovic et al. 2015; Toomey et al. 2017). However, in addition to a decision-making context that is politically, socially, and value-laden, research suggests managers are highly limited by time, and in capacity-poor settings, experience information-overload (Roux et al. 2006; Lemieux et al. 2018; Girling & Gibbs 2019).

The management of freshwater fish in Canada, like most areas in North America is particularly complex, involving managing rapid environmental change and the increasing social considerations of fisheries management. Freshwater fish are among the most endangered organisms globally (Cooke et al. 2013; Reid et al. 2019) and in Canada, 38 of 204 (18.7%) identified freshwater-dependent fish species were assessed as at risk ('Threatened', 'Endangered', 'Extirpated', or 'Extinct') with 32 species progressing towards more critical stages (Desforges et al. 2021). The proportion of fish species classified as 'Extinct' in Canada is over four times higher (1.96% of 204 identified species) than that observed worldwide by WWF (0.44% of 18075 identified species) (WWF 2021). In BC, the most westerly province of Canada, freshwater fish are highly threatened by increased water temperatures (Meka & McCormick 2005; Parkinson et al. 2016; Twardek et al. 2018), declines in dissolved oxygen in lakes (Jane et al. 2021), drought and low water conditions (Whitney et al. 2016; Gronsdahl et al. 2019). Commercial, subsistence and recreational fisheries target many of the same fish species and populations, further stressing vulnerable fish populations. Preferred species in terms of total 2010 catch in BC are rainbow trout (*Oncorhynchus mykiss*) (58%), cutthroat trout (*Oncorhynchus clarkii*) (15%), sockeye salmon and kokanee (*Oncorhynchus nerka*) (15%) (Freshwater Fisheries Society of BC 2013). Besides commercial and recreational fishers, managers in North America are expected to consult other diverse Indigenous rightsholders and non-fishing stakeholders with high interest and expectations for involvement in management processes and decisions (Endter-Wada et al. 1998; Decker et al. 2012; Krausman & Cain 2013). Hence, fisheries management is faced with the daunting task of providing a rational basis for decisions in the face of conflicting objectives, such as improving angling opportunities or conserving wild populations while controlling costs (Smith et al. 1999; Riley et al. 2002; Varkey et al. 2016). In North American fish and wildlife management agencies (Organ et al. 2012; Ryder 2018; Powell 2020) and explicitly in BC (Government of British Columbia 2017) decisions are purportedly evidence-based, supported by the best available science, however recent research suggests that the "hallmarks" of science are missing from management (see Artelle et al. 2018a). In highly politically charged situations, the demand for evidence-based decisions may counter-intuitively politicize evidence (Sarewitz 2004; Pielke 2006).

In Canada, provincial fish and wildlife management agencies are, to some extent, identifying links between their core values/objectives and Indigenous-led governance and are slowly democratizing the process of conserving and managing fish and wildlife (Artelle et al. 2018b; Artelle et al. 2019; Hessami et al. 2021). While the concept of co-management is broad and has become a popular buzzword in environmental governance literature (Crona & Hubacek 2010; Sandström & Rova 2010), informal institutional arrangements which share or partition power and responsibility over fish and fisheries between natural resources branches of western governments and Indigenous governments are increasing in Canada (Armitage et al. 2010). Throughout the majority of BC, colonialization proceeded through direct land seizure in the absence of negotiated treaties, (although for some Indigenous nations formal treaty negotiations are underway). A system of geographically small reserves (slightly more than one-third of one percent of the land area in the province) was imposed by the Dominion of Canada with the province of BC between the 1850s and the 1920s for the many First Nations (Indigenous) communities (Harris 2008). Since the early 1990s, Indigenous title has been recognized and respected by the province of BC to some extent. In BC, Indigenous communities and governments manage Indigenous and non-Indigenous recreational and subsistence fisheries that take place on reserve lands and (in some cases) on traditional territories. Further, the British Columbia Assembly of First Nations (https://www.bcafn.ca/) and the First Nations Fisheries Council of British Columbia (https://www.fnfisheriescouncil.ca/) are striving towards reconciliation. That includes rights-based fishing opportunities and management on traditional territories including the negotiation and transfer of responsibility from crown lands back to First Nations.

Understanding the perceptions of (competing) evidence and evidence producers by potential evidence consumers, and how that information flows between organizations, is of considerable practical importance. This has not been a focus of substantial empirical research to date (Young et al. 2016b; Tengö et al. 2017) but is a necessary step to evaluate under which conditions fish and wildlife conservation and management could become more evidence-based. Here I explore the complex information flows between organizations which inform decisions about freshwater fish and fisheries in BC, Canada to identify barriers and leverage points – key factors/drivers that exert the highest levels of limitation or influence in terms of information in the system which may in turn influence decisions. I use fuzzy cognitive mapping, a participatory modelling methodology (Kosko 1986; Özesmi & Özesmi 2004), to reconstruct the premises behind the information flows affecting decisions four the perspectives of fisheries management actor groups. I aim to help understand the reasons for their decisions and the actions they take and the role of evidence in this process; to better understand the decision-making processes in this system through comparison and amalgamation into a holistic union map for the entire information flow network and decision-making system; and to predict future decisions or actions given different evidence inputs into the decision-making system, i.e., where to intervene in the system in order to produce the desired effects.

5.2 Methods

5.2.1 Fuzzy cognitive maps

A fuzzy cognitive map (FCM, *pl*. FCMs) is a graphical and mathematical representation of the relationships between elements of a system (or issue), as perceived and constructed by "experts", where an expert is an individual with knowledge or experience of the system under scrutiny (Kosko 1986). FCMs can therefore be considered external representations of mental models which are an individual's internal perceptions of the structure and function of a given system or problem domain (Jones et al. 2011; Gray et al. 2015). FCMs comprise variables (or nodes or concepts) and relationships (or edges) between those variables, including feedback relationships. In FCM graphical representations, variables and relationship edges are illustratively mapped as directed graphs (Axelrod 1976), in which variables are connected by arrows indicating the direction of the interaction between them. Each edge relationship in an FCM is weighted by assigning a vector composed of values to indicate the relative interaction strength or magnitude of the putative relationship between variables, making FCMs semi-quantitative in nature.

The "fuzzy" aspect of FCMs is that edge relationships are weighted according to fuzzy logic, in which the true value of relationships in FCMs are represented as a matter of degree on a spectrum of truth rather than certainty. In the context of FCM theory, edge relationship weights are usually bounded in a normalized range of [0, 1] or [−1, +1]. Because FCMs are derived from graph theory and are semiquantitative, the structure between variables can be represented in mathematical terms. In mathematical FCM representations, graphed FCMs are transformed and coded into adjacency matrices which takes each vector assigned to each edge relationship and transposes it into a matrix table. An adjacency matrix's proprieties may be investigated using well-developed graph-theoretic tools and techniques (i.e., mathematical algorithms to explore the complexity of the network diagrams). FCMs can then be compared, combined, and simulated to identify key concepts or relationships in the system or to explore how the system would react to different changes or scenarios such as the effects of different management or policy interventions (Kosko 1986; Özesmi & Özesmi 2004; Gray et al. 2015).

Comparison of multiple FCMs, representing multiple perspectives, may be used to identify areas of agreement and controversy (Giles et al. 2008). While a combined FCM may yield a better presentation of the system under scrutiny being potentially stronger than an individual FCM because the information is derived from multiple sources, making errors less likely (Taber 1991; Özesmi & Özesmi 2004). For any FCM, one can also compute its transitive closure which comprises all the connections between pairs of variable concepts, as well as all the implied connections between two concepts as a result of their being part of the same indirect pathway (Giles et al. 2008; Niesink et al. 2013).

FCMs are useful for environmental decision-making and management where public support is desired or even mandated by law, illuminating the presumptions and behaviour of actors with knowledge of the system (Özesmi & Özesmi 2004; Jones et al. 2011).

5.2.2 Fisheries management focus group workshops

Twelve participants from four fisheries management groups detailing their knowledge and perceptions on the "type, amount, rate, and reliability of evidence influencing freshwater fish and fisheries decisions in BC" created FCMs (one per group), through a day-long facilitated participatory mapping session for each group. Mapping was facilitated by 'the researcher', Kadykalo. If separate FCMs are constructed by different knowledge holders, then differences among FCM in the enumerated concepts (nodes) and causal relationships (edged) reflect differences in perceived system structure. This study including all data collection methods and procedures was approved by and conducted in accordance with the University of Ottawa Research Ethics Board (File Number: 02-18-08). All participants gave informed consent to participate in the study. Face-to-face focus group sessions took place in June 2019 in various cities in BC (Table 5.1) with members from:

1) The Freshwater Fisheries Society of BC (FFSBC; https://www.gofishbc.com) (n = 3), unique actors in BC with similar roles to government fisheries managers. FFSBC is a private non-profit organization that delivers the provincial fish stocking program aimed at diverting recreational angler pressure to hatchery raised fish in efforts to protect wild fish. Under an agreement signed between the province of BC and the FFSBC in 2015, 100% of the revenue generated from fishing licences goes into research, conservation, and education programs, improving angler access and the provincial stocking program.

2) Natural resource management branches of First Nations Indigenous governments (n = 2).

3) Headquarters (i.e., Branch) of the BC Ministry of Forests, Lands and Natural Resource Operations and Rural Development (FLNRORD; https://www2.gov.bc.ca/gov/ministries/forests-lands-natural-resource-operations-and-rural-development) (n = 3). FLNRORD is the main agency responsible for management of freshwater populations of fish is the BC. The provincial capital, Victoria, is home to ministry headquarters, which support, coordinate, and direct the resource management regions. FLNRORD headquarters has specialized Biologists, and Directors for each broad area of focus (e.g., fish and wildlife, fisheries, aquatic habitat) as well as unique actors such as regulations and policy analysts, and human dimensions specialists.

4) Regional offices of FLNRORD (n = 4). Fisheries management and conservation is divided by FLNRORD into nine resource management regions that cover all areas of the

province. Each region has multiple Biologists per region, classified by their area of focus (ecosystem, fish/fisheries, stock assessment, aquatic, habitat, etc.), Fish and Wildlife Section Heads (usually one per region) responsible for fisheries and wildlife program management for a specific region, and Directors of Resource Management (usually one per region) which oversee programs related to fish and wildlife, but also programs related to habitat management, forest policy and practices, land use planning etc.

An additional 57 individuals were contacted but did not participate because they a) did not respond to my request or b) declined to participate (affiliations of these individuals are provided in Appendix K). Thus, my response rate was 17% but previous FCM exercises which used focus groups suggest that FCM facilitation works best with few (e.g., 3-5) participants which allows for greater participation and reduces the required time to completion (Cole & Persichitte 2000; Giles et al. 2008) and this was therefore the research target. The time it took for each focus group to complete their FCM varied from 5 hours and 52 minutes to 7 hours and 15 minutes.

Table 5.1 Affiliations of the 12 participants, grouped as members from the Freshwater Fisheries Society of BC, natural resource management branches of Indigenous governments, and provincial natural resources ministry (branch and regions); and the location, date, and length of the focus group.

Organization	Participants	n	Location	Date	Focus Group Length
Freshwater Fisheries Society of BC (FFSBC)	Officers and Executives	3	Victoria, BC	June 21, 2019	6hr 8min
Indigenous Governments (FN)	Fisheries Managers	2	Prince George, BC	June 25, 2019	6hr 20min
Provincial Natural Resources Ministry (FLNRORD) Branch	Biologists Policy Analysts	2 1	Victoria, BC	June 20, 2019	5hr 52min
Provincial Natural Resources Ministry (FLNRORD) Regions	Biologists Directors	3 1	Kamloops, BC	June 27, 2019	7hr 15min

5.2.3 Fuzzy cognitive mapping procedures and facilitation

For this research I exercise two modifications or departures from conventionally constructed FCMs. Most FCMs aim to capture causal (i.e., cause and effect) relationships but this exploratory study's goal was to examine views on the type, amount, rate, and reliability of evidence influencing freshwater fish and fisheries decisions in BC, and therefore examined descriptive and predictive conceptual relationships (see Özesmi & Özesmi 2004 for an overview of the functions and purpose of FCMs; Papageorgiou & Salmeron 2013). Secondly, most FCMs classify edge relationships by whether they have a negative or positive relationship (or effect) on variables but because these FCMs are non-causal, these edge relationships were not positively (+) or negatively (-) 'signed'.

A multi-step fuzzy cognitive mapping approach was conducted. At the start of each focus group workshop, FCMs were introduced and explained using unrelated example model maps (as per Taber 1991), one of a carbon tax on CO_2 emissions and another on the eutrophication of Lake Erie. Once the participants indicated understanding of the mapping process, the researcher explained how FCMs would be constructed.

All maps were drawn by the researcher in the Mental Modeler software (see http://www.mentalmodeler.org; Gray et al. 2013) via a projector screen in front of each participant group as they were described by participants. Participants discussed each component, relationships, strength in detail and had the ability to eliminate any or all map components during the iterative mapping process. All participants were encouraged to voice their ideas which were not edited or censored. See Figure 5.1 for an example map. Face-to-face focus groups were recorded using a digital audio recorder. Recording was optional for each group so long as each participant agreed.

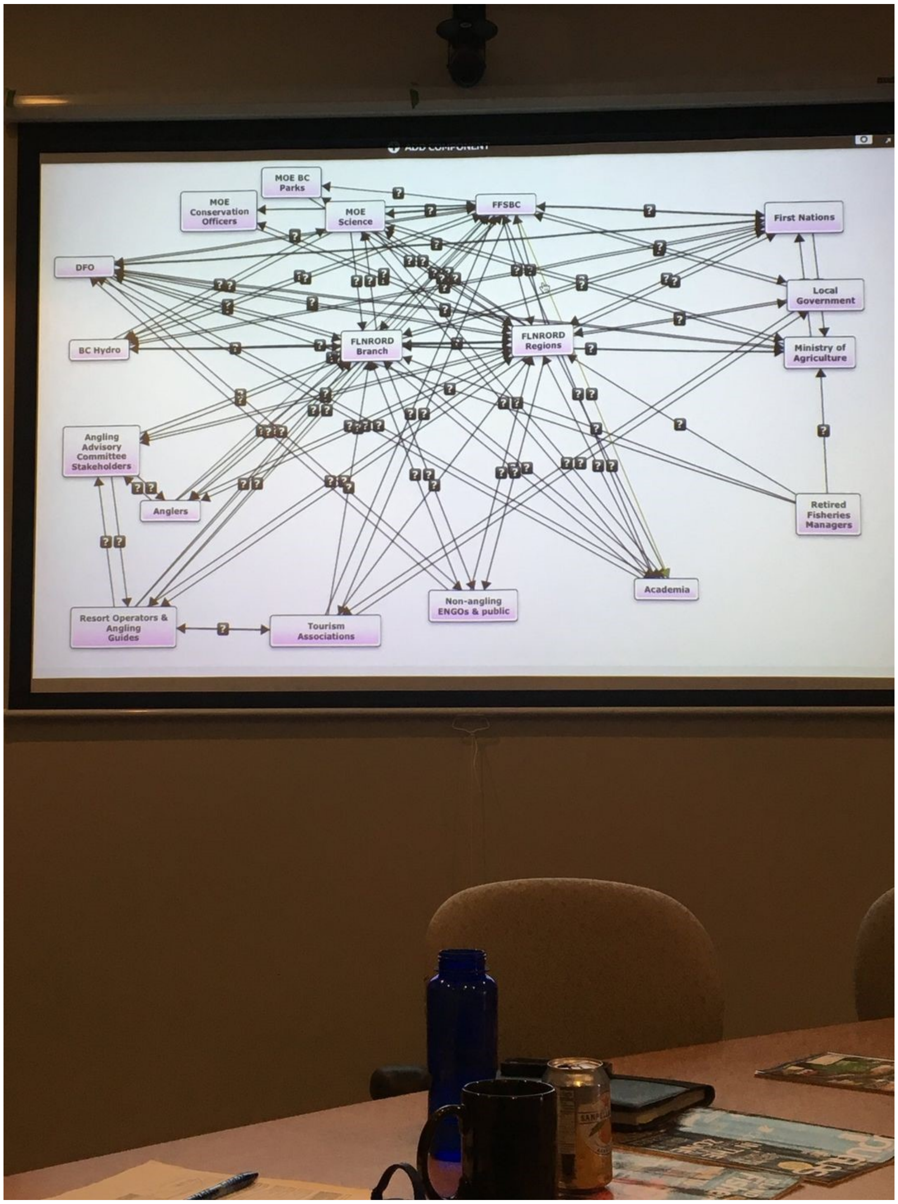

Figure 5.1 Example of Mental Modeler projected in the construction of an FCM during a focus group workshop with FFSBC, Victoria BC (June 21, 2019).

5.2.3.1 Nodes (evidence producers and consumers)

In the mapping process participants were first asked to identify the set of evidence producers and consumers (organizations or groups of individuals) which generate, mobilize, or use information regarding freshwater fisheries decisions in BC. These organizations or groups of individuals formed the nodes (or concepts) in FCMs. Participants were asked to limit maps to 20 nodes at which point maps become too counterproductive for gaining insights (Özesmi & Özesmi 2004). The participants were provided a list of eleven node components based on the authors collective and preliminary view of the system (as per Özesmi & Özesmi 2004) and previous interview work (Kadykalo et al. 2020; Andrachuk et al. 2021; Kadykalo et al. 2021b) to help start them in constructing their FCMs and to maintain the activity's relevance to the research objective: academia, BC Hydro, consultants, The Federal Department of Fisheries and Oceans Canada (DFO), FFSBC, FLNRORD, First Nations, The Habitat Conservation Trust Foundation (HCTF), The BC Ministry of Environment (MOE) retired fisheries managers, and stakeholder groups (for more details on these groups see Table 5.4). Participants had the ability to eliminate any of these nodes and were then asked to propose any additional nodes, and this continued until participants exhausted their (collective) set of nodes. Participants were also asked to group nodes that represent, in their collective view, the same node to simplify maps which resulted in the final set of nodes.

5.2.3.2 Edges (information flow)

In the constructed FCMs, two nodes are joined by an edge if there is specified evidence flow (information exchange and/or mobilization). Participants were asked to discuss and indicate how the nodes should be arranged and the edge directionality of the relationships, including whether these relationships are uni-directional (information mobilization) or bi-directional (information exchange). Participants were then asked to assign weights to each connection (edge). In constructed FCMs, pure evidence producers are thus classified as nodes which only have outdegree (out-arrows directed away from the node) while pure evidence consumers are classified as nodes which only have indegree (in-arrows directed into the node). The subset of nodes between pure evidence producers and consumers (i.e., those hybrid nodes which have edges directed into and away from them) are presumably organizations or groups involved in information exchange.

Edges were then classified by participants by the *type* of information: research/explicit (information easily codified, stored, and retrieved from data repositories, bibliographic databases, and published literature) or experiential/tacit (gained through experience) (Roux et al. 2006; Hulme 2014) or both. Participants were also asked to provide a description of information source(s). The relative strength of these edge connections were also then weighted along three major dimensions of the information being communicated (Table 5.2):

1. *Amount* of information flowing
2. *Rate* of information flowing
3. *Reliability* of the information flowing (i.e., signal to noise ratio) which was comprised of a composite index:
    a. *credibility and reliability* (i.e., trust, faith, and confidence in the information)
    b. *distortion* (i.e., potential of misuse or bias of the information)
    c. *hackability (generativity)* (i.e., the degree to which the information lends itself to tinkering, modification, exploitation, flexion)
    d. *availability*
    e. political-ness

Participants were asked to assign qualitative weightings to one of five likert-style scale categories which were then converted into a quantitative ordinal weight in the interval [0,1] (Table 5.2). Disputes among participants about the presence or level of importance strength of relationships were resolved based on group consensus but disagreements were noted and recorded.

The constructed FCMs thus represent networks which depict how information flows from organization/group to organization/group. As such, the edges are communication channels, which communicate a certain type of information (defined by type), communicate a certain volume of information at a certain rate (amount and rate), and there are a number of factors (reliability indices) that can prevent the information from being communicated faithfully (i.e., they are noisy).

Focus group workshops ended when the participants were satisfied the FCM accurately reflected their collective view of the type, amount, rate, and reliability of evidence influencing freshwater fish and fisheries decisions in BC. The resulting FCM was then converted to an adjacency matrix.

Table 5.2 Scales for converting qualitative weightings into quantitative weightings for fuzzy cognitive maps.

Qualitative Weighting							Quantitative Weighting
		Reliability of Evidence Flowing					
Amount of Evidence Flowing	**Rate of Evidence Flow**	**Credibility and Reliability**	**Distortion**	**Hackability (Generativity)**	**Availability**	**Political-ness**	
Not at All	No Flow	Very Unreliable	Very Distorted	Very Hackable/Flexible	Unavailable	Very Political	0
Small Amount	Slow Flow	Unreliable	Distorted	Hackable/Flexible	Little Availability	Political	0.25
Moderate Amount	Moderate Flow	Neutral Reliability	Neither Distorted nor Clear	Neither Hackable/Flexible nor Secure/Rigid	Moderate Availability	Neither Political nor Apolitical	0.5
Large Amount	Fast Flow	Reliable	Clear	Secure/Rigid	Available	Apolitical	0.75
Very Large Amount	Very Fast Flow	Very Reliable	Very Clear	Very Secure/Rigid	Highly Available	Very Apolitical	1

5.2.4 Analysis

The four adjacency matrices were aggregated into one file and cleaned in which standardized names were provided to nodes that were discussed by participants as the same organization/group across all four focus groups. This results in higher consistency between nodes that represent the same concept across all four maps. See Appendix L for specific changes.

I examined the FCMs by the most mentioned variables, centrality total degree of a variable is the summation of its indegree (in-arrows) and outdegree (out-arrows)), and variable type (evidence producer [transmitter], evidence consumer [receiver], evidence producer/consumer [ordinary]. ANOVAs were performed to explore the variation among quantitative edge weightings for each FCM. I also compared maps to characterize uncertainty (differences in perceived system structure) and to illuminate areas of agreement/consensus.

There was a high degree of correlation between quantitative weightings (mean $r = 0.5$; n = 40). Therefore, the 'amount of evidence flowing' (quantity) variable along with the 5 reliability index variables were combined via Principal Component Analysis (taking the first axis of greatest variance) and normalized to the range of 0 to 1 so as to produce a composite variable that I called RI (reliable information), which represented the ability for information to flow from organization/group to organization/group. See Appendix M to see how the 6 variables were computed in PCA and how they change with the composite variable. Thus, RI would be low when either there is not much information exchanged or the channels of communication reduce the quality of the information that is transmitted. RI would be high when a large amount of information can pass faithfully between organizations/groups. The 'rate of evidence flowing' variable is used to represent five timescales at which the information can flow: Not at All, Slow Flow, Moderate Flow, Fast Flow, and Very Fast Flow.

Communicability (Estrada & Hatano 2008; Estrada & Hatano 2009) is a method for assessing the steady-state transitive influence in complex networks (including ones that feedback loops). Transitive influence of a binary relation (R) on a set (X) is defined as the smallest relation on X that contains R and is transitive. In mathematics, transitivity refers to a relation in which the property of the relation holds between a first element and a second element and a third, it also holds between the first and third elements. Thus, we distinguish *transitive influence* (which is a mathematical concept) from *political influence* defined as "the achievement of (a part of) an actor's goal in political decision-making, which is either caused by one's own intervention or by the decision-makers' anticipation" (Arts & Verschuren 1999). I adapted this technique into a Temporal Communicability that can assess transitive influence at connected, but stratified time scales (i.e., fast interactions can influence slower interactions, but not vice versa). Temporal communicability results in a new dense directed adjacency matrix where we know the transitive influence of every node on every other node. In addition to being able to identify the greatest influencers in a network (in terms of information flowing in the system), this algorithm can assess how soon after an influencer intervenes that the effects will be observable throughout the network. Likewise, given a specific target, we can assess how much and at what time scale each other node in the network will influence it. In the terms of communicability, a node's "sourceness" is how much (transitive) influence it has in the network and its "sinkness" is how (transitively) influenced it is (in terms of information flowing in the system). To this, Temporal Communicability expands sourceness and sinkness to have a value at each of the five timescales.

For the first analysis, I produced communicability source/sink plots for all nodes (organizations/groups) in the network to understand the relative amount of information each node would contribute to or consume from the system. Secondly, I explored the transitive influence of the whole network on those organizations that possess (statutory) decision-making powers. As such, I chose the BC natural resources ministry (FLNRORD) and First Nations fisheries managers as the targets for this analysis. I performed this analysis on each of the FCMs that was collected.

