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Article

Managing Canadian freshwater fisheries: persistent challenges and emerging opportunities

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Abstract

Freshwater fisheries and biodiversity have substantial economic, socio-cultural, and ecological value, but face severe and mounting anthropogenic threats. Canada's freshwater fisheries are not exempt from this, and provide excellent opportunities to better understand these overlooked and undervalued systems. Using expert and chain-referral sampling, we surveyed practitioners from across Canada about the management of freshwater fisheries. We used a mixed methods approach to identify and describe in detail many important aspects of the above processes, including 10 persistent and innate challenges in (1) bureaucratic sprawl, (2) lack of priority, (3) scope, (4) competing interests, (5) political inconstancy, (6) socio-ecological complexity, (7) limited tools, (8) geographies and scale, (9) reactivity, and (10) intersectoral frictions. Many of these challenges defy conventional problem solving (e.g., advocacy, basic science), leading to chronic incapacity and triage management in some freshwater fisheries. We highlight opportunities to increase management capacity, using innovation where conventional solutions fall short (e.g., using novel technologies to increase management scope). Achieving sustainability in Canadian freshwater fisheries will require ingenuity and supportive contributions beyond those that currently exist.

Key words: freshwater fisheries, fisheries management, governance, conservation, sustainability

1. Introduction

Freshwater fisheries and biodiversity face an uncertain and worrisome future due to emergent and intensifying anthropogenic stressors, such as land use (e.g., urbanization , agriculture), exploitation, aquatic invasive species (AIS), and climate change (Reid et al. 2019). The cumulative effects of this are severe, and have led to a deterioration of freshwater ecosystems more severe than declines seen in marine and terrestrial environments (Dudgeon et al. 2006). This deterioration is now recognized as a freshwater biodiversity crisis (Harrison et al. 2018; Albert et al. 2021). Freshwater fisheries are complex socio-ecological systems (Nguyen et al. 2016) which provide numerous ecosystem services (Cowx and Portocarrero Aya 2011) that may be lost in this crisis. Yet, freshwater fisheries are often overlooked and underprioritized (Arlinghaus et al. 2002; Welcomme et al. 2010; Cooke et al. 2016).

Canada's freshwater fisheries are numerous, vast, and high in economic, social, and cultural value (Castañeda et al. 2020; Lester et al. 2021). Over time, the dominant form of use in these fisheries has shifted from subsistence, to commerce, and eventually recreation (Castañeda et al. 2020), though some significant commercial fisheries (e.g., Lake Erie) and many vital Indigenous fisheries still exist in Canadian freshwaters. These fisheries encounter a typical mix of anthropogenic stressors (e.g., land use, climate change)—the impacts of which will be particularly severe in certain ecoregions and for certain species (Chu et al. 2015; Poesch et al. 2016). As elsewhere, freshwater fisheries in Canada have long been undervalued and overlooked (Pearse 1988; Cooke and Murchie 2013), with management and conservation often failing to achieve sustainability. Freshwater fisheries management is a federal responsibility, administered primarily by provincial and territorial governments through various delegations (see Section 1.1.). A diverse "supporting cast" of non-governmental organizations (NGOs), Indigenous communities and governments, academics, and other supporters (not fitting these descriptions) also contributes to conservation and management of Canadian freshwater fisheries.

Here, we use insights from a national survey of freshwater fisheries practitioners to examine persistent and innate challenges (i.e