All four FCMs were also then combined into one cumulative union map which includes any node (organization/group) and relationship thereof constructed in any of the FCMs. Thus, the final "Union Graph" contained one node for each uniquely named node in any of the four FCMs. Two relationships were judged to be the same if their source and target nodes were identical, but not if their variables were equal. As such, to produce the relationships in the Union Graph, the relationships from the base FCMs were grouped by identity and their variables were averaged with a mean. Communicability and transitive influence were then also calculated on the Union Graph. Where each of the base FCMs represent a specific perspective on how the system works, the Union Graph averages those perspectives to form a more unified view (other analyses may also be helpful, such as variance analyses to assess discordant views). This helps to identify barriers and leverage points – key factors that exert the highest levels of limitation or influence on information flowing in this network system which may in turn affect decision-making (to the extent decision-makers consider evidentiary information). It also provides information on the conditions under which new information could influence a management or policy decision. Or the conditions under which a management or a policy decision could be reliably recommended based on the shortest/most efficient distance within the network, helping to determine where to intervene in the system in order to produce the desired effects.

5.3 Results

The FCMs created by the four groups are shown in Figures 5.2-5. The participants from four fisheries management groups produced similar FCMs in terms of structure but FCMs varied in terms of functional attributes. FLNRORD Branch assessed most information flows as both research/explicit and experiential/tacit composed of larger and faster flowing information. FFSBC and First Nations perceived most flows as smaller and slower and differentiated the type of information more often. FCMs assessed flows from *Local Governments*, *Anglers*, *Non-Angling Public & Politicians*, and *Stakeholder Resource-User Groups & Angling Advisory Committees* as less reliable. FLNRORD Branch and FFSBC further assessed *Retired Fisheries Managers*; *Resort Operators & Angling Guides*; *The BC Ministry of Agriculture, Food and Fisheries*; *Community, Local Conservation ENGOs*; and *First Nations Fisheries Managers* as less reliable evidence producers. The map produced by FLNRORD regions was the most complex (Table 5.3).

Only a few variables (nodes) were perceived as pure evidence producers: *Community, Local, Conservation ENGOs*; *Non-Angling Public & Politicians*; *Retired Fisheries Managers* (by FFSBC); *First Nations Fishers* and *Keyoh Holders* (by Indigenous Governments); and *The BC Ministry of Tourism, Arts, Culture and Sport* (by FLNRORD Branch). Only three variables (nodes) were perceived as pure evidence consumers: *Canadian Council of Fisheries and Aquaculture Ministers* (mentioned only by FLNRORD Branch), *The Habitat Conservation Trust Foundation* (by FLNRORD regions) and *Media* (mentioned only by FLNRORD regions).

Several organizations/groups focus groups were discussed at length as participants struggled with defining their roles in this network: participant groups differed in whether *HCTF* was an evidence producer or merely a funding agency, struggling with partitioning influence (in terms of funding) versus information flow about fisheries; participant groups had difficulty in deciding whether to group or keep *BC Hydro* and the *Fish and Wildlife Compensation Program* separate; participant groups differed on the role of private consultants, unsure if they should be a separate node or considered grouped with the first-order evidence producer node which they were contracted to produce evidence for (e.g., FLNRORD).

Table 5.3 Values for the number of variables (nodes), number of connections (edges), and mean centrality from n = 4 fuzzy cognitive maps produced by four fisheries management groups.

Fuzzy Cognitive Map	**No. of variables (nodes), n**	**No. of transmitter variables (Evidence producer)**	**No. of receiver variables (Evidence consumer)**	**No. of ordinary variables (Evidence producer/consumer)**	**No. of connections (edges), *C***	**No. of uni-directional connections (edges), *C***	**No. of bi-directional connections (edges), *C***	**Centrality Mean (± S.D.)**
Freshwater Fisheries Society of BC (FFSBC)	18	3	0	15	78	8	70	3.3 (± 1.0)
Indigenous Governments (FN)	19	2	0	17	59	7	52	3.5 (± 0.7)
Provincial Natural Resources Ministry (FLNRORD) Branch	22	1	1	20	94	8	86	3.9 (± 0.9)
Provincial Natural Resources Ministry (FLNRORD) Regions	25	0	2	23	107	13	94	3.8 (± 0.6)
Mean (± S.D.)	21 (± 3.0)	1.5 (± 1.3)	0.75 (± 1.0)	19 (± 3.5)	85 (± 21.0)	9 (± 2.7)	76 (± 18.6)	

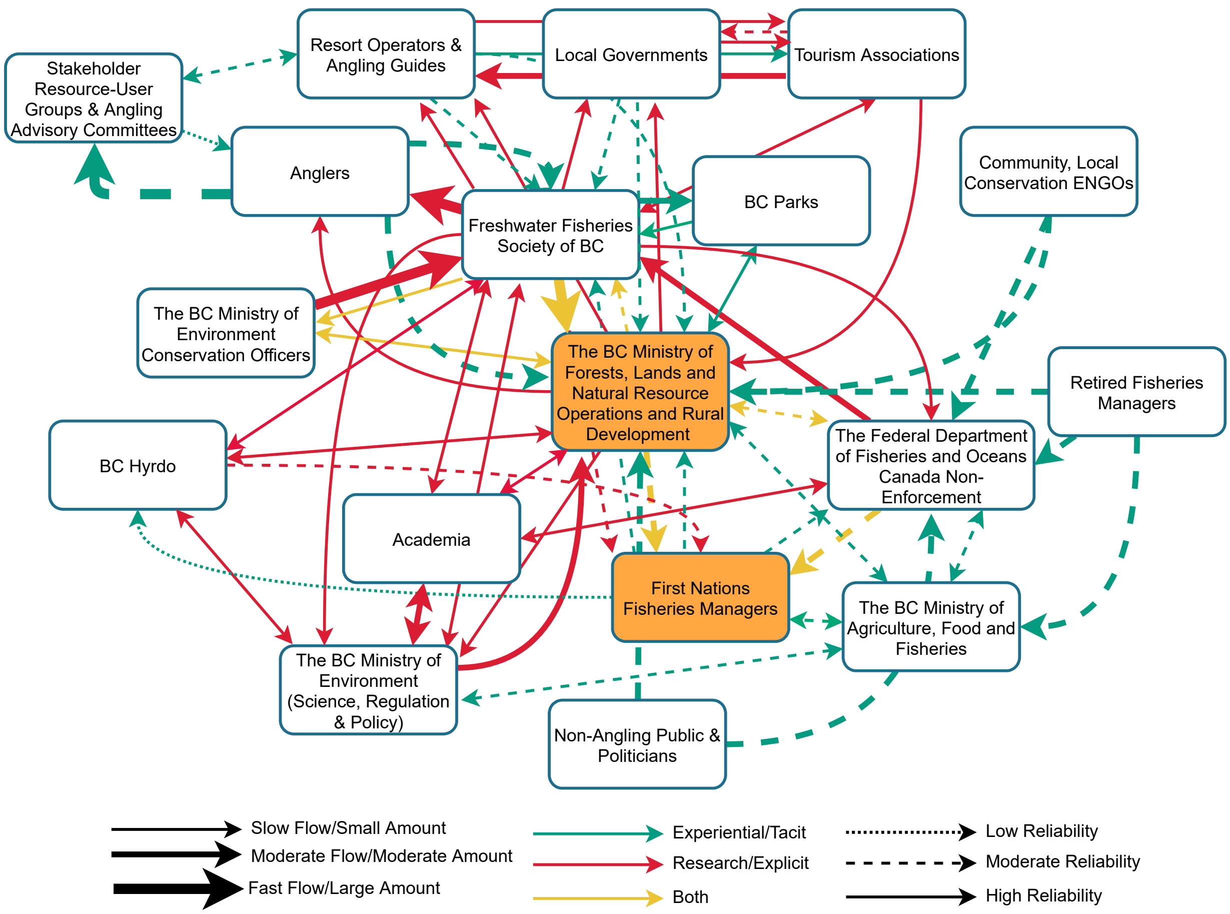

Figure 5.2 Simplified, recoded fuzzy cognitive map of the type, amount, rate, and reliability of evidence influencing freshwater fish and fisheries decisions in BC created by the **Freshwater Fisheries Society of BC (FFSBC)**. Thickness of the links denotes the amount and rate of evidence flow. Colour of the links denotes the type of evidence. Patterns of the links denotes the credibility and reliability of the evidence flowing. Nodes in orange are target variables that possess (statutory) decision-making powers, the BC natural resources ministry (FLNRORD) and First Nations fisheries managers.

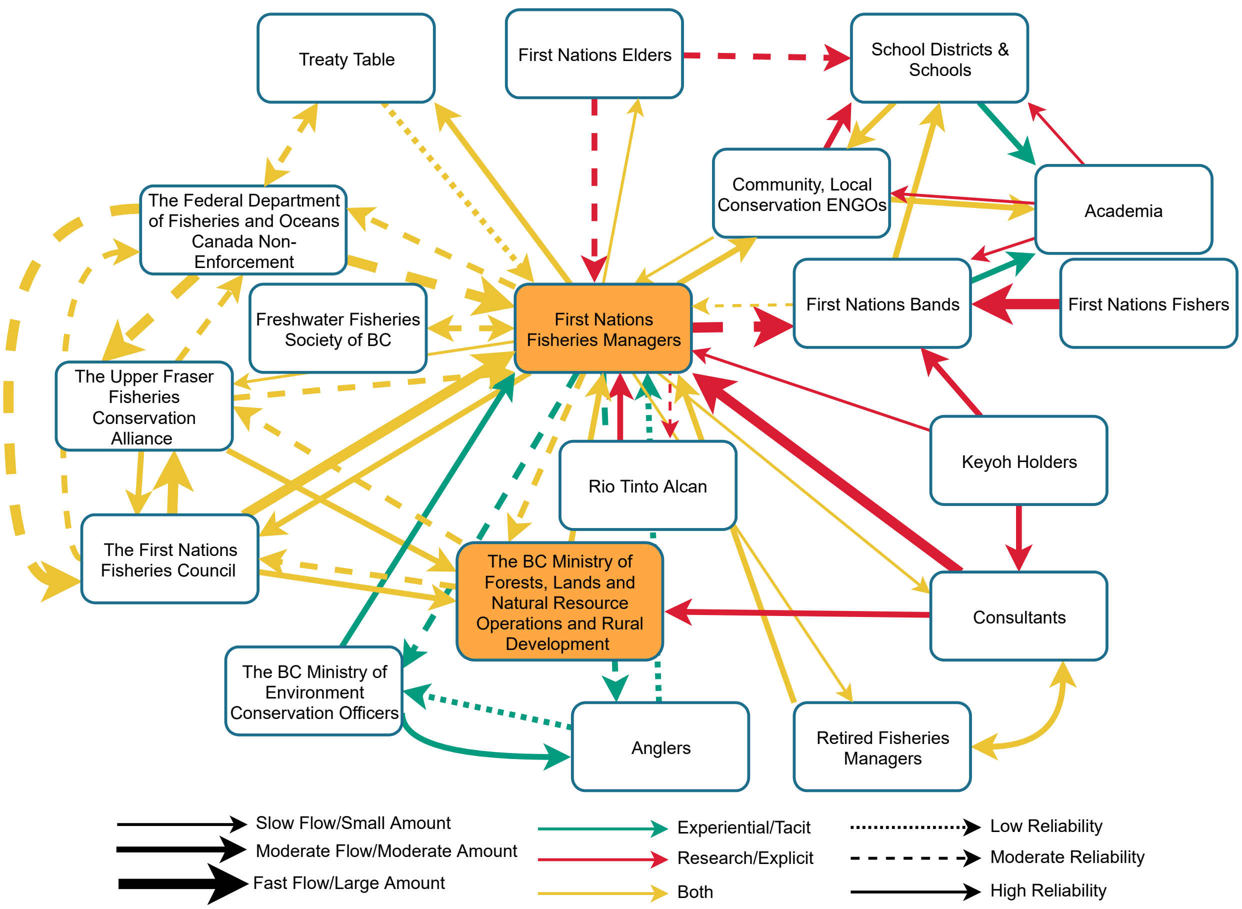

Figure 5.3 Simplified, recoded fuzzy cognitive map of the type, amount, rate, and reliability of evidence influencing freshwater fish and fisheries decisions in BC created by the **First Nations Indigenous Governments (FN)**. Thickness of the links denotes the amount and rate of evidence flow. Colour of the links denotes the type of evidence. Patterns of the links denotes the credibility and reliability of the evidence flowing. Nodes in orange are target variables that possess (statutory) decision-making powers, the BC natural resources ministry (FLNRORD) and First Nations fisheries managers.

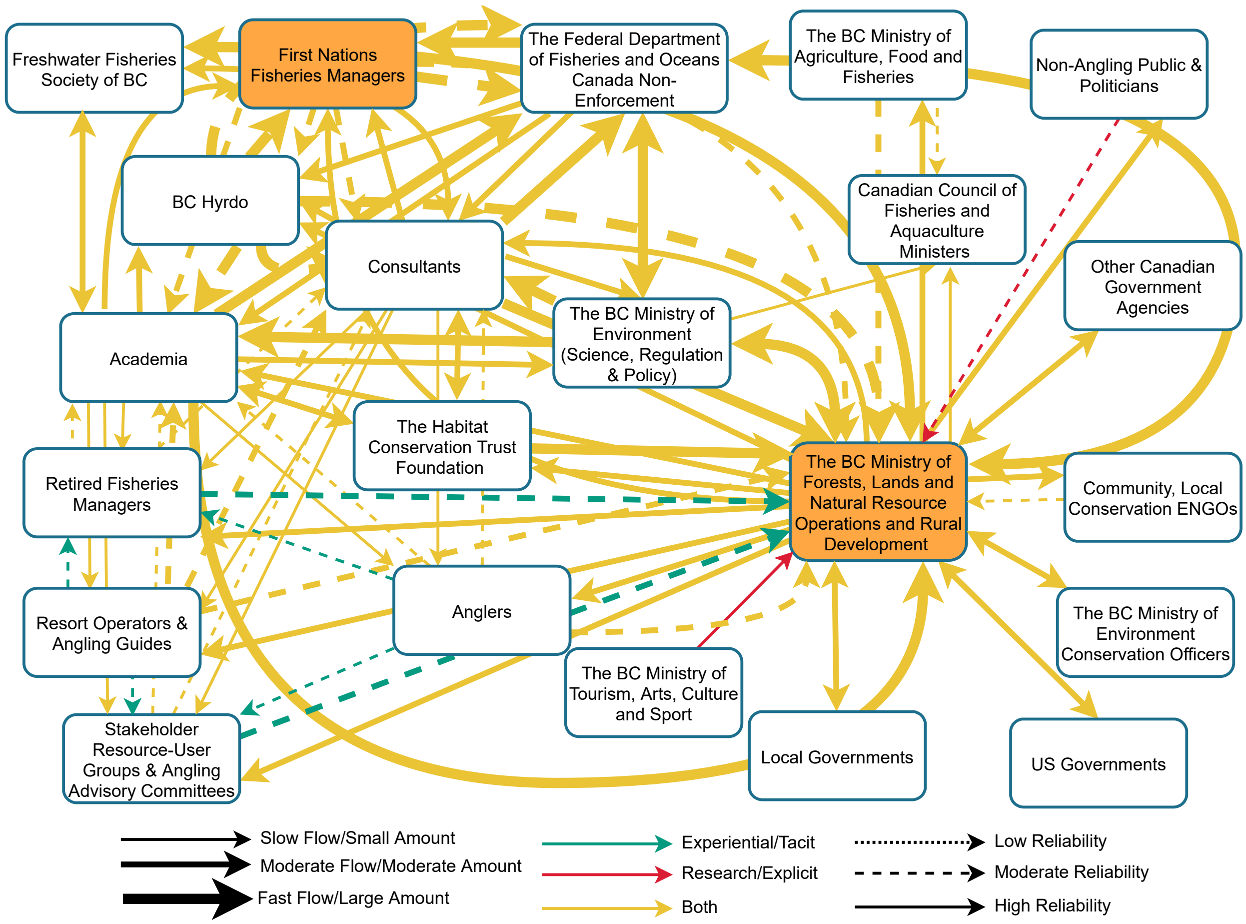

Figure 5.4 Simplified, recoded fuzzy cognitive map of the type, amount, rate, and reliability of evidence influencing freshwater fish and fisheries decisions in BC created by the **BC Ministry of Forests, Lands and Natural Resource Operations and Rural Development (FLNRORD) Branch**. Thickness of the links denotes the amount and rate of evidence flow. Colour of the links denotes the type of evidence. Patterns of the links denotes the credibility and reliability of the evidence flowing. Nodes in orange are target variables that possess (statutory) decision-making powers, the BC natural resources ministry (FLNRORD) and First Nations fisheries managers.

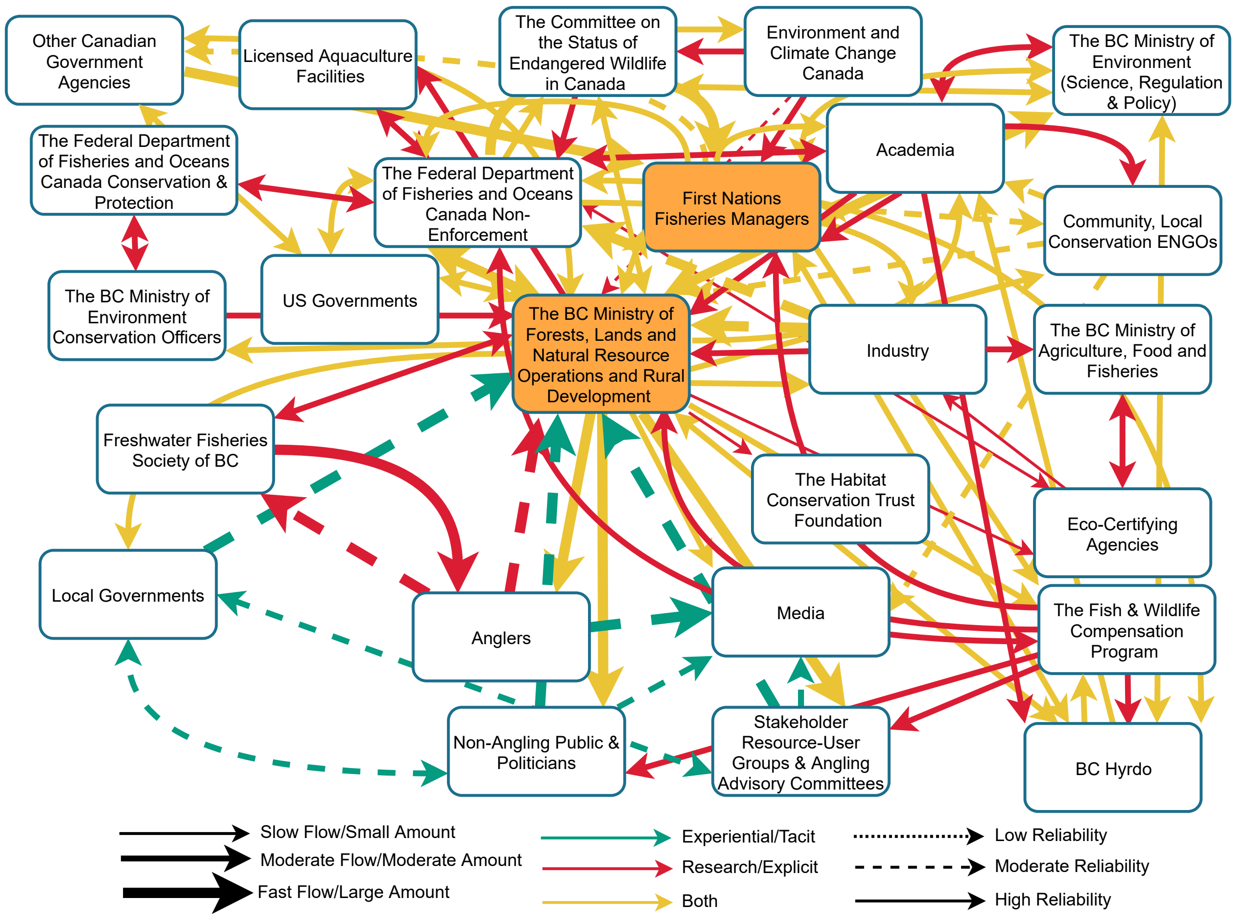

Figure 5.5 Simplified, recoded fuzzy cognitive map of the type, amount, rate, and reliability of evidence influencing freshwater fish and fisheries decisions in BC created by the **BC Ministry of Forests, Lands and Natural Resource Operations and Rural Development (FLNRORD) regional offices**. Thickness of the links denotes the amount and rate of evidence flow. Colour of the links denotes the type of evidence. Patterns of the links denotes the credibility and reliability of the evidence flowing. Nodes in orange are targe variables that possess (statutory) decision-making powers, the BC natural resources ministry (FLNRORD) and First Nations fisheries managers.

The most frequently mentioned and central variables (nodes) across all FCMs were *FLNRORD*, *First Nations Fisheries Managers*, *DFO*, *Academia*, *FFSBC*, *BC Hydro*, *MOE*, and *Consultants* (Table 5.4 and 5.5) which definitively had the most information flowing into or out of them regarding freshwater fish and fisheries decisions in BC.

Table 5.4 The most mentioned variables (nodes) and their description across n = 4 fuzzy cognitive maps produced by four fisheries management groups.

No. Rank	Variables (Nodes)	Description	Count of Mentions
1	The BC Ministry of Forests, Lands and Natural Resource Operations and Rural Development (FLNRORD)	Government department responsible for the stewardship of provincial Crown land and ensures the sustainable management of forest, wildlife, water, and other land-based resources; the primary agency responsible for management of freshwater populations of fish is the BC. Fisheries management and conservation is divided by FLNRORD into nine resource management regions (Region 1: Vancouver Island, Region 2: Lower Mainland, Region 3: Thompson-Nicola, Region 4: Kootenay, Region 5: Cariboo, Region 6: Skeena, Region 7A: Omineca, Region 7B: Peace, Region 8: Okanagan) that cover all areas of the province. FLNRORD fish and fisheries management decisions (e.g., fishing regulations, stocking hatchery fish) in BC are made by dedicated provincial natural resources ministry staff (statutory decision-makers [SDMs]; notably, Deputy Ministers, Directors, and Section Heads) possessing statutory (compliance and permitting) decision-making authorities under legislation.	116
2	First Nations Fisheries Managers	Managers from natural resource management branches of First Nation Bands, Tribal Councils, and other First Nations governments that oversee and make decisions on the conservation and sustainable use of a fishery. This includes but is not limited to monitoring fish and habitat, balancing the needs of the community with those of the environment, and coordinate with other managers in affiliated fisheries.	66
3	The Federal Department of Fisheries and Oceans Canada (DFO) (Excluding Enforcement/Conservation & Protection)	Federal government department responsible for safeguarding Canada's waters, the administration and enforcement of the *Fisheries Act* among others and developing and implementing policies and programs in support of Canada's economic, ecological, and scientific interests in oceans and inland waters. DFO is responsible for regulating aquaculture. Canada's fisheries are a "common property resource", belonging to all the people of Canada. Under the *Fisheries Act*, it is the Minister's duty to manage, conserve and develop the fishery on behalf of Canadians in the public interest (s. 43). However, in practice, jurisdictional authority is concurrently shared between federal and provincial agencies with provincial agencies largely assuming	55

No. Rank	Variables (Nodes)	Description	Count of Mentions
		responsibility for conservation and management of inland fisheries (lakes and rivers). DFO has exclusive jurisdiction over tidal fisheries management in Canada including anadromous fish, which migrate from marine to freshwaters to spawn.	
4	Academia	Academic researchers employed by universities or colleges that are either contracted by, or work in collaborative partnership with Indigenous, federal, and provincial governments as well as FFSBC to carry out research on fish, fish habitat, or fisheries, or to provide advice. They may also conduct research on these organizations and communities.	48
5	Freshwater Fisheries Society of BC (FFSBC)	A private non-profit organization that delivers the provincial fish stocking program aimed at diverting recreational angler pressure to hatchery raised fish in efforts to protect wild fish. FFSBC own and operate six major fish hatcheries. Under an agreement signed between the province of BC and the FFSBC in 2015, 100% of the revenue generated from fishing licences goes into research, conservation, and education programs, improving angler access and the provincial stocking program.	36
6	BC Hydro	A province-owned electric utility monitors impacts associated with hydro dams, primarily in the Kootenay, Columbia, and Peace rivers, to inform wildlife mitigation programs including habitat protection for spawning fish, nesting and migratory birds, as well as fish salvage.	30
7	The BC Ministry of Environment (MOE) Science, Regulation & Policy	Government department that is responsible for the effective protection, management and conservation of BC's water, land, air and living resources. The conservation science section of MOE provides additional scientific and resource support to FLNRORD from specialized research biologists, also classified by their area of focus (species at risk, instream flows etc.).	29
8	Consultants	Private environmental consultants often contracted throughout the province by Indigenous, federal, and provincial governments as well as FFSBC to carry out collaborative research on fish, fish habitat, or fisheries, or to provide advice.	28
9	Anglers	Recreational anglers who fish by means of a fishhook, fishing line, which is usually manipulated by a fishing rod.	23
10	Stakeholder Resource-User Groups & Angling Advisory Committees	End-user special-interest groups that advocate for fish conservation, long-term sustainability of fisheries, and quality of fishing opportunities (often advocating for particular angling gear, bait, or fish species). This	18

No. Rank	Variables (Nodes)	Description	Count of Mentions
		includes the Regional Angling Advisory Committees (which meet at least every two years with FLNRORD in a formalized stakeholder engagement process to solicit stakeholder input from each region in developing angling regulation changes) and the Provincial Angling Advisory Team (which meet twice a year to advise the FLNRORD and FFSBC in terms of policy objectives and funding of projects that benefit recreational fisheries). Such formal processes are chaired by the province and feature representatives from BC conservation officers, FFSBC, The BC Wildlife Federation, and such end-user special-interest groups BC Fishing Resorts and Outfitters Association, The British Columbia Federation of Drift Fishers, The British Columbia Federation of Fly Fishers, Guide Outfitters Association of British Columbia, North Coast Steelhead Alliance, and Steelhead Society of British Columbia.	
11	Community, Local, Conservation ENGOs	Local environmental non-governmental organizations (ENGO) such as the BC Wildlife Federation and BC Conservation Foundation that have broad goals aimed at ensuring the long-term sustainability of BC's fish, other wildlife, and outdoor recreational resources.	17
12	The BC Ministry of Agriculture, Food and Fisheries	Government department responsible for the production, marketing, processing, and merchandising of agriculture and aquaculture products, food security, and supporting enhancement of wild fish populations. This includes responsibility for licensing and tenures for aquaculture sites.	16
13	Resort Operators & Angling Guides	Fishing guides, resorts, lodges, and camps; helicopter fishing; boat charters & cruises in British Columbia	16
14	Retired Fisheries Managers	Retired provincial government employees which often remain active within the realm of fish and fisheries issues, often as part of ENGOs, or as fishing guides, or informal government advisors or lobbyists.	15
15	Local Governments	Municipalities and regional districts that provide British Columbians with essential local and regional services such as clean water, sewer systems, parks and recreation, and fire protection.	14
16	The BC Ministry of Environment (MOE) Conservation Officers	Public safety providers focused on natural resource law enforcement and human wildlife conflicts prevention and response.	14
17	The Fish & Wildlife Compensation Program (FWCP)	A partnership between BC Hydro, the Province of B.C., Fisheries and Oceans Canada, First Nations, and public stakeholders to conserve and enhance fish and wildlife in watersheds impacted by BC Hydro dams. The FWCP operates in three regions of the province of BC with annual funding provided by BC Hydro. In	10

No. Rank	Variables (Nodes)	Description	Count of Mentions
		the Columbia and Peace Regions, the FWCP is a mechanism to meet BC Hydro's water licence conditions. In the Coastal Region BC Hydro's contribution is voluntary.	
18	Non-Angling Public & Politicians	People who do not identify as anglers or fishermen and people who are professionally involved in politics, especially as a holder of or a candidate for an elected office.	10
19	The Committee on the Status of Endangered Wildlife in Canada (COSEWIC)	An independent advisory body of wildlife experts and scientists to the Minister of Environment and Climate Change Canada that meets twice a year to assess the extinction risk of select Canadian wildlife species, providing advice and recommendations on which species should be listed under the federal *Species at Risk Act*.	8
20	The First Nations Fisheries Council (FNFC)	An organization formally linked to the First Nations Leadership – Union of British Columbia Indian Chiefs, the First Nations Summit, and the Assembly of First Nations which works with and on behalf of BC First Nations to protect and reconcile First Nations rights and title as they relate to fisheries and the health and protection of aquatic resources.	8
21	Other Canadian Government Agencies	Federal, provincial, and territorial government departments, agencies, and crown corporations not listed as nodes. Often adjacent to British Columbia. E.g., Alberta Ministry of Environment and Parks, Yukon Department of Environment	8
22	The Upper Fraser Fisheries Conservation Alliance (UFFCA)	A First Nations Natural Resource Management Agency covering the entire Upper Fraser River watershed, committed to developing technical capacity in management, science, and Traditional Ecological Knowledge. It provides advice and support services to member communities on a range of issues including conservation, harvest planning, fisheries management, environmental assessments, and field science. UFFCA members include Aboriginal Governments and Tribal Councils within the UFFCA territories.	8
23	US Governments	Federal or state-level natural resource departments and agencies within the United States often adjacent to British Columbia and responsible for managing transboundary waters and parks. E.g., US Fish and Wildlife Service, Washington Department of Fish and Wildlife, Idaho Fish and Game	8
24	First Nations Bands	Certain First Nations communities in which Bands function as municipalities. They are managed by elected band councils according to the laws of the *Indian Act*.	7

No. Rank	Variables (Nodes)	Description	Count of Mentions
25	The Habitat Conservation Trust Foundation (HCTF)	A non-profit charitable foundation acting as Trustee of the Habitat Conservation Trust which receives 100% of the surcharge revenue collected from hunting, fishing, trapping, and guide-outfitter licenses per BC legislation and in turn funds conservation projects on freshwater fish, other wildlife, and the habitats in which they live	7
26	Tourism Associations	Organizations that promote tourism in British Columbia including Tourism Industry Association of BC, Indigenous Tourism BC, Destination British Columbia	7
27	Eco-Certifying Agencies	A third-party fisheries eco-certification standards organization. Often an independent, global, non-profit organization that provides market-based measure intended to improve the sustainability of fisheries. It aims to raise consumer awareness and retailers' demands for sustainable products. E.g., Global Aquaculture Alliance Best Aquaculture Practices program (BAP), Aquaculture Stewardship Council (ASC), Aboriginal Principles for Sustainable Aquaculture, Canadian Organic Aquaculture Standard	6
28	School Districts & Schools	Local and regional elementary schools, for students from kindergarten to grade 8; and secondary schools, for students from grade 9 to 12; and school boards, groups of elected members of a community to whom the provinces have delegated authority over some aspects of education.	6
29	Industry	Local and regional agriculture, construction, film and television, forestry, high technology, manufacturing, mining, oil and gas.	5
30	Media	Local and regional newspapers, radio, television, magazines, and online media.	5
31	The Federal Department of Fisheries and Oceans Canada (DFO) Conservation & Protection	Enforce the Federal *Fisheries Act* and other regulations and legislation. Enforcement activities are carried out by fishery officers across Canada which work to conserve and protect Canada's freshwater and marine fisheries resources and habitat. They conduct regular patrols on land and sea as well as in the air.	4
32	Environment and Climate Change Canada (ECCC)	Federal government department responsible for coordinating environmental policies and programs, the administration and enforcement of the *Canadian Environmental Assessment Act* and *Species at Risk Act* among others, as well as preserving and enhancing the natural environment and renewable resources.	4
33	The BC Ministry of Environment (MOE) BC Parks	An agency of MOE that manages all provincial parks and other conservation and historical properties of various title designations.	4

No. Rank	Variables (Nodes)	Description	Count of Mentions
34	Treaty Table	First Nations treaty processes in BC involve negotiation between The Ministry of Indigenous Relations and Reconciliation and First Nation(s). There are three parties at each negotiating treaty table: the First Nation(s), Canada, and British Columbia where details of matters under negotiation may include land title, governance, fisheries, etc.	4
35	Canadian Council of Fisheries and Aquaculture Ministers (CCFAM)	National body and committee including federal, provincial, and territorial Ministers, which has worked since 1999 to identify and resolve harmonization issues including policies, laws and regulations to fisheries and aquaculture.	3
36	First Nations Elders	Elders are very important members of First Nation, communities. The term Elder refers to someone who has attained a high degree of understanding of First Nation history, traditional teachings, ceremonies, and healing practices.	3
37	Keyoh Holders	The Keyoh is an ancestral Indigenous territory owned by an extended family whose head manages the land. The Keyohwudachun title, predates colonization, and is passed from the family head of one generation to the next generation.	3
38	Licensed Aquaculture Facilities	Aquaculture contributes significantly to B.C.'s economy. Three main groups are currently cultured in BC: Finfish (including FFSBC trout hatcheries), Shellfish, Aquatic plants.	3
39	Rio Tinto Alcan	A mining and metals company that dammed the Nechako River in the 1950s to provide power to an aluminum smelter in Kitimat.	2
40	First Nations Fishers	Indigenous fishermen with inherent Aboriginal and Treaty rights who may use traditional fishing methods including small nets, underwater traps, weirs, harpoons, and spears.	1
41	The BC Ministry of Tourism, Arts, Culture and Sport	Government department that integrates the tourism sector with the vibrant arts, culture, and sport sector to promote British Columbia for residents, visitors, and investors.	1

Table 5.5 The centrality of ordered and ranked n = 41 nodes from n = 4 fuzzy cognitive maps produced by four fisheries management groups and the number of outdegree (out-arrows) and indegree (in-degree) per each node in the union map.

No. Rank	Variables (Nodes)	Outdegree	Indegree	Centrality	Union Outdegree	Union Indegree
1	The BC Ministry of Forests, Lands and Natural Resource Operations and Rural Development (FLNRORD)	235	207.25	442.25	29	28
2	First Nations Fisheries Managers	101.25	121.25	222.5	20	22
3	The Federal Department of Fisheries and Oceans Canada (DFO) Non-Enforcement	95.25	104	199.25	18	21
4	Academia	99	87.25	186.25	14	14
5	Freshwater Fisheries Society of BC (FFSBC)	77	64.75	141.75	13	13
6	The BC Ministry of Environment (MOE) Science, Regulation & Policy	62.25	57.25	119.5	10	9
7	BC Hydro	59	59.5	118.5	8	8
8	Consultants	59.75	51.5	111.25	11	12
9	Anglers	32.5	40.25	72.75	9	7
10	Community, Local, Conservation ENGOs	28.5	27	55.5	6	4
11	Stakeholder Resource-User Groups & Angling Advisory Committees	19.5	33.25	52.75	7	7
12	The BC Ministry of Environment (MOE) Conservation Officers	28	24.25	52.25	5	5
13	Resort Operators & Angling Guides	22	28.75	50.75	7	6
14	Retired Fisheries Managers	24.5	24.75	49.25	6	7
15	The BC Ministry of Agriculture, Food and Fisheries	21.5	24.5	46	6	6
16	Local Governments	20	23.75	43.75	5	5
17	The Fish & Wildlife Compensation Program (FWCP)	26.75	14.75	41.5	6	4
18	The Committee on the Status of Endangered Wildlife in Canada (COSEWIC)	16.5	16.5	33	4	4
19	Other Canadian Government Agencies	16.75	15.25	32	3	3
20	The Habitat Conservation Trust Foundation (HCTF)	14.25	17	31.25	3	3
21	US Governments	15.5	15.5	31	3	3
22	Non-Angling Public & Politicians	14.75	16	30.75	4	3
23	The First Nations Fisheries Council (FNFC)	15.25	13.75	29	4	4
24	The Upper Fraser Fisheries Conservation Alliance (UFFCA)	14	14	28	4	4
25	Tourism Associations	15.75	11.25	27	4	3
26	First Nations Bands	10.25	16	26.25	3	4
27	Eco-Certifying Agencies	11.75	12	23.75	3	3
28	School Districts & Schools	7.5	14.75	22.25	2	4
29	Industry	6	12.25	18.25	2	3
30	The Federal Department of Fisheries and Oceans Canada (DFO) Conservation & Protection	8.25	8.25	16.5	2	2
31	Media	0	15.75	15.75	0	5
32	Environment and Climate Change Canada (ECCC)	11	4.25	15.25	3	1
33	The BC Ministry of Environment (MOE) BC Parks	7	8.25	15.25	2	2
34	Keyoh Holders	13.75	0	13.75	3	0
35	Treaty Table	5.25	7.5	12.75	2	2
36	Licensed Aquaculture Facilities	4.25	7.75	12	1	2
37	Canadian Council of Fisheries and Aquaculture Ministers (CCFAM)	0	10.5	10.5	0	3
38	First Nations Elders	6.5	3.5	10	2	1
39	Rio Tinto Alcan	3.5	3	6.5	1	1
40	First Nations Fishers	4	0	4	1	0
41	The BC Ministry of Tourism, Arts, Culture and Sport	3.5	0	3.5	1	0
Grand Total		**1237**	**1237**	**2474**	**237**	**238**

Assessing the five reliability dimensions (credibility, distortion, hackability, availability, political-ness) FFSBC had the largest within-group variation thus they were more likely to pick the more (e.g., very political, very apolitical) extreme options (Figure 5.6). FLNRORD Branch had the highest correlations among the 5 dimensions ($r = 0.52$-0.95) and FNs the lowest ($r = 0.01$-0.81). *Availability* of evidence generally had low-moderate correlations (mean $r = 0.3$; $r = 0.33$-0.66) with the other dimensions indicating that the scoring of other dimensions may not overly depend on the degree of availability. *Political-ness* had low-negligible correlations with other dimensions for FNs ($r = 0.03$-0.25) and FLNRORD regions ($r = 0.20$-0.43), some moderate for FFSBC ($r = 0.28$-0.67), and moderate-high for FLNRORD Branch ($r = 0.66$-0.84). Three correlations were consistently and unsurprisingly quite high: hackability and distortion ($r = 0.51$-0.89); distortion and credibility ($r = 0.56$-0.79); and hackability and credibility ($r = 0.4$-0.85) indicating the distortion, security, and credibility of evidence are dependent on one another.

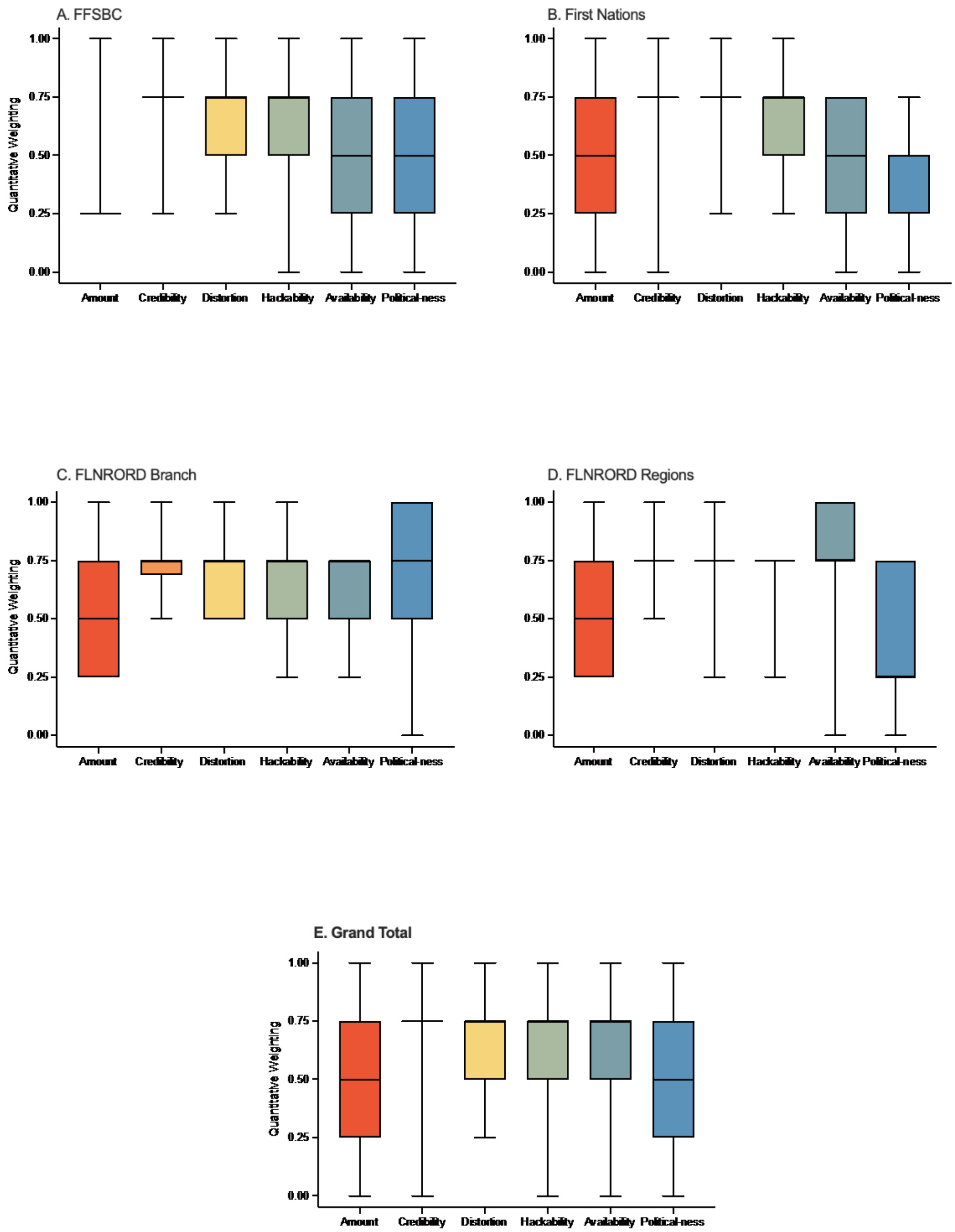

Figure 5.6 Boxplots of the amount of information and five reliability dimensions (credibility, distortion, hackability, availability, political-ness) of information connections as weighted in n = 4 FCMs created by fisheries management groups. Also shown is the grand total boxplot pooling over all 4 FCMs.

See Table 5.6 for the weighting for major dimensions of the information being communicated by each node averaged over the four constructed FCMs. Averaged over all four FCMs, the largest amount of information per node come from *First Nations Fishers*, *The Habitat Conservation Trust Foundation*, *Industry*, and *Treaty Table* ($\bar{x}$ = 0.75); the smallest amount from *DFO Conservation & Protection*; *Environment and Climate Change Canada*; *Licensed Aquaculture Facilities*; *The BC Ministry of Tourism, Arts, Culture and Sport*; *BC Parks*; *Rio Tinto Alcan*; and *School Districts & Schools* ($\bar{x}$ = 0.25). The most credible and reliable nodes are *First Nations Fishers* and *Keyoh Holders* ($\bar{x}$ = 1), *FFSBC* ($\bar{x}$ = 0.82 ± 0.12 SD), and *Tourism Associations* ($\bar{x}$ = 0.81 ± 0.13SD); the most unreliable are *Anglers* ($\bar{x}$ = 0.37 ± 0.19SD) while *Industry*, *Non-Angling Public & Politicians*, *Stakeholder Resource-User Groups & Angling Advisory Committees*, and *Treaty Table* are all $\bar{x}$ = 0.5. The clearest nodes are *Keyoh Holders* ($\bar{x}$ = 1), *Environment and Climate Change Canada* ($\bar{x}$ = 0.83 ± 0.14SD), *Tourism Associations* ($\bar{x}$ = 0.81 ± 0.13SD) and *FFSBC* ($\bar{x}$ = 0.79 ± 0.10SD); the most distorted are *The BC Ministry of Agriculture, Food and Fisheries* ($\bar{x}$ = 0.47 ± 0.21SD), *Retired Fisheries Managers* ($\bar{x}$ = 0.47 ± 0.21SD), *Non-Angling Public & Politicians* ($\bar{x}$ = 0.42 ± 0.13SD), *Industry* ($\bar{x}$ = 0.38 ± 0.18SD), and *Treaty Table* ($\bar{x}$ = 0.25). The most secure/rigid nodes are *Keyoh Holders* ($\bar{x}$ = 1), *Tourism Associations* ($\bar{x}$ = 0.81 ± 0.13SD), and *FFSBC* ($\bar{x}$ = 0.78 ± 0.08SD); the most hackable/flexible are *Non-Angling Public & Politicians* ($\bar{x}$ = 0.42 ± 0.13SD), *Anglers* ($\bar{x}$ = 0.40 ± 0.13SD), *Resort Operators & Angling Guides* ($\bar{x}$ = 0.39 ± 0.18SD), *Industry* ($\bar{x}$ = 0.38 ± 0.18SD), and *First Nations Fishers* ($\bar{x}$ = 0.25). The nodes with the most available information are *Eco-certifying Agencies* and *Licensed Aquaculture Facilities* ($\bar{x}$ = 1), *COSEWIC* ($\bar{x}$ = 0.94 ± 0.13SD), and *FWCP* ($\bar{x}$ = 0.92 ± 0.13SD); the nodes with least available information are *The BC Ministry of Agriculture, Food and Fisheries* ($\bar{x}$ = 0.44 ± 0.35SD), *The Upper Fraser Fisheries Conservation*

Alliance (UFFCA) ($\overline{x}$ = 0.44 ± 0.13SD), *Resort Operators & Angling Guides* ($\overline{x}$ = 0.39 ± 0.31SD), *The BC Ministry of Tourism, Arts, Culture and Sport*, and *BC Parks* ($\overline{x}$ = 25). The most apolitical nodes are *The Habitat Conservation Trust Foundation* and *The BC Ministry of Tourism, Arts, Culture and Sport* ($\overline{x}$ = 1), *Consultants* ($\overline{x}$ = 0.79 ± 0.17SD), *MOE Conservation Officers* ($\overline{x}$ = 0.79 ± 0.27 SD) and *Academia* ($\overline{x}$ = 0.78 ± 0.11SD); the most political are *Stakeholder Resource-User Groups & Angling Advisory Committees* ($\overline{x}$ = 0.19 ± 0.18SD), *Treaty Table* ($\overline{x}$ = 0.13 ± 0.18SD) and the *Non-Angling Public & Politicians* ($\overline{x}$ = 0.08 ± 0.13SD) while *First Nations Elders*, *Industry*, *Keyoh Holders*, *Local Governments* and *Rio Tinto Alcan* are all $\overline{x}$ = 0.25.

Table 5.6 Mean $\overline{x}$ (± SD) for n = 41 variable nodes which were weighted along major dimensions of the information being communicated: amount of information flowing and reliability of the information flowing (i.e., signal to noise ratio) which was comprised of a composite index: credibility and reliability, distortion, hackability, availability, and political-ness.

Variables (Nodes)	Amount	Credibility	Distortion	Hackability	Availability	Political-ness
Academia	0.38 (± 0.20)	0.76 (± 0.05)	0.75 (± 0.00)	0.75 (± 0.00)	0.71 (± 0.10)	0.78 (± 0.11)
Anglers	0.38 (± 0.24)	0.37 (± 0.19)	0.50 (± 0.00)	0.40 (± 0.13)	0.44 (± 0.29)	0.40 (± 0.24)
BC Hydro	0.53 (± 0.27)	0.75 (± 0.00)	0.67 (± 0.12)	0.67 (± 0.12)	0.73 (± 0.27)	0.58 (± 0.18)
Community, Local, Conservation ENGOs	0.35 (± 0.13)	0.58 (± 0.12)	0.53 (± 0.18)	0.50 (± 0.17)	0.55 (± 0.11)	0.35 (± 0.17)
Consultants	0.52 (± 0.21)	0.75 (± 0.00)	0.75 (± 0.00)	0.75 (± 0.00)	0.71 (± 0.13)	0.79 (± 0.17)
The Committee on the Status of Endangered Wildlife in Canada (COSEWIC)	0.31 (± 0.13)	0.75 (± 0.00)	0.75 (± 0.00)	0.75 (± 0.00)	0.94 (± 0.13)	0.63 (± 0.25)
The Federal Department of Fisheries and Oceans Canada (DFO) Conservation & Protection	0.25 (± 0.00)	0.75 (± 0.00)	0.75 (± 0.00)	0.75 (± 0.00)	0.88 (± 0.18)	0.75 (± 0.00)
The Federal Department of Fisheries and Oceans Canada (DFO) Non-Enforcement	0.58 (± 0.29)	0.71(± 0.09)	0.67 (± 0.15)	0.66 (± 0.19)	0.63 (± 0.24)	0.40 (± 0.22)
Environment and Climate Change Canada (ECCC)	0.25 (± 0.00)	0.75 (± 0.00)	0.83 (± 0.14)	0.58 (± 0.29)	0.83 (± 0.29)	0.42 (± 0.38)
Eco-Certifying Agencies	0.33 (± 0.14)	0.75 (± 0.00)	0.75 (± 0.00)	0.75 (± 0.00)	1.00 (± 0.00)	0.33 (± 0.14)
Freshwater Fisheries Society of BC (FFSBC)	0.49 (± 0.26)	0.82 (± 0.12)	0.79 (± 0.10)	0.78 (± 0.08)	0.71 (± 0.23)	0.69 (± 0.28)
The BC Ministry of Forests, Lands and Natural Resource Operations and Rural Development (FLNRORD)	0.50 (± 0.25)	0.76 (± 0.06)	0.72 (± 0.10)	0.75 (± 0.09)	0.71 (± 0.20)	0.68 (± 0.31)
First Nations Bands	0.42 (± 0.29)	0.67 (± 0.14)	0.67 (± 0.14)	0.67 (± 0.14)	0.58 (± 0.29)	0.42 (± 0.14)
First Nations Elders	0.50 (± 0.00)	0.75 (± 0.00)	0.50 (± 0.00)	0.50 (± 0.00)	0.75 (± 0.00)	0.25 (± 0.00)
First Nations Fisheries Managers	0.45 (± 0.22)	0.66 (± 0.12)	0.64 (± 0.14)	0.56 (± 0.20)	0.45 (± 0.20)	0.41 (± 0.18)
First Nations Fishers	0.75	1.00	0.75	0.25	0.75	0.50
The First Nations Fisheries Council (FNFC)	0.56 (± 0.24)	0.75 (± 0.00)	0.75 (± 0.00)	0.69 (± 0.13)	0.56 (± 0.24)	0.50 (± 0.00)
The Fish & Wildlife Compensation Program (FWCP)	0.54 (± 0.25)	0.75 (± 0.00)	0.75 (± 0.00)	0.75 (± 0.00)	0.92 (± 0.13)	0.75 (± 0.00)
The Habitat Conservation Trust Foundation (HCTF)	0.75 (± 0.00)	0.75 (± 0.00)	0.75 (± 0.00)	0.75 (± 0.00)	0.75 (± 0.00)	1.00 (± 0.00)
Industry	0.75 (± 0.00)	0.50 (± 0.00)	0.38 (± 0.18)	0.38 (± 0.18)	0.75 (± 0.35)	0.25 (± 0.00)
Keyoh Holders	0.58 (± 0.29)	1.00 (± 0.00)	1.00 (± 0.00)	1.00 (± 0.00)	0.75 (± 0.00)	0.25 (± 0.43)
Licensed Aquaculture Facilities	0.25	0.75	0.75	0.75	1.00	0.75
Local Governments	0.32 (± 0.12)	0.57 (± 0.12)	0.57 (± 0.12)	0.50 (± 0.20)	0.64 (± 0.28)	0.25 (± 0.35)
The BC Ministry of Agriculture, Food and Fisheries	0.31 (± 0.12)	0.69 (± 0.12)	0.47 (± 0.21)	0.50 (± 0.19)	0.44 (± 0.35)	0.28 (± 0.09)
The BC Ministry of Tourism, Arts, Culture and Sport	0.25	0.75	0.50	0.75	0.25	1.00
The BC Ministry of Environment (MOE) BC Parks	0.25 (± 0.00)	0.75 (± 0.00)	0.75 (± 0.00)	0.75 (± 0.00)	0.25 (± 0.00)	0.75 (± 0.00)
The BC Ministry of Environment (MOE) Conservation Officers	0.32 (± 0.12)	0.79 (± 0.09)	0.75 (± 0.14)	0.75 (± 0.29)	0.61 (± 0.28)	0.79 (± 0.27)
The BC Ministry of Environment (MOE) Science, Regulation & Policy	0.58 (± 0.32)	0.75 (± 0.00)	0.72 (± 0.13)	0.73 (± 0.06)	0.72 (± 0.13)	0.65 (± 0.32)
Non-Angling Public & Politicians	0.33 (± 0.20)	0.50 (± 0.00)	0.42 (± 0.13)	0.42 (± 0.13)	0.71 (± 0.25)	0.08 (± 0.13)
Other Canadian Government Agencies	0.69 (± 0.24)	0.75 (± 0.00)	0.75 (± 0.00)	0.75 (± 0.00)	0.81 (± 0.13)	0.44 (± 0.38)
Resort Operators & Angling Guides	0.28 (± 0.08)	0.53 (± 0.08)	0.53 (± 0.08)	0.39 (± 0.18)	0.39 (± 0.31)	0.33 (± 0.18)
Retired Fisheries Managers	0.41 (± 0.23)	0.69 (± 0.12)	0.47 (± 0.21)	0.66 (± 0.13)	0.56 (± 0.22)	0.28 (± 0.31)
Rio Tinto Alcan	0.25	0.75	0.75	0.75	0.75	0.25
School Districts & Schools	0.25 (± 0.00)	0.75 (± 0.00)	0.75 (± 0.00)	0.75 (± 0.00)	0.75 (± 0.00)	0.50 (± 0.00)
Stakeholder Resource-User Groups & Angling Advisory Committees	0.34 (± 0.19)	0.50 (± 0.13)	0.50 (± 0.00)	0.44 (± 0.18)	0.47 (± 0.39)	0.19 (± 0.18)
Tourism Associations	0.31 (± 0.13)	0.81 (± 0.13)	0.81 (± 0.13)	0.81 (± 0.13)	0.56 (± 0.13)	0.63 (± 0.32)
Treaty Table	0.75 (± 0.00)	0.50 (± 0.00)	0.25 (± 0.00)	0.50 (± 0.35)	0.50 (± 0.35)	0.13 (± 0.18)
The Upper Fraser Fisheries Conservation Alliance (UFFCA)	0.44 (± 0.13)	0.75 (± 0.00)	0.75 (± 0.00)	0.69 (± 0.13)	0.44 (± 0.13)	0.44 (± 0.13)
US Governments	0.44 (± 0.13)	0.75 (± 0.00)	0.75 (± 0.00)	0.75 (± 0.00)	0.75 (± 0.00)	0.44 (± 0.38)
Grand Mean	**0.45**	**0.70**	**0.67**	**0.66**	**0.64**	**0.53**

The union map resulted in 41 variable nodes and 237 connections (Figure 5.7).

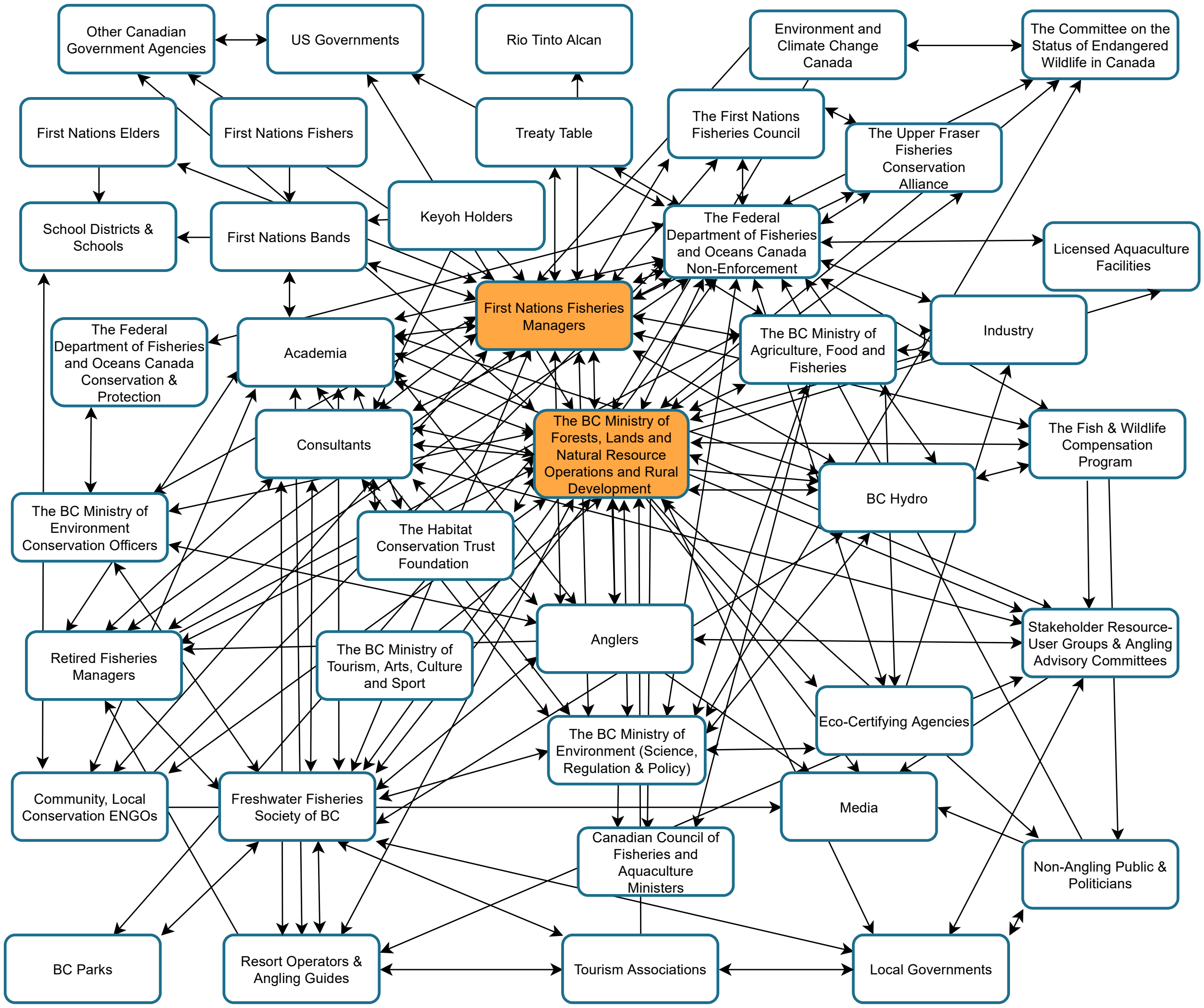

Figure 5.7 Simplified, recoded union fuzzy cognitive map of the type, amount, rate, and reliability of evidence influencing freshwater fish and fisheries decisions in BC created by four fisheries management groups. Nodes in orange are target variables that possess (statutory) decision-making powers, the BC natural resources ministry (FLNRORD) and First Nations fisheries managers.

Communicability analyses of the Union Graph indicates *FLNRORD*, *FWCP*, *Keyoh Holders*, *FFSBC* and *Consultants* are net contributors of information to the system, relatively; and *Media*, *CCFAM*, *Stakeholder Resource-User Groups & Angling Advisory Committees*; *Resort Operators & Angling Guides*, and *Anglers* are net consumers, relative to other organizations/groups (Figure 5.8). Individual communicability plots from each of the four FCMs are provided in Appendix N.

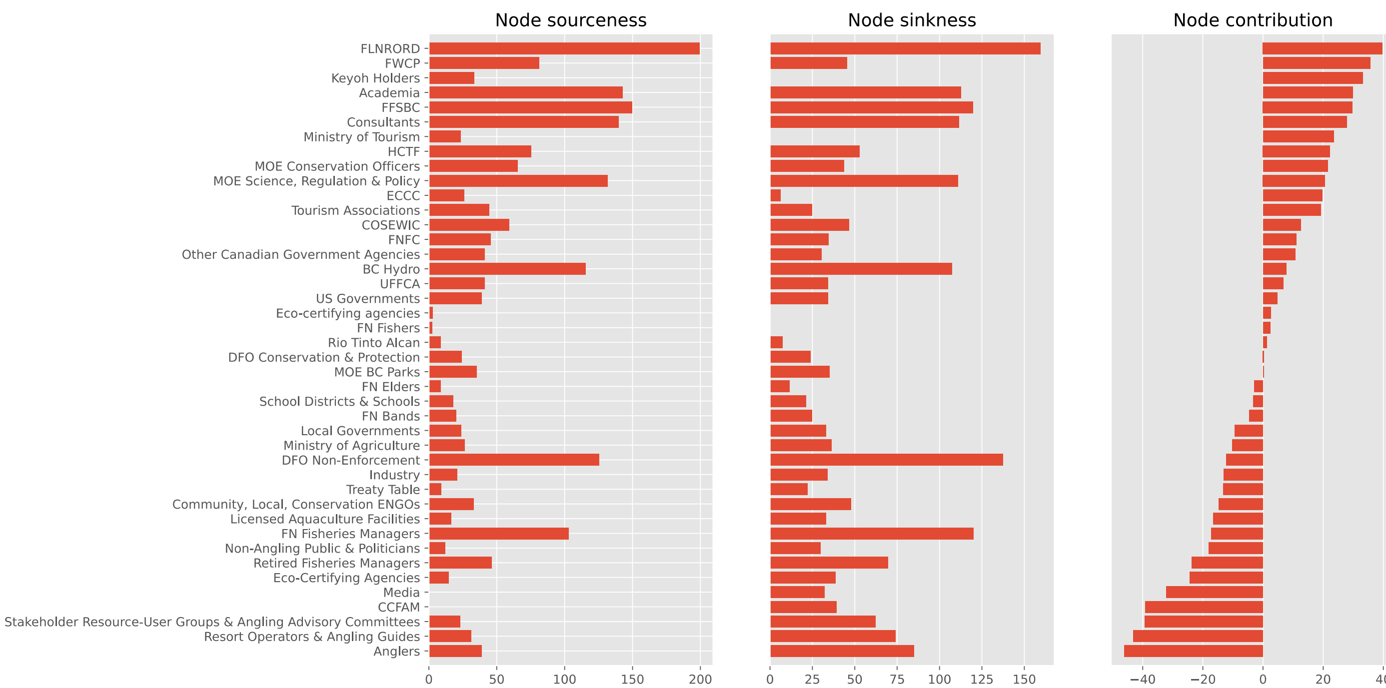

Figure 5.8 Communicability source/sink plots for all nodes (organizations/groups) in the network to understand the relative amount of information each node would contribute to or consume from the system in the Union Graph from n = 4 fuzzy cognitive maps.

Transitive influence analyses indicated *FLNRORD*; *FFSBC*; *Consultants*; *Academia*; *MOE Science, Regulation & Policy*; *DFO*; *BC Hydro* and *First Nations fisheries managers* have the largest influence on freshwater fisheries decisions made by FLNRORD (Figure 5.9). The exact same organizations/groups were demonstrated to have the largest influence on fisheries decisions made by First Nations fisheries managers also, except the influence of *Academia* was higher than *FFSBC* and *Consultants* (Figure 5.10). Individual transitive influence plots from each of the four FCMs on FLNRORD and First Nations fisheries managers are provided in Appendix N.

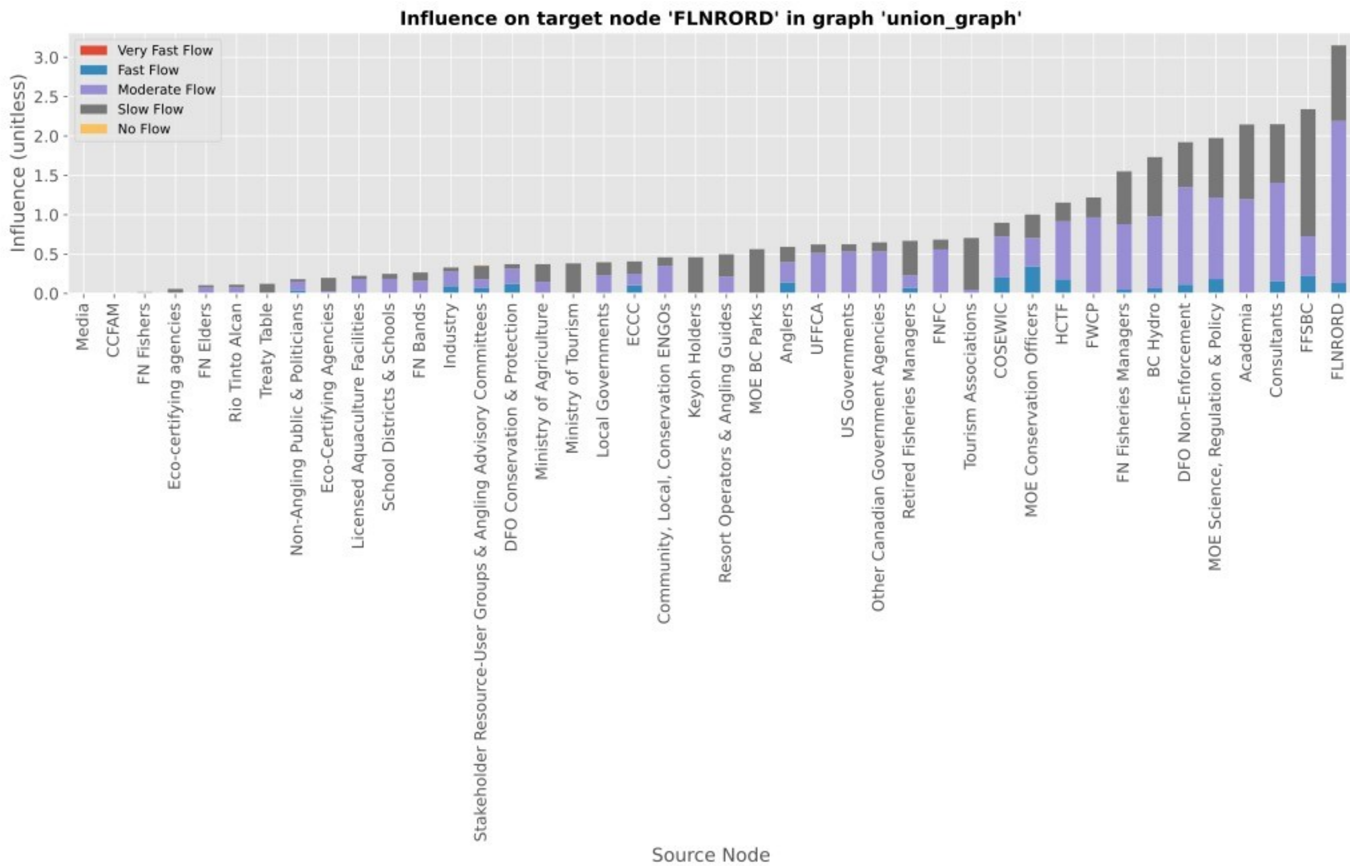

Figure 5.9 Transitive influence of all nodes (organizations/groups) in the whole network based on the Union Graph from n = 4 fuzzy cognitive maps on the target variable the BC natural resources ministry (FLNRORD). The ‘rate of evidence flowing’ variable is used to represent five timescales at which the information can flow.

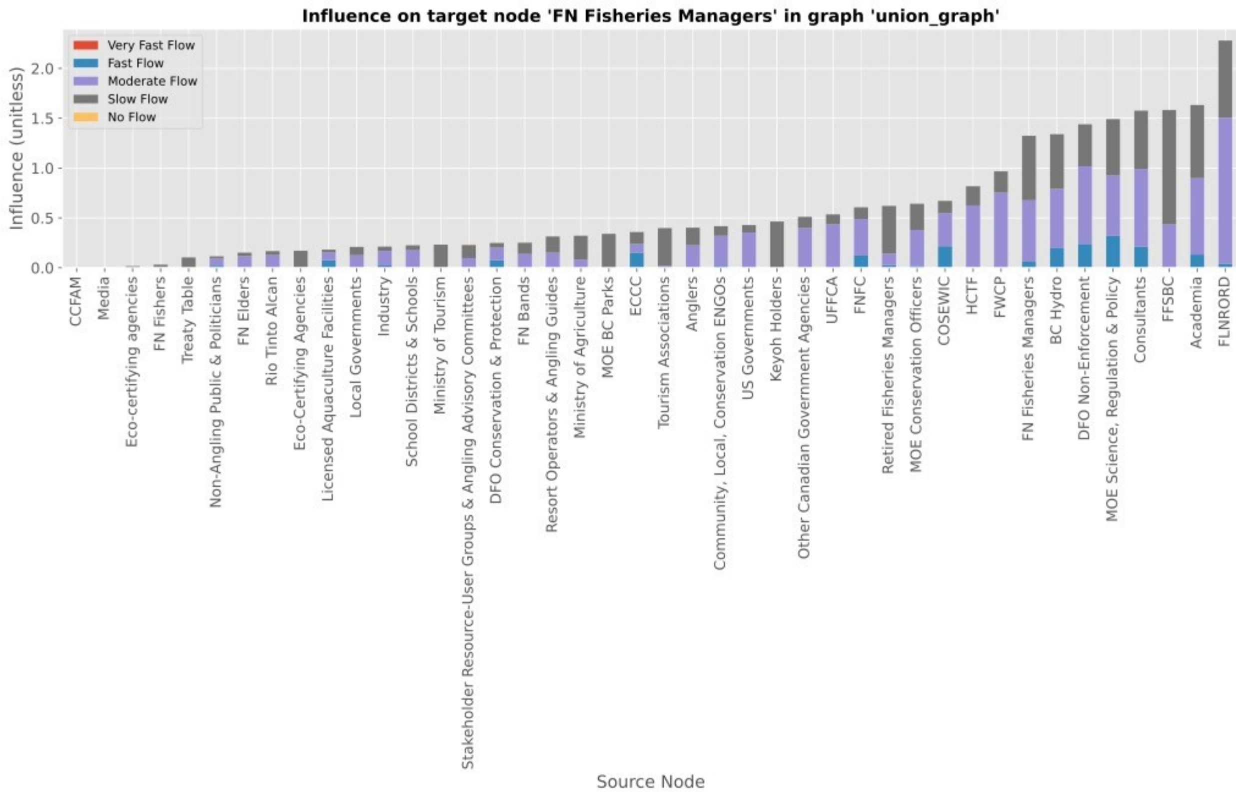

Figure 5.10 Transitive influence of all nodes (organizations/groups) in the whole network based on the Union Graph from n = 4 fuzzy cognitive maps on the target variable the First Nations fisheries managers. The 'rate of evidence flowing' variable is used to represent five timescales at which the information can flow.

5.4 Discussion

The purpose of this study was to explore the complex information flows between organizations which inform decisions about freshwater fish and fisheries in BC, Canada and to identify key factors that exert the highest levels of limitation or influence on information flowing in the system which may in turn influence decisions. The FCMs created by four fisheries management groups were similar in terms of structure but varied in functional attributes. Like Zinngrebe et al. (2020) which investigated the social network of agroforestry governance I identified a strong density of actor linkages, but a more coherent and connected network of actors exchanging and mobilizing evidence. As seen here, a network of heterogeneous actors promotes bridging disparate perspectives and a common view of the system (Sandström & Rova 2010), potentially reducing rigidity, and promoting adaptability in decision-making (Gray et al. 2012). However, while the system was dense and diverse, the influence in terms of information flowing in the system was centralized to a handful of groups or organizations, including Indigenous and non-Indigenous decision-making government agencies, and partnered organizations like *BC Hydro* (a province-owned electrical utility) and *FFSBC* (who delivers the provincial fish stocking program). This contrasts environmental governance literature which suggests with increases in co-management arrangements, governments are no longer the most important source of decision-making as new actors are playing critical decision-making roles (c.f., Armitage et al. 2012).

The results strongly imply that the number of organizations or groups that influence information concerning freshwater fisheries decisions in BC is relatively small. Indigenous and non-Indigenous government departments and agencies, those groups with decision-making powers, had the largest influence on information flowing in the network suggesting evidence exchange and mobilization which may influence decisions is within a rather closed system, relying heavily on internal evidence. This pattern of results is consistent with previous interview research in this system suggesting that within natural resource management agencies, internal (i.e., institutional) sources of evidence (e.g., government websites and databases, grey literature) are relied on more heavily than external ones (Young et al. 2016a; Kadykalo et al. 2021b; Piczak et al. 2021). This suggests that much available evidence is not immediately actionable and relevant to known problems faced by natural resource managers. Sharing of knowledge among actors in this network was found to be influenced by the movement of individuals from one organization to another throughout their careers, resulting in broadening social networks, which was critical for the ways that knowledge moves among actors both in the short term and long term (Andrachuk et al. 2021). Young et al. (2016a) found the same in the management of Pacific salmon fisheries in Canada's Fraser River, that actors rely heavily on personal contacts as sources of information and that social networks play a major role in the movement of information. Comparably, Leonard et al. (2011) found that in the management of lake sturgeon in the Great Lakes, information flows were dependent on the formation of social ties within networks influenced by individuals' employer type. This research further hints that evidence exchange and mobilization influencing fisheries management and conservation decision-making depends heavily on a social network of close personal connections and relationships (i.e., peers and colleagues).

These findings are also consistent with previous research outside of this study area. Pullin et al. (2004) and Pullin and Knight (2005) found that in the United Kingdom and Australia existing management plans and expert opinion were more frequently used than external sources of evidence by natural resource managers. Bayliss et al. (2012) found that in the United Kingdom practitioners and stakeholders working with invasive species used colleague knowledge more than any other evidence source. In Australia, Kenya, and Belize, Cvitanovic et al. (2014) found that marine protected area managers relied mostly on commissioned technical reports and local government reports. Koontz and Thomas (2018) found that an ecosystem management agency in the United States referenced gray literature the most in producing ecosystem management plans. Across Canada, Lemieux et al. (2018) found protected area managers prioritize information by staff within organization over other forms of empirical evidence such as Indigenous knowledge and peer-reviewed literature. Lastly, Fabian et al. (2019)

found that in Switzerland natural resource managers and practitioners, direct exchange with colleagues and experts were more important than other evidence-based sources.

5.4.1 Implications

This body of evidence reveals several practical implications for applied evidence producers and their evidence to be considered in freshwater fisheries management and conservation decisions.

These findings highlight evidence exchange and mobilizations conceptualizations of others, that the linear “information-deficit” model of knowledge transfer from evidence producers to decision makers – which suggests a lack of effective communication and understanding limits the use of evidence in practice – is antiquated (see Cvitanovic et al. 2015; Toomey et al. 2017). Environmental evidence is embedded in a collaborative social and decision processes that engage evidence, not a scientific process that engages society (Clark & Clark 2002; Adams & Sandbrook 2013). It is becoming increasingly clearer that collaboration and engagement with natural resource managers and other decision-making practitioners are needed to produce actionable evidence. This implication is consistent with Nguyen et al. (2019) findings that fish tracking researchers with extensive collaborations, who are highly involved and familiar with fisheries management processes, and who spent more time engaging in outreach including research dissemination experienced greater uptake of their findings. This need not apply just to conventional scientific and academic researchers, but also to other sources of evidence such as ENGOs, First Nation members, anglers, other government departments and agencies, etc. The empirical results of this study support environmental management and governance literature which call for greater collaboration and knowledge co-production with partners (Cooke et al. 2020; Karcher et al. 2021). Knowledge co-production is defined as an ‘iterative and collaborative processes involving diverse types of expertise, knowledge and actors to produce context-specific knowledge and pathways towards a sustainable future' (Norström et al. 2020). Increased collaboration and engagement can decrease problems of value-laden evidence by increasing transparency and promoting inclusiveness in knowledge production (Pielke 2007).

Consultants and academics had similar roles in the freshwater fisheries management and decision-making system, both highly influential and reliable. This may suggest these groups are well-trusted by decision-making authorities. Consultants and academics are often contracted to produce evidence for, or work in research partnerships with, fisheries managers and other decision-makers. In certain contexts, consultants and academics could be considered agents of first-order evidence producers/decision-makers which outsource evidence production. Andrachuk et al. (2021) found that consultants in this system play an intermediary role as evidence bridgers (i.e., knowledge brokers) connecting fisheries managers with applied research results and scientists. This includes preparing and distributing easy-to-use synthesized evidence summaries and developing and maintaining networks of connections with researchers and fisheries managers (Kadykalo et al. 2021a). Cvitanovic et al. (2017) show that knowledge brokers in Australia developed an extensive stakeholder network which increased in density and became more cohesive over time, underpinning successful knowledge exchange. Knowledge brokers also played important roles in the flow of information in the management of lake sturgeon in the Great Lakes (Leonard et al. 2011). Information flow networks depend on these sorts of actors that bridge communities by having connections to multiple networks that are otherwise poorly connected (Posner & Cvitanovic 2019).

Resource-user groups (anglers, angling advisory committees, resort operators, angling guides, First Nations fishers) were rated relatively low in terms of reliably producing and communicating evidence. Further, these results indicate they are net evidence consumers in this system relative to other organizations and groups; their information not considered as much by decision-makers. Similarly, Turner et al. (2016) found commercial fishers in Australia's Great Barrier Reef Marine Park were perceived as low in terms of legitimacy and trust in information from management agencies. This implies Indigenous, local (or stakeholder), place-based knowledge accumulated across generations by close and continuous observation within specific cultural contexts and worldviews (Díaz et al. 2015; Tengö et al. 2017), such as that from fishermen, may be discounted by decision-makers. The results here provide support to the idea that stakeholders are perceived largely as 'issue advocates', with particular agendas leading to 'agency capture', i.e., undue influence of narrow special interests on agency decision-making (Culhane 1981; Bixler et al. 2016; Artelle et al. 2018a). The same general patterns were also found in the results for industry and non-angling public and politicians. Retired fisheries managers, often the most vocal critics of current management regimes (unpublished data) also fall within this categorization suggesting an intergenerational tension. For stakeholders, industry, and others, higher levels of trust and credibility will be associated with openness about their views (i.e., 'honest brokerage') and high engagement with governing bodies, especially those with positive previous experiences and interactions (Pielke 2007; Crona & Parker 2011; Turner et al. 2016; Rose et al. 2018b; Cvitanovic et al. 2021). Establishing relationships with internal staff of natural resource management agencies can be considered an entry point for evidence to become available to practitioners and policy advisors (Andrachuk et al. 2021).

These results further support the idea of 'evidence complacency', providing empirical support that the availability of evidence has little influence on the way it is perceived. The perceptions of political-ness were highest for FFSBC and FLNRORD Branch which suggests these fisheries management groups, given their institutional governance roles, experience the most politicized information and interactions, even amongst themselves. Indeed, it was FFSBC that consistently weighted FLNRORD Branch as less reliable along distortion, hackability, and availability dimensions than FLNRORD Regions.

5.4.2 Limitations

It is important to note a couple important limitations of FCMs. They represent only one point in time and they encode all participants knowledge of the system in question, including associated ignorance, misconceptions, and biases (Kosko 1992; Özesmi & Özesmi 2004). I have no bearing on biased perceptions. For these reasons, I added many FCMs together by which the Union Graph was informed by many experts or informed local people helping to improve the accuracy of the union map. Thus, the mapped system is one in which participants chiefly define, which was the research objective. However, it is not possible for the facilitator to remain completely detached from the process despite participating as little as possible in creating the FCM (Giles et al. 2008). The facilitator must, for example, interpret participants' ideas in creating node names and short descriptions to represent similar concepts as expressed by participants. Accordingly, any input by the facilitator was presented to the entire focus group creating the FCM and the final decision for any FCM elements remained with participants. Moreover, using the same facilitator for all groups, in theory, reduced the variation in the nature of the facilitation, helping control confounds in the skill of the facilitator and the duration of the focus groups (Eden et al. 1992). Relatively standardized focus groups give confidence in comparing variables and indices between FCMs.

While some prefer individual drawing of FCMs for data collection (e.g., Özesmi & Özesmi 2004; Sparks 2018) I selected focus groups for logistic purposes – to get various experts from across BC highly limited by time to dedicate no more than one day to the process – and to encourage group brainstorming, concept clustering and multiple perspectives of the same system. Due to selecting focus groups as the method of obtaining FCMs, I acknowledge that power relationships among group members play a role. For example, in the FLNORD Regions focus group more senior participants were more outspoken. Power dynamics, while present, were minimized by the facilitator asking every participant in the focus group to weigh in on every FCM element, as was done here. Lastly, coverage from natural resource branches of Indigenous governments was limited primarily to the regional perspective of FLNRORD resource management Region 7A: Omineca. Thus, the Union Graph is missing several key First Nations natural resource management agencies in other parts of the province such as the Skeena Fisheries Commission, The Lower Fraser Fisheries Alliance, and the Secwepemc Fisheries Commission although many of these roles would be represented by the node 'First Nations fisheries managers'.

5.4.3 Conclusion

Four fuzzy cognitive maps representing the information flows which may inform and influence decisions about freshwater fish and fisheries in BC, Canada, constructed by separate fisheries management groups were similar in structure. The maps represented heterogeneous actors as social agents embedded in a collaborative social and decision processes that engage evidence, promoting multiple perspectives in the formulation of a common view, and potential adaptability in decision-making. However, while the network of information flows was dense and diverse, the influence on information flowing in the system which may in turn influence decisions was centralized to a handful of groups or organizations either with decision-making powers (i.e., natural resource management agencies), or closely partnered with decision-making organizations. This suggests that despite an abundance of available evidence, much of it is not immediately applicable (‘actionable’) and relevant to known problems faced by natural resource managers. It further implies collaboration and engagement with natural resource managers and other decision-making practitioners is needed to produce actionable evidence. This work suggests improving evidence exchange and mobilization for natural resource management and conservation will depend on strategies like knowledge co-production with natural resource management agencies and knowledge brokerage with specialized actors like private environmental consultants which bridge otherwise poorly connected communities. For potential evidence producers in this system like Indigenous and local knowledge holders, higher levels of trust and credibility will be associated with openness about their views (i.e., ‘honest brokerage’) and frequent constructive engagement with natural resource management agencies.

Chapter 6: General conclusions and future directions

The overall goal of my thesis was to investigate the role of evidence in conservation and environmental management decisions, policies, and practices using the case of managed fish and wildlife resources in British Columbia (BC), with particular emphasis on rainbow trout (*Oncorhynchus mykiss*) fish and fisheries. To this end, each data chapter investigated a different facet of evidence-informed decision-making in the governance, management, and conservation of fish and wildlife in the province. In Chapter 2, I assessed how decision-makers and other potential knowledge users (a) perceive, evaluate, and use western-based scientific, Indigenous and local knowledge and (b) the extent to which social, political and economic considerations challenge the integration of different forms of evidence into decision-making. In Chapter 3, I examined stakeholder, Indigenous rightsholder, and regulatory/governance group perceptions on the current and future status of rainbow and steelhead trout populations and fisheries. In Chapter 4, I analyzed how potential knowledge users (conservation practitioners) perceive and evaluate a particular type of evidence, conservation genomics using the case of managed rainbow trout fisheries in BC. In Chapter 5, I examined the perceptions of freshwater fisheries managers in BC on the type, amount, rate, and reliability of evidence (i.e., information flows) influencing fish and fisheries decisions.

This thesis reveals several interesting themes concerning evidence-informed decision-making (or lack thereof) in wildlife management. Collectively, this research suggests that wildlife management and conservation issues and decisions are time-sensitive and value-laden (Chapter 4; Kadykalo et al. 2021a), supporting the idea of conservation as a crisis discipline in which actions are prioritized in a triage process and where decisions are made quickly without complete information (Bottrill et al. 2008). A major theme coming out of this thesis research which supports this notion is that interviewees (members from natural resource management branches of Indigenous and parliamentary governments, as well as nongovernmental stakeholder groups) relied heavily on personal contacts with internal colleagues (and their intuition, personal experience, or opinion) and institutional information to inform decisions and practices (Chapter 3 and 5; Andrachuk et al. 2021). Thus, for the case study explored in this thesis, evidence which may influence wildlife management and conservation decisions is within a rather closed social network, centralized to a handful of individuals, groups or organizations either with decision-making powers (i.e., natural resource management agencies), or those closely partnered with such organizations (Chapter 5).

The barriers to evidence use are wide-spread and perverse (reviewed in Rose et al. 2018a; Walsh et al. 2019) but in this case study the biggest barriers to incorporating other forms of (external) evidence into decision-making was a lack of time and information overload (Chapter 2 and 4). The data within this thesis also suggests that despite an abundance of available environmental evidence, much of this evidence may not be immediately 'actionable' and relevant to known problems faced by natural resource managers, supporting the idea of "evidence complacency" in conservation (Sutherland & Wordley 2017) (Chapter 4 and 5). This may be due in part to poor communication and dissemination of evidence between researchers and practitioners (Chapter 4). Hence, providing more evidence is unlikely to translate to better decision-making and may in fact have the opposite effect of making a decision-maker less likely to use the evidence if they are overloaded with information. Additionally, a key theme related to the application of Indigenous and local knowledge specifically was a lack of trust and hesitancy to share knowledge (Chapter 2, 3, and 5).

Despite conservation being purported as the highest priority of wildlife managers, economic, social, and political drivers are perceived as increasingly superseding conservation decisions and actions (Chapter 2, 3, and 4). This may imply that returns on investments in research and gathering evidence are low terms of informing policy and practice actions as much of it goes underutilized or ignored. Thus, the collective research of this thesis supports an underlying and concerning trend, of the diminishing role of evidence in fish and wildlife management and conservation in North America (Carroll et al. 2017; Westwood et al. 2017; Artelle et al. 2018a), that "runs far deeper than ephemeral political cycles" (Artelle 2019). Alternatively, perhaps claims of evidence-informed decision-making in conservation and environmental management (e.g., Organ et al. 2012; Ryder 2018; Powell 2020) was always a bit of an assumption and misnomer given investigations into the use of evidence only began in the in the early 2000s (e.g., Pullin et al. 2004). This raises questions as to whether the perceived diminishing role of evidence in wildlife decision-making is indeed a true phenomenon and whether there ever was a 'golden era' of evidence-informed decision-making to hearken back to. Moreover, it raises questions if the increased democratization of wildlife management (e.g., stakeholder and Indigenous consultation, co-management etc.) enables or disables evidence-informed decision-making and results in management outcomes that are beneficial for wildlife resources. This thesis work also suggests a lack of evidence-informed decision-making may be in part due to (1) shared jurisdictional authority between federal and provincial agencies over wildlife resources as well as, (2) the organizational structure of natural resource management agencies which are not autonomous from competing commercial and industrial objectives and directions, which may enable mismanagement, inaction, and decision paralysis (Chapter 3; Jeanson et al. 2021b).

This collective work suggests that using evidence in decision-making is not necessarily limited solely by funding, but by capacity and infrastructure (Chapter 2 and 3). It seems as if interviewees (decision-makers and practitioners) *want* to use evidence but do not know how, i.e., there is resoundingly high interest from participants in this research to use evidence in decision-making informing management and conservation actions if barriers are reduced or removed. The traditional form of disseminating research through scholarly publications is therefore not the best way to mobilize knowledge and more is needed to bridge research and practice in wildlife management and conservation. The next logical steps to enable effective knowledge exchange in fish and wildlife management and conservation is to make evidence more accessible. Practically, I envision two key steps to bridge this divide, (1) open science and data, but also (2) synthesized evidence based on the priorities of practitioners that is prepared and distributed in easy-to-find and easy-to-use evidence summaries. This last step is crucial given that wildlife management and conservation practitioners are highly constrained by time. Hence, knowledge brokers, researcher-practitioner knowledge and sharing interfaces and collaborative relationships are needed to identify research topics based on the priorities of practitioners and to develop and maintain networks of connections with researchers and practitioners.

To enable effective knowledge exchange in fish and wildlife management and conservation, based on this thesis I broadly recommend:

- researcher-practitioner knowledge and sharing interfaces at research project outset;
- researcher collaboration and engagement with natural resource managers and other decision-making practitioners to produce actionable evidence;

- knowledge sharing and co-production (or co-assessment of knowledge when it is not practical or desirable) with Indigenous and local communities, and collaborative management (or co-management) of fish and wildlife resources to be mindful of power and equity asymmetries and embrace adaptive management principles, demonstrate respect, and create the time and space to listen to Indigenous and local communities and their information needs to foster trust and mutual learning;
- investment in government science capacity to minimize the reliance on professionals employed by the same industry the government regulates (which compromise objective science and decisions);
- institutional reform ensuring wildlife research and management are all within the same department or ministry uncompromised by other competing mandates;
- stronger cohesion, communication, and coordination amongst management agencies in transboundary or overlapping jurisdictions as well as between conservation researchers and practitioners;
- and knowledge brokerage with specialized actors who bridge otherwise poorly connected communities ('evidence bridgers' – see Kadykalo et al. 2021a).

Further, this research emphasizes a need for transparency in how (multiple forms of) evidence contribute to decision-making including transformative change (Díaz et al. 2019) to organizational cultures so that wildlife managers are motivated and enabled to apply evidence.

While the call for transparency in how evidence contributes to decision-making is nebulous, increased documentation of how a person's or agencies decisions may be traced to empirical evidence or other sources of information such as experience or judgement is possible and encouraged. New tools like Evidence-to-Decision [E2D] tool: www.evidence2decisiontool.com) have been developed to accomplish exactly this (see Christie et al. 2021). Transparency in how evidence contributes to decision-making would help to assess the degree to which fish and wildlife management and conservation decisions are truly evidence-informed (Adams & Sandbrook 2013) or evidence-based (Haddaway & Pullin 2013) in BC (Government of British Columbia 2017) and beyond (as per Organ et al. 2012; Artelle et al. 2018a; Ryder 2018; Powell 2020).

6.1 Future directions

The research in this thesis generates further questions. I outline suggestions for future research inspired by this work. Future research is needed on which solutions (e.g., project researcher-practitioner knowledge and sharing interfaces) effectively transform barriers to evidence-informed decision-making into an enabler, and specifically, how each of these enablers facilitate the use of scientific evidence in conservation practice (Walsh et al. 2019). Research from Rose et al. (2018a) suggests that public support could improve prospects for evidence-informed decision making in conservation and environmental management – assessing this empirically with a case study or mining existing data sets would help reveal how much influence the public has in enacting these desired changes.

I have assessed how wildlife managers evaluate knowledge, but how they procure it in organizational cultures with capacity shortages and information overload is also important. Whether potential knowledge users perceive claims as more knowledge-based or more advocacy-based and the factors which predict this outcome would benefit evidence-based management and conservation. It would be important in any follow-up work to distinguish how different types of knowledge might be more or less helpful in answering questions that mix empirical data and values (e.g., what is the sustainable level of fish harvest for this lake?), what that information would be, and how it would be used. Also, important to consider in future work is the extent to which wildlife managers ask questions that involve values (e.g., should trout be introduced in this lake where they are currently and/or historically not present?) to Indigenous rightsholders and local stakeholders.

In terms of knowledge brokerage, there are several organizations that fulfill models of evidence bridgers (e.g., FRI Research https://friresearch.ca/, Electric Power Research Institute https://www.epri.com/, National Council for Air and Stream Improvement https://www.ncasi.org/) that provide examples of how they can influence the use of evidence in conservation and environmental management practice (see Kadykalo et al. 2021a). Doing deep investigations into how these knowledge brokers operate, and which factors facilitate evidence exchange and use of evidence is vital to improving the use of evidence in conservation and environmental management in building further knowledge brokerage capacity. In this space, it would also be helpful for an investigation into the interest and capacity to form "a college for conservation decision making" which could track which practitioners need evidence regarding which issues and which evidence bridgers are synthesizing evidence for which broad issues (Kadykalo et al. 2021a)

Future research is also needed to determine what extent adjacent governance jurisdictions coordinate to manage interregional ecosystem services/disservices flows, such as fisheries, and how they government agencies compare to and learn from policies in other jurisdictions. Further, empirical investigations of co-assessing (Sutherland et al. 2017) and co-producing knowledge (Cooke et al. 2020; Norström et al. 2020) and applying the 'Two-Eyed Seeing' (Reid et al. 2020) approach are needed to assess their effectiveness and limitations in wildlife management contexts. A study on the use of Conservation Evidence's (https://www.conservationevidence.com/) subject-wide evidence syntheses found that well-summarized evidence can direct management choices away from ineffective interventions when it is timely and packaged in a form the meets the needs of practitioners (Walsh et al. 2015). The same approach could be adopted, for example, to investigate whether co-assessed or co-produced knowledge affects practitioner decision-making and the role of evidence in decisions. Lastly, and most ambitiously, if environmental decisions are becoming less evidence-based and more economically or politically based, we must ask honest questions as for the reasons why (e.g., Is this a product of management becoming more democratized and consensus-driven? Is there lower evidence literacy? Is the profusion of information or mis-information detrimental to evidence use? Are echo chambers which influence decisions more prevalent and more biased? etc.).

Appendices

Appendix A

A list of 19 example commentary papers on the 'knowledge-action' or 'research-implementation' gap in conservation and environmental management. See also *Biological Conservation*'s Special Issue on "Implementation Spaces in Conservation Science": https://www.sciencedirect.com/journal/biological-conservation/special-issue/109PW5Z450C

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Appendix B

I systematically searched (May 2020) in Web of Science – Core Collection (309 records) and Scopus (452 records) for relevant articles using search terms listed below. Each record was screened based on its title and/or abstract for relevance. I specifically sought studies that surveyed conservation practitioners, using interviews or questionnaires, to determine how they make decisions. I further reviewed the bibliographies of all selected articles for any additional relevant studies that might have been missed in the initial search.

Search terms and phrases used:

((TITLE: “evidence” OR “knowledge” OR “information” OR “scien*” OR “literature”) AND (TITLE: "use" OR "used" OR "using" OR "utility" OR "gather*" OR "role" OR "base*" OR "consider*" OR “exchange” OR “mobilization” OR “mobilisation”) AND (TITLE-ABS-KEY: “manager*” OR “farmer*” OR “land*owner*” OR “industry” OR “industries” OR “commercial” OR “stakeholder*” OR “rancher*” OR “resident*” OR “household*” OR “ENGO*” OR “NGO*” OR “proponent*” OR “citizen*” OR “practitioner*” OR “knowledge user*” OR “end-user*”) AND (TITLE: “conservation” OR “biodiversity” OR “ecology” OR (“environment*” AND “manag*”) OR (“natural resource*” AND “manag*”) OR (“environment*” AND “practice”) OR (“environment*” AND “science*”)))

Appendix C

Citations in the main text and Table 2.3 linked to respondent sources and illustrative quotations. (A-academia, B-BC Hydro, E-ENGO, F- Freshwater Fisheries Society of BC (FFSBC), P-private environmental consultant, R-retired provincial government employee).

Citation	**Source**				**Further Details**	**Illustrative Quotations**
	n (%)	**FN**	**GOV**	**STKH**		
Indigenous Knowledge (*n* = 65)						
1	33 (51%)	1f/3m	4f/14m	11m (4A,2F,4P,1R)	Many respondents recognized Indigenous knowledge as less quantitative than other knowledge types and more "anecdotal", "traditional", "experiential"; shared using narrative 'stories'.	
2	6 (9%)	-	3m	3m (2B,1P)		
3	14 (22%)	-	1f/6m	1f (1F)/7m (1A,2E,2F,1R)		
4	15 (23%)	1f/2m	1f/4m	7m (1A,3E,1P)		
5	11 (17%)	1m	8m	2m (1B,1P)	i.e., "duty to consult and accommodate", "reconciliation", "treaties", "compensatory mitigation", United Nations Declaration of Rights for Indigenous Peoples	
6	7 (11%)	-	1f/3m	3m (1B,1E,1R)		
7	-	-	Interview #54; female; FLNRORD affiliation	-		The challenge that I have is that we're not currently set up to protect that information with the Freedom of Information and Protection of Privacy Act (FIPPA). And so, the Indigenous groups really want to make sure that what they're telling us is not going to be available to the public. But we're not currently set up, at least to the best of my

						knowledge, to ensure that. And so, there's some changes I think that need to happen to the Act itself to enable those protections to be put in place for sensitive and cultural information. Information that Indigenous peoples are okay with being publicly available, if it were to go through a Freedom of Information request.
8	6 (9%)	1m	1f/2m	2m (1B,1E)		
Local Knowledge (*n* = 65)						
9	38 (59%)	1m	4f/18m	1f (1F)/14m (6A,3E,2F,1P,2R)	Similar to Indigenous knowledge, respondents recognized distinct attributes of local knowledge (i.e., "anecdotal", "experienced", "historical", "stakeholder-type"), mostly used in reference to the knowledge held by fishermen.	
10	2 (3%)	-	-	2m (1B,1F)		
11	12 (19%)	-	6m	6m (2A,3E,1P)		
12	4 (6%)	-	1f/1m	2m (1E,1F)		
13	9 (14%)	-	5m	4m (1E,2F,1P)		
14	-	-	Interview #14; male; FLNRORD affiliation	-		It can take you off in the wrong path. In our roles as civil servants, in as much as we can, we try to provide objective management and management decisions. So, when you're getting constantly lobbied by stakeholder groups to take something, or do this instead of that, we have to be very careful as to how we sort of incorporate that information and manage that sort of particular type of lobbying.

15	-	-	Interview #33; male; FLNRORD affiliation	-		It is possible to over credit those folks with inherent knowledge on how they think things should be managed, despite the fact that they should reasonably not know how to manage at all based on what they do, which is normally consume, or act as consumers. So, I think at times we use this local knowledge, particularly where it can help manage local fisheries in a way where we have certainty around meeting core objectives.
16	-	-	-	Interview #51; male; FFSBC affiliation		Anglers will come talk to us advocating for the consumptive use – killing of wild summer run Steelhead. Whereas we're trying to manage for a different outcome. So, it's made for very adversarial relationships. (Interview #51; male; FFSBC affiliation).
The Interface Between Indigenous and Local Knowledge and Management						
17	29 (45%)	2m	4f/10m	13m (3A,1B,2E,3F,3P,1R)		
18	9 (14%)	-	3f/3m	3m (1B,1F,1R)		
19	2 (3%)	1m	-	1m (1P)		
20	3 (5%)	-	1f	2m (1A,1F)		
21	7 (11%)	-	1f/3m	3m (1A,1P)	i.e., on how the populations are doing and what kind of management strategies need to be used	
22	9 (14%)	1m	1f/4m	5m (1A,1B,1E,2F)		I think the day has come where we have to work more closely with BC's First Nations. The role of traditional ecological knowledge is significantly more important today compared to 25 years

						ago. I also strongly believe the fisheries management paradigm has shifted from a "government-led top-down approach" to a much more collaborative, community-oriented model where government agency staff work as partners with the other sectors. (Interview #49; male; ENGO affiliation)
23	6 (9%)	-	3f/2m	1m (1B)		
24	2 (3%)	-	1m	1m (1E)		
25	3 (5%)	1m	1m	1m (1R)		
26	3 (5%)	-	1m	2m (1F,1R)		
The Interface Between Indigenous and Local Knowledge and Western Scientific Knowledge						
27	-	Interview #22; male; Indigenous government natural resource branch affiliation	-	-		First Nations have been practicing science forever. It's just it's how they do it. So, instead of using null hypothesis and process by elimination they use a multipath. They've been using science. I don't want to say that the two are not aligned when in fact they are. It's always learn-by-doing.
28	1 (2%)	1m	-	-	i.e., experience, beliefs, norms, and relationships	
29	4 (6%)	1m	1f/2m	-		
Western Scientific Knowledge (*n* = 65)						
30	64 (99%)	1f/3m	7f/25m	1f (1F)/27m (6A,2B,5E,5F,6P,3R)		
31	42 (65%)	1f	5f/20m	16m (4A,2B,3E,4F,2P,1R)		

32	-	-	Interview #48; male; FLNRORD affiliation	-		I mean I more manage organizations, people, and resources. I don't actually really manage specific decision points around, for instance, making recommendations on stocking or making recommendations on angling harvest or retention and those sorts of things.
33	5 (8%)	-	4m	1m (1F)		
34	11 (17%)	-	1f/9m	1m (1E)		
35	10 (15%)	-	1f/7m	2m (1E,1F)		
36	7 (11%)	1m	3m	3m (2F,1P)		
37	32 (49%)	2m	1f/13m	1f (1F)/15m (3A,2B,2E,5F,3P)		
38	11 (17%)	-	7m	4m (1A,2F,1P)		
39	8 (12%)	1m	3m	4m (1A,1B,2P)		
40	25 (39%)	1m	2f/11m	11m (4A,3E,3P,1R)		
41	13 (20%)	-	1f/6m	1f (1F)/5m (1A,1F,2P,1R)		
The Diminishing Role of Evidence in the Decision-Making Process						
42	18 (28%)	-	4f/14m	-		
43	6 (9%)	-	-	6m (1A,1E,2F,2R)		
44	4 (6%)	-	-	4m (1B,2E,1P)		
45	18 (28%)	-	3f/9m	6m (1A,2E,2F,1R)		
46	6 (9%)	-	1f/3m	2m (1F,1P)		

47	6 (9%)	-	1m	5m (1B,1E,1F,1P,1R)		
What is ‘Reliable’ or ‘Unreliable’ Knowledge? (*n* = 63)						
48 (see also main-text citation 18)		Interview #56; female; Indigenous government natural resource branch affiliation				From a cultural perspective…yeah that's outside of my realm to be honest, like what is valid and what isn't, that's not really my call. It's all considered valid from my perspective until I hear otherwise. So, I think it's quite early with that information.
49	-	-	-	Interview #7; male; private environmental consultant affiliation		I guess it depends on what you call reliable. So, I mean scientific information has the whole idea that it has to be repeatable and things like that. I don't think you can actually look at traditional knowledge through the same kind of lens. They're different types of information.
	-	-	Interview #54; female; FLNRORD affiliation	-		I mean I can't speak to what Indigenous folks would view as reliable information, but I know that it's different. I think that there's a general tendency to view Indigenous or traditional ecological knowledge as less reliable, because it's not reproducible in the same kinds of ways. It depends a lot on oral history. It depends a lot on an individual's perspective and point of view and experience.
50	-	Interview #27; male; Indigenous government natural resource branch affiliation	-	-		For traditional use, there's also ways to collect that data. There's research methodology and survey techniques, but I'm less familiar with that. There are ethical procedures you need to go through to make sure you're collecting things in a way that is not biased. So, there are best practices for that kind of data as well. It's

						all reliable and robust data if you collect it reliably. The devils in the details and whatever tools you're using. There’s a burden of proof, we call it strength of claim.
	-	-	-	Interview #12; male; academia affiliation		If I go out and start asking people a few things and their answers tend to be consistent then you start relying more on that. But when some person says one thing and then you go ask another person who should have the same knowledge and they tell you a different story, then you start to have uncertainty in what is going on. But if the story is consistent then you start relying on it more.
	-	-	Interview #14; male; FLNRORD affiliation	-		In terms of First Nations knowledge, it could be considered to be more useful if it's multiple individuals coming forth with the same information. So, it's like developing confidence intervals around any particular piece of data we collect if three people are saying it versus one. The weight of evidence starts to build. So, we're learning how to deal with that.
51	6 (10%)	-	1f/2m	3m (1A,1E,1P)		
52	-	-	Interview #33; male; FLNRORD affiliation	-		There are always stories around abundance which are hard to fully understand or describe contemporarily. It’s always intriguing when we hear stories of a hundred-pound Chinook or whatever it is…pitch-forking Atlantic salmon onto the farm fields in Newfoundland. There are often cases where I wonder if our shifting baseline has created a condition now where we're consistently pigeonholing ourselves and

						discounting our envisioned potential for watersheds. So, we may have credible stories from individuals based on an accurate recollection of their experience on the land base, but we can do nothing but ignore that as crazy because it's not within the context of modern science. That being said, we have a 40-year history of pretty high-quality data collection here, maybe 50 now. But that's a pretty short-term view when we consider that we've been on the land base, as westerners, for probably several hundred years or more. Frankly, you can see photos of the catches of the "good old days". And so, it's very hard to understand what's reliable and unreliable. We're shifting baselines in every generation and perhaps every decade around what our expectations are.
TABLE 2.3: *Indigenous Knowledge*						
1	9 (14%)	1f/2m	4m	2m (1A,1F)		
2	24 (37%)	2m	2f/8m	12m (5A,2B,1E,1F,2P,1R)		
3	9 (14%)	1m	3m	5m (3A,1E,1R)		
4	-	-	-	Interview #57; male; academia affiliation		A lot of the scientific knowledge today, like population genetics, has only been around since the 1980s. So, for decades before genetics you're relying on people's observations of what they saw. Genetics research informed by Indigenous knowledge has shown that First Nations can be remarkably accurate.
5	5 (8%)	-	-	5m (1A,1F,2P,1R)		

6	4 (6%)	-	1m	2m (1P,1R)		
7	8 (12%)	1m	4m	3m (1B,1F,1R)		
8	5 (8%)	1m	1m	3m (2A,1P)		
9	2 (3%)	1m	1m	-		
TABLE 2.3: *Local Knowledge*						
10	12 (19%)	-	2f/6m	4m (3A,1E)		
11	1 (2%)	-	-	1m (1A)	A feedback loop was also referenced, in which information or data ("answers") are then provided back to local knowledge holders to maintain the linkage and trust in knowledge sharing.	
12	10 (15%)	-	5m	5m (3A,1E,1F)		
13	24 (37%)	-	2f/11m	1f (1F)/10m (1A,1B,3E,2F,2P,1R)	Of course, as described by a subset of respondents, these "red flags" may be informed by Community ("citizen") scientific data (e.g., Angler's Atlas, capturing fish for monitoring or inventory, creel surveys, pictures, videos).	
14	-	-	Interview # 26; male; FLNRORD affiliation	-		We have limited time and resources we can't be everywhere at the same time.
	-	-	-	Interview #38; male; ENGO affiliation		So certainly, it's an early warning signal that we can also use to raise with government agencies because there are

						many lakes that they probably don't get to for years.
	-	-	Interview #40; female; FLNRORD affiliation	-		Because we can't be in the field as often, the public are our eyes and our ears. So, we listen to them. We appreciate them telling us things.
	-	-	-	Interview #49; male; ENGO affiliation		The information can be very important as it is virtually impossible to know every watershed as well as some local residents do.
15	7 (11%)	-	3m	4m (2A,2E,1P)		
16	5 (8%)	-	4m	1m (1F)		
17	7 (11%)	-	3m	4m (1A,1F,1P,1R)		
18	4 (6%)	-	2m	2m (1A,1P)		
19	13 (20%)	-	4f/4m	5m (1A,1B,1F,1P,1R)		
TABLE 2.3: *Western Scientific Knowledge*						
20	45 (69%)	1f/2m	5f/21m	16m (2A,2B,5E,3F,3P,1R)		
21	11 (17%)	-	7m	4m (1A,2F,1P)		

Appendix D

A sample of quotations from (n = 6) respondents illustrating the political and socio-economic interference to evidence-based decision-making.

Illustrative Quotations	Respondent
My role is to provide science advice to directors and deputies. They decide what to do with it from there. It gets combined with all the other social, economic stuff. I don't see my science advice has a big role in the outcomes that are made. The decisions are generally economic based.	Interview #42; male; MOE affiliation
I think we've diverged from making science-based decisions to more social decisions. We're finding that science isn't weighing through to make the decisions because in many cases social and economic factors outcompete the science which is pretty disappointing. That's a frustrating thing as a biologist because conservation shouldn't have a back-door exit.	Interview #37; male; FLNRORD affiliation
Life in government as a decision maker, as a fisheries manager, was way easier when we were the benevolent dictators who got to make calls about fishing regulations based on the science of the day to manage a fishery. The benevolent dictator no longer exists. Decision-making in the public sector has evolved to a bun fight of consensus building and consensus building is very challenging. Consensus building in fisheries is an admirable goal, but it's been a barrier to good decision-making, I think, in many cases.	Interview #51; male; FFSBC affiliation
Typically, the regional provincial fisheries scientists were considered the folks that knew what was going on and they would make a decision, you might not agree with it, but it was considered to be in all likelihood the right thing to do, because these knowledgeable people said it was.	Interview #53; male; retired provincial government employee
I would argue at a society level it's becoming more difficult to rationalize the use of science in decision-making. I wouldn't go so far as to say it's always going to be science first for us, but we absolutely will stand by and support and defend using rigorous scientific practice and methods to provide and support our decisions.	Interview #48; male; FLNRORD affiliation
I'm seeing a shift from science-based decisions to more gut-based decisions, which is scary. The best that we can do is continue to provide the best available information, (whether it's natural science, social science, Indigenous and local knowledge) for a more wholesome picture of what an issue is. For us to provide that information up and for it to be ignored or not completely understood and for decision-makers to go with a gut feeling or to go with media reports or public opinion polls is alarming. None of which is scientifically based and none of which is very robust in the way it's done. As we move towards more wicked issues in nature like climate change, invasive species, you name it, which have cumulative effects, there's not going to be one particular way of solving it or one particular piece of information that is needed to provide the best decision. So, I think it's important we do our best to communicate the best information up to the decision-makers. I don't really have a good solid feel of where that shift is coming from. But it seems like it's not just this current government. It seems like a more global shift away from science-based decisions. Given the consensus realm that we're in, you would think that instead of going more towards a gut-based decision that you would go more towards a science-based decision.	Interview #54; female; FLNRORD affiliation

But I don't know. Maybe it's speed. For certain things it takes a long time to do it right. And so maybe that's part of it.

Appendix E

The thematic codes—criteria—associated with “reliable” and “unreliable” knowledge respectively, along with the number of respondents making mention of each theme.

Table E.3 Criteria for judging knowledge to be “reliable” (number of respondents making a mention).

	Indigenous Governments	Parliamentary Governments	Stakeholders	**Total**
Acknowledgement of assumptions, limitations, uncertainty	–	4	4	8
Claimants history with the resource	–	–	1	1
Confirmation bias	–	2	1	3
Expertise, education, training, of claimant(s)	–	5	4	9
Factual corroboration and validation	2	8	9	19
First-hand experience of claimant(s)	–	7	1	8
Language used	–	–	1	1
Longer time-horizons/Long-term datasets	–	1	1	2
Neutrality of claimant(s) (i.e., unbiased)	1	1	3	5
Peer-reviewed	1	5	8	14
Publicly available	2	–	1	3
Quantifiable/numerical	1	5	3	9
Repeatability and reproducibility corroboration	1	7	10	18
Scientific-based approach and method	1	5	6	12
Sound research design and methods	2	8	8	18
Transparency of process	1	5	1	7
Trustworthiness/reputation of claimant(s)	1	5	5	11
Total	13	68	67	148

Table E.2 Criteria for judging knowledge to be "unreliable" (number of respondents making a mention).

	Indigenous Governments	Parliamentary Governments	Stakeholders	**Total**
Anecdotal/hearsay	–	5	5	10
Bias and distortion	–	3	4	7
Citizen/community science	–	1	1	2
Claimant(s) lack of abilities or understanding	–	3	2	5
Inconsistency		4	5	9
Indigenous and local knowledge	–	3	1	4
Issue and self-interest advocacy	–	5	7	12
Limited applicability (not broadly inferable)	–	–	1	1
Opinion, conjecture, speculation	–	3	10	13
Poor or non-transparent research design and methods	–	7	6	13
Reliance on memories/recollections	–	2	3	5
Social media	–	–	1	1
Social ("soft") sciences	–	–	1	1
Uncertainty	–	3	1	4
Underestimation of claimant(s) influence	–	1	–	1
Total	0	39	48	88

Appendix F

Affiliations of the 96 non-participants (who were contacted for an interview but did not participate because they a) did not respond to my request, or b) declined to participate), grouped as members from natural resource management branches of Indigenous governments, and parliamentary governments, as well as Freshwater Fisheries Society of BC and non-governmental stakeholders.

Indigenous Governments (FN)	**n**	**Parliamentary Governments (GOV)**	**n**	**Freshwater Fisheries Society of BC (FFSBC)**	**n**	**Stakeholders (STKH)**	**n**	**TOTAL n**
Biologists	2	Assistant Deputy Minister (FLNRORD)	3	Biologists	1	Academia	4	
Fisheries Managers	19	Biologists (FLNRORD)	31	Hatchery Managers	4	BC Hydro	2	
		Directors (FLNRORD)	10	Officers and Executives	2	ENGO	2	
		Fish & Wildlife Section Heads (FLNRORD)	2			Private environmental consultants	1	
		Fisheries Advisor	1					
		Managers (FLNRORD)	2					
		Permit Clerks (FLNRORD)	3					
		Policy Analyst (FLNRORD)	1					
		Policy Leads (FLNRORD)	2					
		Regulations Officers (FLNRORD)	1					
		Regional Resource Manager (DFO)	1					
		Science Branch (DFO)	1					
		Provincial Fish Science Specialist (Government of Alberta)	1					
Non-Participant Sub-Total	(21)		(59)		(7)		(9)	96

Appendix G

Additional results for Chapter 3: Uncertainty, anxiety, and optimism: Views of stakeholders, Indigenous rightsholders, and regulators on the past, present, and future status of Rainbow and Steelhead Trout fisheries governance in British Columbia

Table G.1 Open-ended interview questions analyzed in this chapter and to which interviewee group they were directed: Natural resource management branches of Indigenous governments (FN); parliamentary governments (GOV); representatives from Freshwater Fisheries Society of BC (FFSBC) and nongovernmental stakeholder groups (STKH) (Table 3.2). Also included are relevant survey questions analyzed in this chapter which were directed to n = 1029 rainbow trout and steelhead anglers. n/a = not applicable.

Interview Question	Interviewee Group	Survey Question
Conservation Status Assessment of Rainbow Trout Populations		
In your opinion, do you think that wild rainbow trout populations are currently threatened [under threat]? [*If yes*] What do you think are the primary causes of these threats? Why do you think that? [*If no*] Why do you think that?	ALL (n = 65)	Please indicate your level of agreement or disagreement with the following statements: - I believe that [previously selected fish] populations in British Columbia are currently at risk of decline due to environmental changes
		In your opinion, how much of a threat do the following factors pose to [previously selected fish] populations? – Agriculture, Climate change, Commercial bycatch, Dams, First Nations fishing, Fish diseases, Fish farming/Aquaculture, Forestry, Habitat alterations, Invasive species, Mining, Predation, Recreational fishing, Residential & commercial development. Water quality
		In your opinion, over the past ten years, water temperatures of the waters you regularly fish in British Columbia...
		In your opinion, over the next ten years, water temperatures of the waters you regularly fish in British Columbia...
		In your opinion, climate change in British Columbia is...

Interview Question	Interviewee Group	Survey Question
		Please indicate your level of agreement or disagreement with the following statements: - I believe that climate change will not harm [previously selected fish] populations in British Columbia for many years
		Please indicate your level of agreement or disagreement with the following statements: - I believe that climate change will never harm [previously selected fish] populations in British Columbia
Ensuring the Long-term Sustainability of Rainbow Trout Fisheries in British Columbia		
In your opinion, what can or should be done to ensure the long-term sustainability of rainbow trout fisheries in British Columbia?	ALL (n = 65)	n/a
Managing Wild Populations Versus Stocked Populations		
As a manager, do you spend more time managing wild populations or managing stocked populations? Approximately how much time between these two?	GOV, FFSBC (n = 39)	Are you able to differentiate a wild and a hatchery reared fish?
Do you see a distinct difference between these two objectives? Which is more important from an organization and also a personal perspective?		Do you treat wild and hatchery-raised fish differently?
Rainbow Trout Management Plan		
Are there plans/have there been discussions about a potential provincial rainbow trout management plan? If yes, explain details and timeline. If not, do you think there should be one? And what are the limiting factors?	GOV, FFSBC (n = 39)	n/a
The Most Challenging Aspects of Rainbow and Steelhead Trout Management and Conservation		
What are the most challenging aspects of your work?	GOV, FFSBC (n = 39)	n/a
Contact With Stakeholders		
		n/a

Interview Question	Interviewee Group	Survey Question
Do you have direct contact with stakeholders in the course of a fishing season? *[If yes]* Which ones? How frequently? In what ways?	GOV, FFSBC (n = 39)	
Stakeholder Input, Feedback, Consultation in Decision-Making		
How important is stakeholder input/feedback/consultations in your decision-making?	GOV, FFSBC (n = 39)	n/a
Balancing Different Demands and Interests of Stakeholders in Decision-Making		
How do you balance the different demands/interests of stakeholders in your decision-making? How do you prioritize these competing demands/interests?	GOV, FFSBC (n = 39)	n/a
Prioritizing Conservation Concerns in Decision-Making		
In your opinion, at what point do stakeholder interests or demands override potential conservation concerns?	GOV, FFSBC (n = 39)	n/a
Criticisms of Decisions Made with Respect to Fisheries Management of Rainbow Trout Populations		
As you know, some people are critical of the decisions made with respect to fisheries management of rainbow trout populations. What are the most common criticisms that you hear? What do you personally think of these criticisms? [In your opinion, are these criticisms valid?]	GOV, FFSBC (n = 39)	n/a

G.1 Conservation status assessment of rainbow and steelhead trout populations

Several participants acknowledged that environmental changes may favour rainbow trout over other cold-water endemic species such as Bull Trout (*Salvelinus confluentus*) and Arctic Grayling (*Thymallus arcticus*) which are likely to be outcompeted.

Three unique threats were mentioned by interviewees that were not identified in the development of the angler survey: abstraction of water, droughts (including low flows), and hatchery and stocking activities (i.e., unregulated stocking, hatchery overuse). These provide second-tier greater detail to perceived first-tier threats like habitat alterations and climate change

Interview and survey respondents recognize that many of the identified threats to anadromous and non-anadromous wild rainbow trout are related and interacting. Several interviewees highlighted the cumulative nature of these threats -- that when taken together present extinction risk in the form of "death by a thousand cuts" (Interview #50, FFSBC).

G.2 Ensuring the long-term sustainability of rainbow and steelhead trout fisheries in British Columbia

Interviews responses of what can or should be done to ensure the long-term sustainability of rainbow trout fisheries in BC mirrored criticisms. Forty percent of all interviewees mentioned inventorying and long-term monitoring of wild populations as a practice to ensure the long-term sustainability of rainbow trout. Mentioned in similar numbers by interviewees was the need to be proactive at protecting habitat, particularly water level, flow, and temperature requirements for all fish life stages. Relatedly, interviewees called for exploring the variability in, and resiliency of populations of rainbow trout and for increased resources for government fisheries managers. The following quotation captures the call for increased resources, "Governments need to significantly ramp-up base funding and staffing levels, province-wide, to facilitate more hands-on management by provincial biologists. Alternately, they need to create a more robust system of discretionary annual grants for the ENGO sector to pursue rainbow trout related conservation initiatives." (Interview #49, retired provincial government employee). Repeatedly, interviewees stated the need for a specific, clear, and consistent management plan and framework. More on this in the Section G.4 below 'Rainbow trout management plan'. Suggested by some interviewees, was a re-structuring of FLNRORD – ensuring fish, fish habitat, aquatics research and management are all within the same department and ministry, and that the fish and wildlife branch be independent of decisions compromised by industry interests like forestry.

Of course, several interviewees pointed out, all these practices to ensure the long-term sustainability of rainbow trout ultimately depend on political will. Moreover, they identified that levers and legislative tools available to fisheries managers are discrete and limited, and many decisions concerning long-term sustainability of fish (e.g., land use impacts), are outside of the scope of a typical fisheries program.

G.3 Managing wild populations versus stocked populations

In this sample, slightly more parliamentary government and FFSBC interviewees reported managing stocked populations of rainbow trout (50%), compared to wild populations (43%). This distinction was contingent on job title, role, and location. For example, biologists who are responsible for the small lakes program spend more time managing hatchery reared stocked populations; biologists who are responsible for the large lakes program, stock assessment, or in locations with few stocking programs (e.g., Skeena region) or large lakes (e.g., Kootenay region) spend more time managing wild populations. However, across an entire fisheries program, respondents reported that the time spent on managing stocked or wild populations is fairly even – with two interviewees assuming this 50/50 balance within their personal workload. All respondents to this particular question, saw a distinct difference between wild and stocked populations of rainbow trout, with clearly different objectives. This is captured in the following example, “We treat them very differently. The objectives are quite different on hatchery, stocked systems. The intent is to maximize the value of those fisheries, right, get as many people out there fishing as possible. Providing fishing opportunity. Providing harvest opportunity. Providing variety of opportunity. Versus on the wild side, it's quite the opposite where we're very conservative and look to move effort from those wild populations onto our stocked fisheries strategically so we can mitigate potential impacts to those [wild] stocks” (Interview #5, FLNRORD). Interviewees discussed having more control over factors affecting stocked populations, i.e., more levers to manipulate them. For wild populations, respondents discussed them in the context of conservation – making sure all aspects of their life (stages and habitat) are protected and focusing on sustainable harvest rates.

From an organization perspective, conservation of wild populations of rainbow trout were described as more important and of higher priority by mandate than stocked populations. However, many interviewees provided a more nuanced response. Describing that in practice, wild and hatchery supplemented stocks of rainbow trout are equally important in management. For example, “I don't think there's really a dichotomy there. It's one big fishery. Both those things are important. One has more conservation value, one has more recreational value. So, I wouldn't be able to choose one over the other.” (Interview #20, FFSBC). Stocked populations of rainbow trout were considered more important for angler stakeholders. Providing recreational opportunities, and thus contributing to local economies. Many respondents pointed out that managing hatchery reared fish *is* functionally managing for wild stocks. That is, hatchery reared fish reduce pressure on and relieve wild fish by meeting the demand for angling and directing fishing pressure to stocked lakes. From a personal perspective, respondents described wild populations of rainbow trout as more important, in terms of conservation and biodiversity and ecological values.

Both rainbow and steelhead trout angler survey respondents claim to be able to differentiate wild and hatchery reared fish, with this self-professed detection more prominent in steelhead anglers ($p < 0.001$) (Figure G.1A). Both types of anglers vary in terms of whether they treat wild and hatchery-raised fish differently, with steelhead anglers slightly more likely to treat wild and hatchery fish differently ($p < 0.05$) (Figure G.1B). A common response for treating wild and hatchery fish differently were that anglers were more likely to retain and harvest a hatchery fish opposed to a wild fish. Conversely, many anglers stated they released all fish regardless of whether it was wild, or hatchery raised.

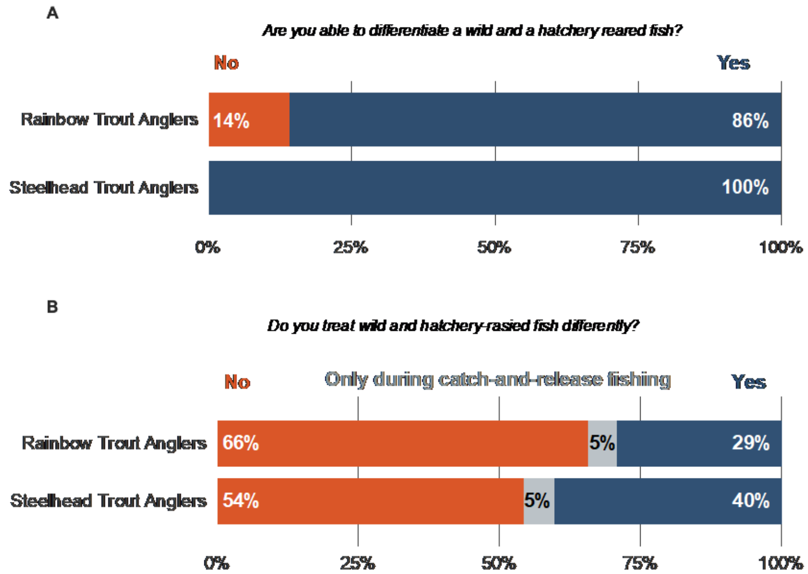


Figure G.1 Stacked bar plot of angler responses to online survey questions. A: rainbow trout anglers, n = 711; steelhead trout anglers, n = 133; B: rainbow trout anglers, n = 598; steelhead trout anglers, n = 129.

G.4 Rainbow trout management plan

Fourteen FLNRORD employees indicated that there are no specific plans or discussions about a potential rainbow trout management plan, and no one suggested anything to the contrary. Some respondents referenced the *Provincial Framework for Steelhead Management in British Columbia* (2016) which provides guidance for abundance-based steelhead trout management. Others noted that there are regional small lakes (<1000 ha) fisheries management plans, focused on socking and angling management, but not on wild rainbow trout or in other habitats *per se*.

Most interviewees (70%) were supportive of or thought a provincial rainbow trout management plan is necessary. Several interviewees were undecided (24%), while few (6%) were non-supportive. In the latter group, respondents suggested other species (e.g., Arctic Grayling *Thymallus arcticus*, Sturgeon sp. *Ascipenser*, westslope cutthroat trout *Oncorhynchus clarkii lewisi*) were a higher priority or thought management in the province is adequate.

Interviewees specified that a management plan should provide long-term direction and set specific priorities and objectives including sustaining populations and diversity of wild indigenous rainbow trout.

The creation of a provincial management plan was described as a significant undertaking, and many interviewees questioned the degree to which a plan could be relevant, implementable, and useful (i.e., articulate various meaningful management strategies and truly inform local management and practice). Interviewees described that a plan would need a balance in scope between something that is high-level, foundational, and overarching with a complimentary component that is more specific and operational. In the former, interviewees imagined a set of generalized, concrete and consistent province-wide objectives which would provide useful and forward-looking strategic guidance for decision-makers. In the latter, interviewees cited challenges associated with the large diversity of not only rainbow trout stocks, but also with the highly geographically-differentiated province of BC. Many interviewees imagined specific operational management plans focused on the regional- or watershed-scale. Several respondents were assertive in declaring that a management plan should not be species-specific but should instead be holistic and ecosystem-based.

Respondents described such a plan needing to be implementable, holding people accountable (through compliance and enforcement), and ensuring management agencies are adequately staffed. According to interviewees, the prospective plan should also be linked to assessing conservation status of rainbow trout and to the management actions available to protect them. Management actions such as reducing interception and by-catch in commercial and non-selective First Nations fisheries. Careful planning would allow governments to move away from reactive, policies and regulations described several interviewees.

In this planning process interviewees described the inclusion of First Nations (Indigenous traditional values and knowledge systems) and human dimensions (i.e., values, preferences, attitudes, behaviours), especially also non-angling values. “It's pretty hard for the general public to appreciate fish because they're hard to see. What's key for the long-term sustainability of rainbow populations is for the government not to unduly prevent people from appreciating them, whether it's by fishing or whether it's by other means by whatever is socially acceptable way of doing so. Including non-angling public is a challenge for government now.” (Interview #19, FLNRORD). Interviewees also envisioned a management plan developed around stock assessments and prescriptions differentiating hatchery-reared, feral and wild systems/populations; anadromy versus non-anadromy; protection of habitats from a changing climate and other anthropogenic threats; and the articulation of rainbow trout populations, eco-types, and diversity.

G.5 The most challenging aspects of rainbow trout management and conservation

A major challenge to managing rainbow trout fisheries is a lack of sufficient resources and capacity (funding, staff, time) to meet internal and external expectations – mentioned by 54% of interviewees.

Illustrative quotations from interviewees demonstrating a lack of sufficient resources and capacity (funding, staff, time) to meet internal and external expectations for rainbow trout fish and fisheries management.

- “We cover a large area, have a lot of lakes, a lot of unique challenges in terms of geography. It's almost a 12-hour drive to go from one end of the area to the other, twelve

or more hours. And I have one person for all of it. So, there's a lot of work we can do. There's a lot of work we probably should be doing we just don't have the time to do it."
(Interview #10, FLNRORD)

- "Lack of staffing resources has been a big one. I mean it is me and [my co-worker] covering sixteen hundred lakes. People will phone and say hey what about this lake? And I'm like, I've never heard of it, sorry. I can't know them all. We can get around that like I mentioned – we can hire staff but it's always a struggle to have enough money and time with the staff we have. So, if we had more resources and I think we could do a lot more."
(Interview #18, FLNRORD)

- "Essentially, we have to fund our own positions. The government doesn't give us any money. You get a desk and a computer and a list of tasks and objectives. So, if I want a co-worker, I have to go find the money to hire a co-worker and then I got to work with the public service bureaucracy to get that person hired. it's just a lack of resources and having to do everything yourself."
(Interview #42, MOE)

According to respondents, this also includes a lack of sound ministerial information and data on rainbow trout to support decisions. This information or data may exist but is claimed to be dispersed, not well organized and not readily available – limited by poor data management. To cope with these challenges, provincial government employees claim to hire or partner with seasonal field staff (e.g., contracted consultants, students, volunteers, First Nation communities, etc.). These challenges also compel fisheries managers to prioritize and focus efforts on the most meaningful and impactful projects, despite recognizing that funding decisions which ultimately determine priorities are out of their control. Management plans were cited here as being potentially helpful in prioritizing objectives.

The other large theme interviewees discussed as a challenge was dealing with people and navigating complex social and political issues and relationships. "I would say the most challenging component is reconciling various interests on the land base or amongst various parties who have an interest in a limit resource…in an increasingly skeptical world" (Interview #48, FLNRORD). Interviewees focused on the necessity of effective two-way communication, for example "being able to get your message across effectively so that people understand…getting that social interaction, getting the message across, understanding how to resolve social issues is where I spend probably 50 percent of my time" (Interview #37, FLNRORD). Interviewees also spoke of jurisdictional challenges and the 'fractured components to administering fisheries in BC' which hamper flexibility in management. They also scrutinized FLNRORD for frequent changes in its organizational function, role, and nomenclature. For example, "There's a major jurisdictional split between federal and provincial government and in the provincial government there's major splits in function and role and organizational structure. There's First Nation agencies now in play and of course, stakeholders as well." (Interview #19, FLNRORD).

A particular challenge flagged by FFSBC is that angler license fees for senior citizens (aged 65 and older) have been stagnant at $5 CDN since 1994, compared to fees for ages under 65 at $36 CDN. As the large baby boomer generation population ages into senior-hood, the province and FFSBC angler-derived license revenue will be impacted significantly.

G.6 Fishery actors

G.6.1 Contact with stakeholders

Nearly all interviewed parliamentary government and FFSBC employees (85%) have direct contact with stakeholders in the course of a fishing season. This contact was often described it as frequent and continuous interactions throughout the year. The specific stakeholders which are involved in such interactions included from most to least frequently mentioned: recreational anglers (64%), fish and wildlife game (i.e., rod and gun) clubs (62%), First Nations (33%), local conservation organizations (e.g., The BC Wildlife Federation) (28%), the general public (26%), angling guides and outfitters (15%), FFSBC (8%), local government (5%), tourism associations (e.g., Destination BC, visitor centres, BC Fishing Resorts and Outfitters Association) (5%), private environmental consultants (5%), and commercial and industry users (5%). Stakeholders also extend beyond resource users, to individuals and groups impacted by resource decisions such as vendors, tackle shops, hotels, and restaurants. Such interactions take place over the phone (39%), at in-person meetings and presentations (39%), or by email (31%).

To help manage such interactions formally, many interviewees (39%) mentioned Regional Angling Advisory Committees (which meet at least every two years in a formalized stakeholder engagement process to solicit stakeholder input from each region in developing angling regulation changes) and the Provincial Angling Advisory Team (which meet twice a year to advise the provincial government natural resources ministry and FFSBC in terms of policy objectives and funding of projects that benefit recreational fisheries). Such formal processes are chaired by the province and feature representatives from FFSBC, The BC Wildlife Federation, BC Fishing Resorts and Outfitters Association, The British Columbia Federation of Drift Fishers, The British Columbia Federation of Fly Fishers, Guide Outfitters Association of British Columbia, North Coast Steelhead Alliance, Steelhead Society of British Columbia, and BC conservation officers.

G.6.2 Stakeholder input, feedback, consultation in decision-making

Stakeholder input, feedback, and consultation is important or very important in government employee and FFSBC decision-making as indicated by 90% of these interviewees. Several interviewees qualified their responses, that the power to incorporate stakeholder feedback in decision-making may be limited: “It’s very important, but having said that, we’re not empowered to make that many decisions” (Interview #40, FLNRORD), “Our toolbox is fairly constrained in that respect” (Interview #14, FLNRORD), “the process only allows me to say yes or no matter what I think about in terms of fisheries values potentially impacted. So not all processes allow me to balance the different interests” (Interview #16, FLNRORD). Interviewees described seeking stakeholder input and feedback to illuminate interests, preferences, concerns, and perceptions of management actions.

Illustrative extracts from interviewee describing seeking stakeholder input and feedback to illuminate interests, preferences, concerns, and perceptions of management actions.

- “To understand what our stakeholders know; my sense or understanding of where the stakeholders are sitting: are they happy or unhappy? Whether that's with government or with the Society. Are they upbeat or are they positive on what's going on in sport fishing in BC? And by and large because of what's happening in British Columbia with regards to stock status for salmon and sport fisheries and freshwater, my gut is telling me in my

interactions with anglers that generally they're pessimistic about angling opportunities in BC because of the negative press that's coming with all of the Department of Fisheries and Oceans salmon closures. The doom and gloom that's been reported in the general media, the restriction of angling opportunity. Getting that sentiment or understanding of what angling stakeholders think and how they perceive those often-necessary fiscal management actions that are being undertaken by the province or by the federal government, it's helpful in my role. We'd like to hear about it up front."
(Interview #51, FFSBC)

Seeking stakeholder input and feedback was perceived as necessary in making informed management decisions around products, programs, and regulations that attempt to optimize benefits for the public. Proposed freshwater fishing regulation changes are an area where input is especially sought. Interactions also include informing stakeholders around decisions made, educating them about the state of the resource and to gain their support and buy-in.

FLNRORD government employees recognize that angling clubs and associations, which are often the most vocal, represent a very small proportion of the full angling community. For example, "We really try to engage as many people as we can, but we realize that the clubs represent a very small proportion of anglers in general. I think it's like 5 percent of the people from what I understand, and we know their viewpoints are not necessary aligned with the majority of anglers out there" (Interview #35, FFSBC). For this reason, stock assessment information and the current conservation status of a particular fishery tend to outweigh most stakeholder information or preferences according to these interviewees. That is, stakeholder input is important for informing decisions, but does not often result in tipping decision, whereas science is the purported foundational crux. Decisions are claimed to maximize benefits for all residents of BC (including stakeholders) and for the health of the resource, and not for a certain stakeholder group or individual.

G.6.3 Balancing different demands and interests of stakeholders in decision-making

Fisheries managers (i.e., FLNRORD government and FFSBC employees) do not often find themselves in scenarios where they must balance competing demands and interests of stakeholders in their decision-making. "In terms of a lake association versus an angling community, typically they're not that different and typically the goal is to always have the best fishery in the system preserved. And in that sense, I haven't run into too many conflicts" (Interview #16, FLNRORD). Some government employees clarified that in their roles and positions they are not technically statutory decision makers, and that they simply inform decision makers on issues that are not generally overly complex. However, the rare times there are competing demands and interest amongst stakeholders (examples in Table G.2), things become very complicated and difficult, especially for statutory decision makers. When decisions are complex or have significant social value, FLNRORD government employees rely on a combination of provincial policy (regulations, statutes, legislation) and experience (e.g., professional opinion, other departments/agencies, Ministry Headquarters in Victoria, executives at FFSBC) for advice and consistency. Concerning provincial policy, FLNRORD government employees referred to an "allocation framework", a "hierarchical policy" which helps guide which group has first rights – in it, conservation of species is the highest priority, second to that is First Nations rights and title, third is recreational opportunity (i.e., general angling public and other stakeholders), and fourth is commercial opportunity (e.g., angling guides and outfitters, international anglers). For example, a recreational fishery may be entertained after a populations long-term sustainability and First Nations sustenance needs are addressed, “Is there enough to support First Nations harvest for sustenance as a food source? If we can meet conservation plus First Nations needs and still have extra, then can we open it up to recreational fishing or harvest? So, when we get down to recreational harvest, we've gone through a check box that the population is stable and viable” (Interview #10, FLNRORD). While some decisions, and situations are too complex to address with policy alone, there is some desire from interviewees for more consistent and clearer policy guidance, for example, in working with aquatic invasive species and First Nations. “One of the criticisms we often get in our stakeholder engagement process is: five years ago, it was this way, or under this biologist it was this way. And that's probably just due to a lack of consistent provincial policy on some things” (Interview #31, FLNRORD).

Table G.2 Situational examples in which stakeholders may have competing demands or interests relating to freshwater fisheries in British Columbia as provided by parliamentary government (GOV) and FFSBC employees (n = 39).

Stakeholder A	Stakeholder B	Reference
Wants to launch a fishing vessel but there are no public boat launches on Paul Lake	Private landowners have private boat launches	Interview #18, FLNRORD
General public wants bigger fish	A fishing lodge resort's clients want smaller fish that are more catchable	Interview #18, FLNRORD
Anglers desire motorized boats on Swan Lake	Swan Lake is a wildlife management area and the birding public wish wetland habitat to remain undisturbed	Interview #21, FLNRORD
Fly fishing clubs want fly fishing only fisheries and want lakes closed in the winter	Ice fishers want to fish in the winter, Drift fishers want terminal gear	Interview #24 and 40, FLNRORD; Interview #59, retired provincial government employee
Angers interested in a more quality/trophy/catch and release-oriented fishery (large boat fisheries)	Anglers interested in a more harvest-oriented fishery with lower sizes (small boat fisheries or off-shore)	Interview #5, 32 and 37, FLNRORD
Anglers want access to private lakes near Merritt where fish are stocked	Public fish are stocked on private land to conduct research on stocked strains	Interview #35, FFSBC

Fisheries managers prioritize competing interests in decisions on a case-by-case basis, based on weighing the best available evidence and relative values of stakeholder groups. They assess how interests align with organizational objectives/mandate (of valuing a diversity of opportunity) and whether they benefit the majority of public. This involves evaluating trade-offs and assessing which interests are feasible to implement, with some government employees mentioning that in cases they use deliberate structured decision-making approaches (e.g., Gregory et al. 2012; O'Donnell et al. 2017) to do so.

G.7 Prioritizing conservation concerns in decision-making

G.7.1 Thresholds, limits, indicators which indicate when conservation values are exercised/constituted (the point when conservation priorities override stakeholder interests or demands)

Several indicators are used by FLNRORD government employees to indicate when there is a conservation concern, i.e., to determine when a population is threatened. Namely, high temperature thresholds, when a species is listed on the *Species at Risk Act*, population size based on stock assessments (changes in abundance levels, density levels, fish size, age structure, spawners, or spawning periods), escapement (size of and changes in spawner runs, spawner returns, spatial distribution of spawner abundance), hybridization, exploitation rate/allowable morality (how many fish can be harvested safely without causing stock decline and potential decline in size), recruitment failure (fishing rate is greater than spawners can produce more recruits), catch rates (if they've gone down), and bycatch levels. If these pieces of evidence suggest a conservation concern, at that point, measures are purportedly taken to close fisheries or change regulations such as bag limits

Illustrative quotation from an interviewee describing an example of an in-season science-based management decision.

- "We closed a particular river – the Horsefly River – when we have reached a certain temperature threshold. Fish just get stressed and tend to concentrate on a limited number of pools where they're quite vulnerable to exploitation." (Interview #43, FLNRORD)

Appendix H

Illustrative extracts from interviewees demonstrating the unique threat of mountain pine beetle (*Dendroctonus ponderosae*) outbreaks and the resulting salvage harvesting on the habitat of interior BC populations of rainbow trout.

- "We're fighting with the forestry department to widen buffer lines in our areas because we've got 90 percent bug kill in our territory. We live in a matchbox. So right now, we've got about 60 percent of all that bug killed logged out in our territory. So, we've got a lot of bald spots. It causes a lot of issues for us. It causes water to raise a lot. Dry droughts. I mean our snow doesn't last very long. Our water doesn't stay very long. We'll have high water for a few months then once the sun heats it, our water just drops.

  We've all noticed big changes in our land and water and our fish. Not only that, but also how it affects our trapping and our fur-bearing animals. For example, our moose population has gone down, our bear. We don't know any more porcupines. Hardly any rabbits. Hardly any crows. Everything is going on account of the pine beetle. So, the more clear-cuts, the less fur-bearing animals we have, the less water we have also.

  When we're doing the rainbow trout studies in Babine [lake]. We set the net at the Sutherland River. We got 40 rainbow trout. I would say about half of those rainbow trout, their stomachs were filled with pine needles. And that's from the clear-cuts. So, all those pine needles just wash into the water, and they get into these fish, and they can't digest it. So, all that cut stuff has nowhere to go but into the watersheds and into the fish." (Interview #11, natural resource management branch of Indigenous government)

- “We get floods in the spring. We get drought in the summer. I think a lot of it is due to mountain pine beetle harvest. And so, we have some rainbow trout lakes that have never winter killed before and never had algae blooms. Now we're having massive algae blooms and winter kill events.

  Mountain pine beetle has hit this area of the Interior like 15 years ago, killed a large portion of our pine. And so, Forestry has said, well, now that the [pine] is dead and dying, let's harvest it begore it gets wasted. So, they're cutting at a much higher rate than what's sustainably growing and so they're calling it salvage, and they're salvaging these huge areas. What we're seeing in forestry now it's all reliance based. The government isn't checking a lot of things. We're relying on companies to basically check themselves and to be honest, it isn't working that great. There are regulations and these companies are logging in places they're not supposed to be. We did a check last year for compliance on some of these sensitive lakes and they've logged them right to the shore. So, we're putting up a little bit of a red flag saying hey this harvesting that you're doing is having an impact on the lakes.

  They [forestry companies] say they harvest watersheds that have lakes on them heavier because it's a hydraulic buffer. So, from their perspective we can log watersheds with lakes because when you're going to get more runoff, the lake buffers it and then slowly releases. But from a nutrient perspective, which they haven't thought of at all, we're saying hey you're loading these lakes with nutrients. So, what we're seeing is an earlier runoff because there's no tree cover, so stuff is melting and it's melting fast. So, we get this huge flush in the spring which is causing a lot of turbidity which brings a lot of nutrients into the lake. Typically, we'd have more of a slow release. What we're seeing is way faster deposition of that water and materials and so we're getting these algae blooms and nutrient loading."

(Interview #18, FLNRORD)

- "In the Kamloops region, we were trying to protect Roche Lake, which is the highest angler use on a small lake in the province. And there were several hectares of residual trees in there that were being part of the pine beetle salvage. And so, we went in the office and said, 'Look, because you removed the pine trees, because of the scale of the pine beetle epidemic, that results in more precipitation you get in the ground, because trees typically intercept a third of the snow and move it into the atmosphere as rapid transpiration. So, less trees, more snow in the ground, more erosion in the spring, and more runoff and more mobilization of soil and nutrients in the lakes. And that causes algal blooms, which then create oxygen depletion, and that sets you up for a winter kill of the trout population. So, could you leave the few hectares of remaining trees that weren't dead?' And they just said, 'F you, we're into fiber farming. We don't care about the lake. We're going to go in and shave the last few trees out of that watershed.' So, the science was irrelevant to the driver of the economics of the local mills. Even though you put it completely in front of them what was going to happen, and then it became almost like the Trumpian-type of denial of climate change: 'Oh there's no relation to denuding the landscape and changes in hydrology.' And you just look at these people and go, 'What planet did you grow up on?'

  We've had the pine beetle kill, which is the biggest land base change in North American history outside of wiping out the buffalo, and government is sleepwalking through it. And what I'm seeing is the public is burning out and giving up, because it's been a decade plus of the government being unresponsive. So, it's pretty depressing times right now for anybody who is in it. Anybody who's walking around happy saying, ‘Things are great because we've developed rainbow trout that can tolerate high alkalinity.’ It's like they're on Valium. They don't see the big picture. They may be ecstatic about some micro-issue that they think is great news, but big picture wise, in terms of budget and direction and threats, we're in the sixth-grade extinction right now and it's happening a thousand times the normal extinction rate. So, information like this and trying to get government's attention to manage our natural heritage, it's an important issue.”

(Interview #57, academia affiliation)

Appendix I

An illustrative quotation that provides context to the formation and role of FFSBC and how that has altered the perception of government agencies like FLNRORD.

“My hat is really off to those Freshwater Fisheries Society guys. I think one of the best things that ever happened to the rainbow trout fishery is that the Freshwater Fishery Society was created out of the fish culture section of the government ministry at the time. They read the tea leaves pretty well a few years ago when they sort of severed their relationship with government and went off to become a non-profit society. They cherry picked the best people out of the former ministry, sequestering them into the society and that brain trust of lake fisheries management capability in British Columbia moved into this new house. They're pretty well positioned to be doing what they're doing, and they do a pretty good job. They've managed to essentially exempt themselves from the annual agonizing process of budget preparation and always being concerned about whether or not their budget proposals are being defended properly within government and whether or not they're ever going to be fulfilled. When the Society was created, along with it, the license revenue was guaranteed to go to them. So, they're sort of self-sustaining as long as they can demonstrate their worth by maintaining resident rainbow fisheries and resonant trout population fisheries throughout the province. They are propped up and their budget is assured. So being in charge of their own destiny as opposed to being reliant on government whims and priorities from year to year. A much better situation.

There's science and there's management. And the science is not in bad hands with the Freshwater Fisheries Society and their links to the academic community. The management, the ability to apply the results of all the good science, that's going to be the struggle in days ahead.

And it goes back to this business of who's in charge of the landscape out there and it ain't the government agencies anymore” (Interview #63, retired provincial government employee).

Appendix J

Genomics, genetics, and rainbow trout fish formed the basis of inductive coding as common keywords (Figure J.1).

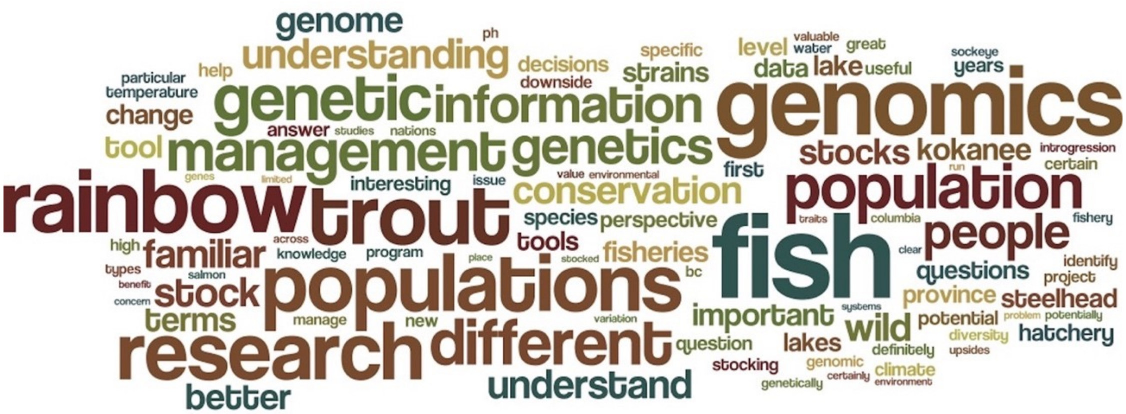


Figure J.1 Summary visualization of the 100 most common contextual words in responses to open-ended questions. Wordle (word cloud) constructed excluding common structural words (e.g., and, the, to, etc.) to ensure meaningful data using Wordle Version 0.2 (http://www.wordle.net).

Appendix K

Affiliations of the 57 non-participants (who were contacted for fuzzy cognitive mapping workshops but did not participate because they a) did not respond to my request, or b) declined to participate), grouped as members from the Freshwater Fisheries Society of BC, natural resource management branches of Indigenous governments, provincial natural resources ministry (branch and regions), and BC Hydro. BC Hydro (https://www.bchydro.com) is a province-owned electric utility monitors impacts associated with hydro dams to inform wildlife mitigation programs including habitat protection for spawning fish, nesting and migratory birds, as well as fish salvage. I sought BC Hydro participation, and although there was interest, management did not approve participation due to the amount of time it would cumulatively take from biologists and environmental coordinators.

Freshwater Fisheries Society of BC (FFSBC)	n	Indigenous Governments (FN)	n	Provincial Natural Resources Ministry (FLNRORD) Branch (Central Management)	n	Provincial Natural Resources Ministry (FLNRORD) Regions	n	BC Hydro	n	**TOTAL n**
Biologists	2	Biologists	5			Biologists	13	Biologists	5	
		Fisheries Managers	24			Directors	1	Environmental Coordinators	2	
						Fish & Wildlife Section Heads	5			
Non-Participant Sub-Total	(2)		(29)		(0)		(19)		(7)	**57**

Appendix L

Combining and cleaning data nodes resulted in the addition of some pathways, the union of others and the deletion of several redundant pathways. This resulted in the union adjacency matrix going from 314 connections to 338. Below are the specific changes which were made in combining and cleaning data nodes across n = 4 FCMs:

- MOE Science & Policy → MOE Science, Regulation & Policy
- MOE Science, Reg, Policy → MOE Science, Regulation & Policy
- MOE Science → MOE Science, Regulation & Policy

- MOE COs → MOE Conservation Officers
- Conservation Officers → MOE Conservation Officers

- Academia/Consultants → Duplicated row to have a division of 1. Academia; 2. Consultants

- DFO → DFO Non-Enforcement
- DFO C&Ps → DFO Conservation & Protection

- Non-indigenous Anglers → Anglers

- Anglers & Angling Guides → Duplicated row to have a division of 1. Anglers; 2. Resort Operators & Angling Guides

- Stakeholder groups, angling committees, ex-fisheries managers → Duplicated row to have a division of 1. Retired Fisheries Managers; 2. Stakeholder Resource-User Groups & Angling Advisory Committees

- Retired Fish. Managers → Retired Fisheries Managers

- First Nations → FN Fisheries Managers

- FLNRORD Branch → FLNRORD
- FLNRORD Regions → FLNRORD

- ENGOs → Community, Local, Conservation ENGOs
- Conservation ENGOs → Community, Local, Conservation ENGOs
- Community/Local ENGOs → Community, Local, Conservation ENGOs
- Non-angling ENGOs & Public → Duplicated row to have a division of 1. Community, Local, Conservation ENGOs; 2. Non-Angling Public & Politicians
- Stakeholder Resource-User Groups & Public → Duplicated row to have a division of 1. Stakeholder Resource-User Groups & Angling Advisory Committees; 2. Non-Angling Public & Politicians

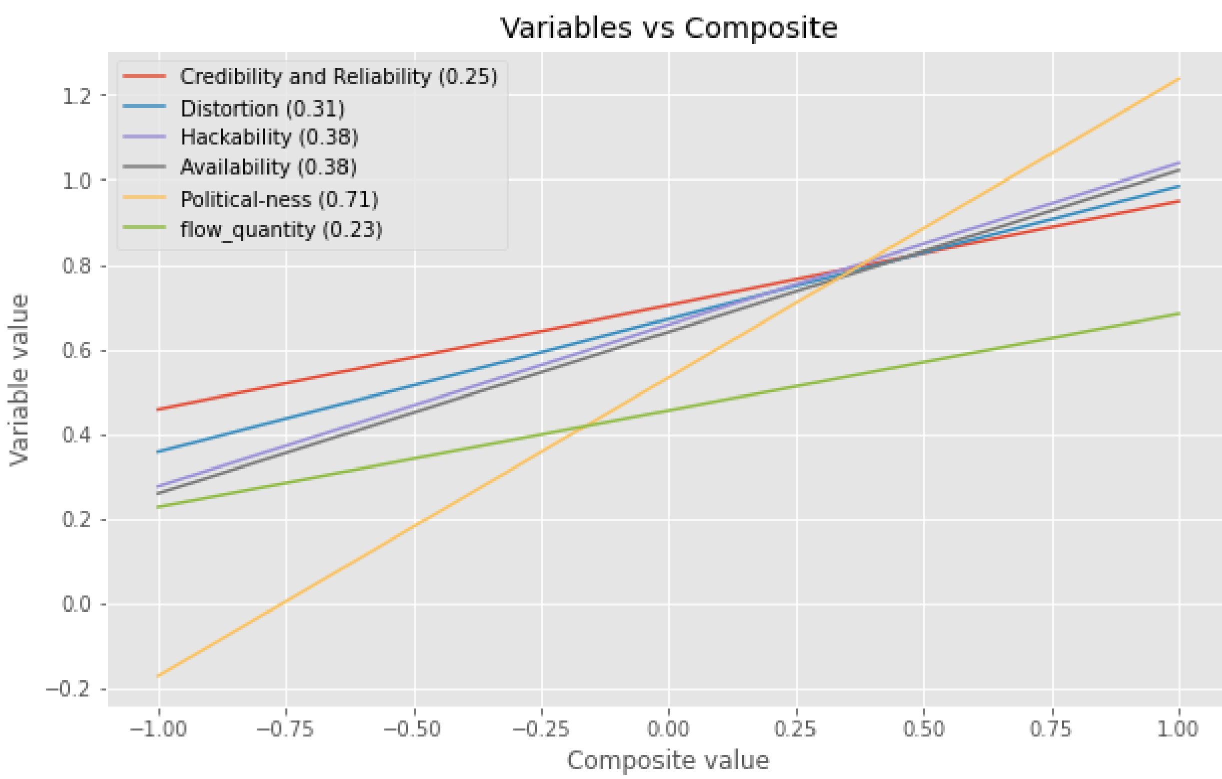
In the FFSBC FCM, FLNRORD Branch and Regions were created as separate nodes, the only FCM for which this was the case. For several reliability dimensions (distortion, hackability, and availability) FFSBC weighted FLNRORD Branch and Regions differently. In combining and cleaning nodes I combined FLNRORD Branch and Regions into one node in which I used the lowest quantitative weighting (e.g., FLNRORD Branch → Anglers was weighted as 0.8 for distortion but FLNRORD Regions → Anglers was weighted as 1.0 for distortion so in the new FLNRORD only node I used the 0.8 weighting for distortion) for which weightings differed (Table L.1). FFSBC consistently weighted FLNRORD Branch as less reliable along these dimensions than FLNRORD regions.

Table L.1. Quantitative weightings for distortion, hackability, and availability of the information being communicated from and to FLNRORD Branch and Regions in the FFSBC FCM. The lower weight for these dimensions were used in the final union adjacency matrix.

FCM	From	To	Distortion	Union Distortion Weight	Hackability	Union Hackability Weight	Availability	Union Availability Weight
FFSBC	FLNRORD Branch	Anglers	0.8	0.8				
	FLNRORD Regions	Anglers	1.0					
	FLNRORD Branch	Resort Operators & Angling Guides	0.8	0.8				
	FLNRORD Regions	Resort Operators & Angling Guides	1.0					
	DFO Non-Enforcement	FLNRORD Branch	0.6	0.6	0.4	0.4		
	DFO Non-Enforcement	FLNRORD Regions	0.8		0.8			
	FLNRORD Branch	DFO Non-Enforcement	0.4	0.4	0.4	0.4		
	FLNRORD Regions	DFO Non-Enforcement	0.8		0.8			
	FFSBC	FLNRORD Branch					0.4	0.4
	FFSBC	FLNRORD Regions					0.8	
	FLNRORD Branch	FFSBC	0.6	0.6			0.4	0.4
	FLNRORD Regions	FFSBC	0.8				0.6	
	FLNRORD Branch	FLNRORD Regions	0.4	0.4			0.4	0.4
	FLNRORD Regions	FLNRORD Branch	0.6				0.6	

Appendix M

The ‘amount of evidence flowing’ (quantity) variable along with the 5 reliability index variables were combined via Principal Component Analysis (taking the first axis of greatest variance) and normalized to the range of 0 to 1 so as to produce a composite variable that I called RI, which represented the ability for information to flow from organization/group to organization/group. I swept through 1000 values for the composite variable (between -1 and 1) and computed the inverse transform. The following plot demonstrates how the composite variable views the original variables. Printed are the components (slopes) in the legend.



Appendix N

Communicability source/sink plots and transitive influence plots from each of the n = 4 fuzzy cognitive maps.

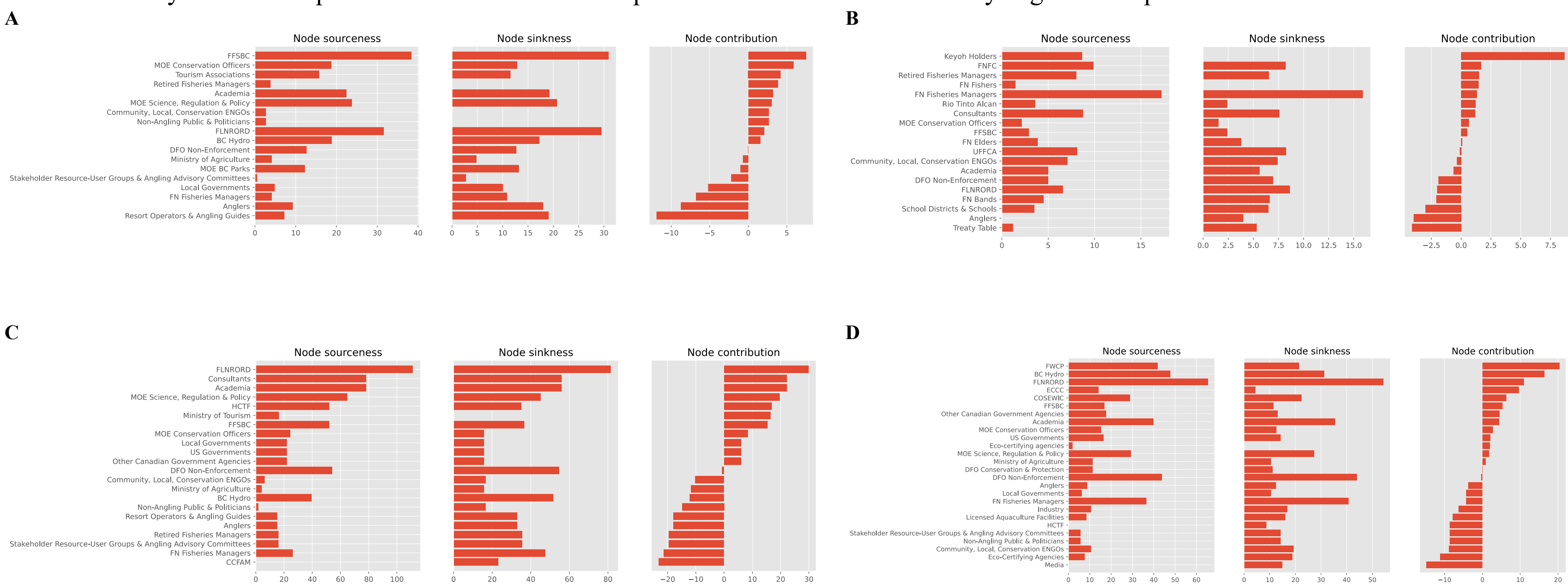


Figure N.1 Communicability source/sink plots for all nodes (organizations/groups) to understand the relative amount of information each node would contribute to or consume from the system in n = 4 constructed fuzzy cognitive maps, A. Freshwater Fisheries Society of BC, B. First Nations Indigenous Governments, C. FLNRORD Branch, and D. FLNRORD Regions.

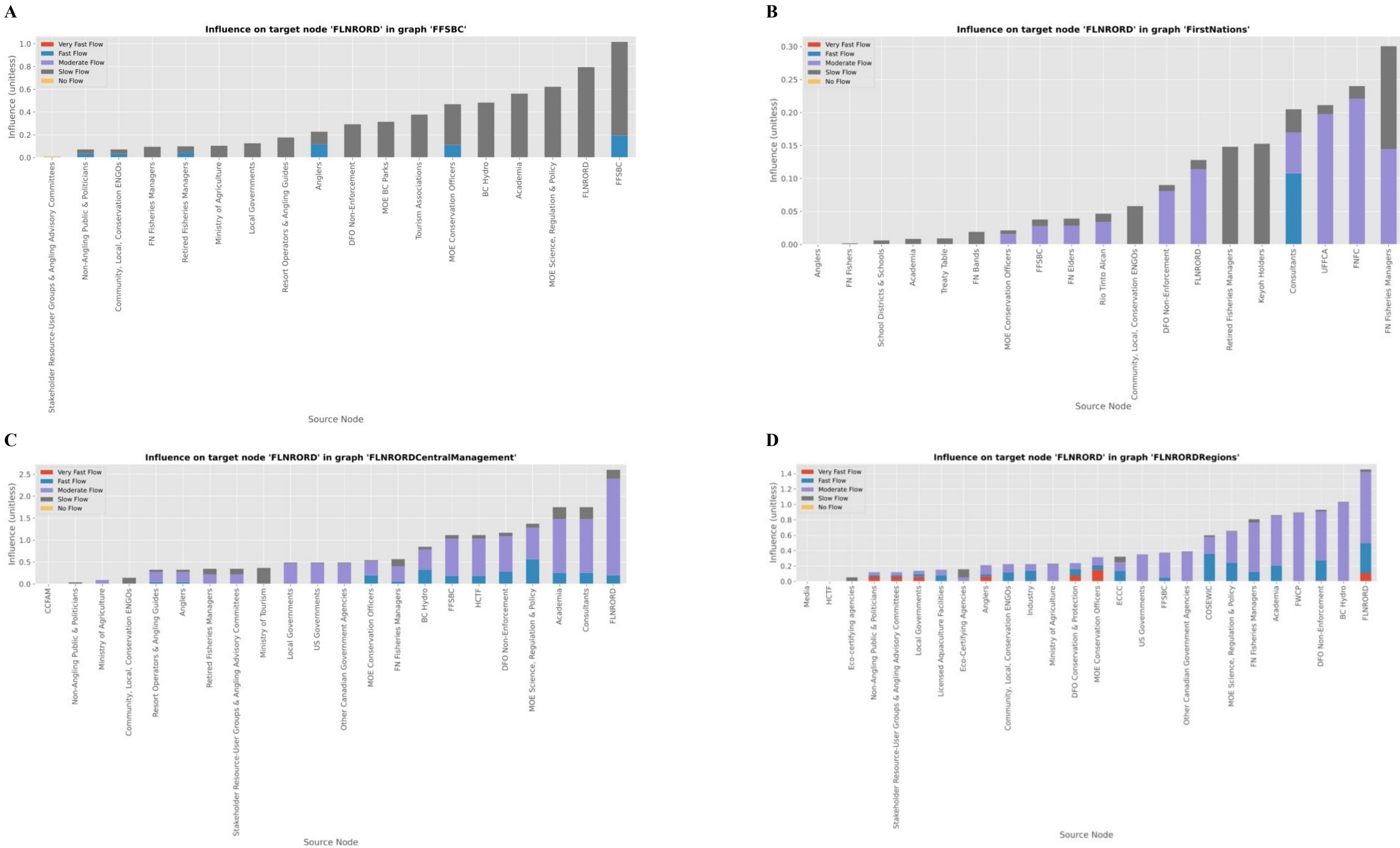
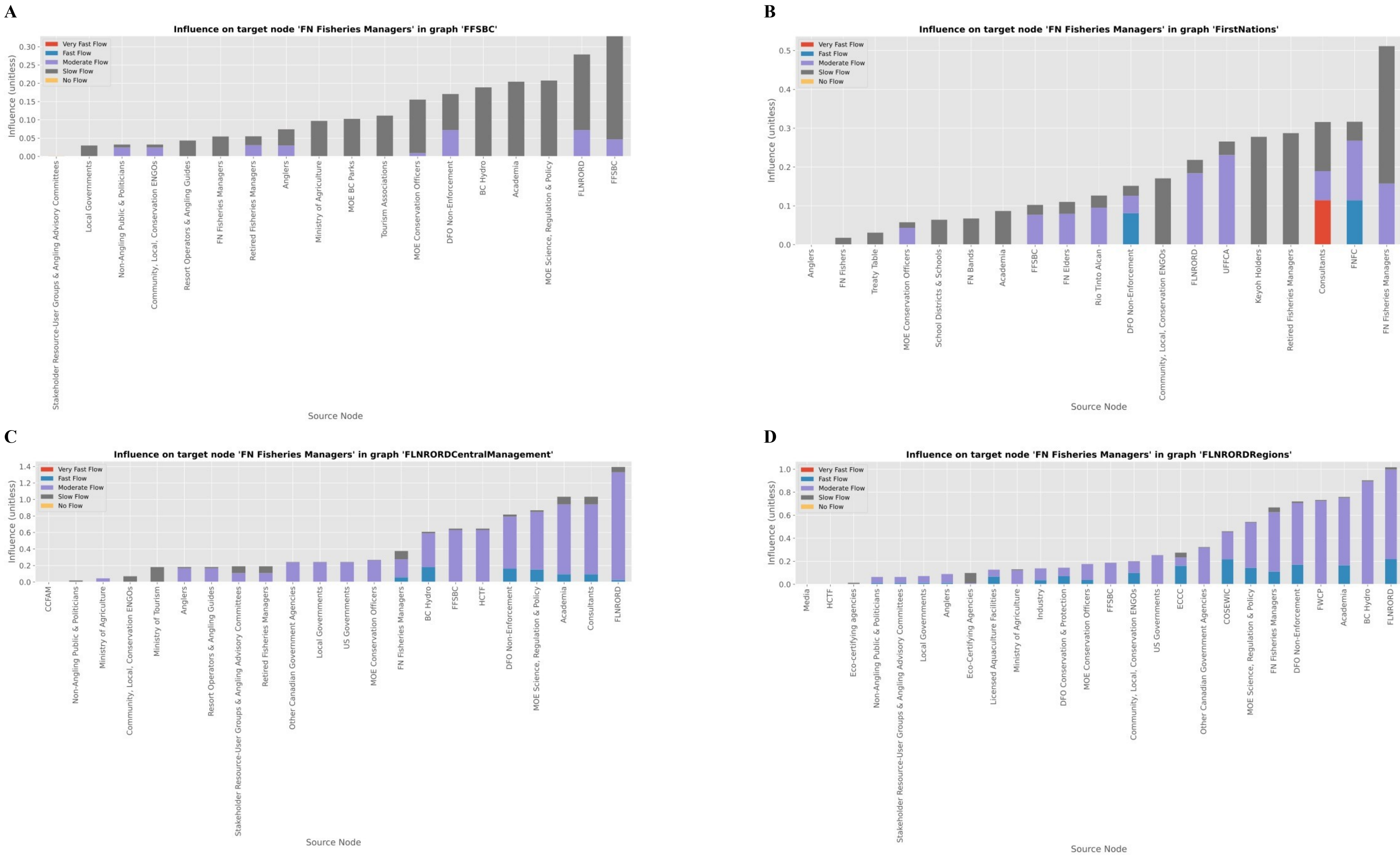


Figure N.2 Transitive influence of all nodes (organizations/groups) on the target variable the BC natural resources ministry (FLNRORD) in n = 4 constructed fuzzy cognitive maps, A. Freshwater Fisheries Society of BC, B. First Nations Indigenous

Governments, C. FLNRORD Branch, and D. FLNRORD Regions. The ‘rate of evidence flowing’ variable is used to represent five time scales at which the information can flow.



A
Influence on target node 'FN Fisheries Managers' in graph 'FFSBC'
Very Fast Flow
Fast Flow
Moderate Flow
Slow Flow
No Flow
Influence (unitless)
Stakeholder Resource-User Groups & Angling Advisory Committees
Local Governments
Non-Angling Public & Politicians
Community, Local, Conservation ENGOs
Resort Operators & Angling Guides
FN Fisheries Managers
Retired Fisheries Managers
Anglers
Ministry of Agriculture
MOE BC Parks
Tourism Associations
MOE Conservation Officers
DFO Non-Enforcement
BC Hydro
Academia
MOE Science, Regulation & Policy
FLNRORD
FFSBC
Source Node
B
Influence on target node 'FN Fisheries Managers' in graph 'FirstNations'
Anglers
FN Fishers
Treaty Table
MOE Conservation Officers
School Districts & Schools
FN Bands
Academia
FFSBC
FN Elders
Rio Tinto Alcan
DFO Non-Enforcement
Community, Local, Conservation ENGOs
FLNRORD
UFFCA
Keyoh Holders
Retired Fisheries Managers
Consultants
FNFC
FN Fisheries Managers
C
Influence on target node 'FN Fisheries Managers' in graph 'FLNRORDCentralManagement'
CCFAM
Non-Angling Public & Politicians
Ministry of Agriculture
Community, Local, Conservation ENGOs
Ministry of Tourism
Anglers
Resort Operators & Angling Guides
Stakeholder Resource-User Groups & Angling Advisory Committees
Retired Fisheries Managers
Other Canadian Government Agencies
Local Governments
US Governments
MOE Conservation Officers
FN Fisheries Managers
BC Hydro
FFSBC
HCTF
DFO Non-Enforcement
MOE Science, Regulation & Policy
Academia
Consultants
FLNRORD
D
Influence on target node 'FN Fisheries Managers' in graph 'FLNRORDRegions'
Media
HCTF
Eco-certifying agencies
Non-Angling Public & Politicians
Stakeholder Resource-User Groups & Angling Advisory Committees
Local Governments
Anglers
Eco-Certifying Agencies
Licensed Aquaculture Facilities
Ministry of Agriculture
Industry
DFO Conservation & Protection
MOE Conservation Officers
FFSBC
Community, Local, Conservation ENGOs
US Governments
ECCC
Other Canadian Government Agencies
COSEWIC
MOE Science, Regulation & Policy
FN Fisheries Managers
DFO Non-Enforcement
FWCP
Academia
BC Hydro
FLNRORD

Figure N.3 Transitive influence of all nodes (organizations/groups) on the target variable First Nations fisheries managers in n = 4 constructed fuzzy cognitive maps, A. Freshwater Fisheries Society of BC, B. First Nations Indigenous Governments, C. FLNRORD Branch, and D. FLNRORD Regions. The ‘rate of evidence flowing’ variable is used to represent five time scales at which the information can flow.

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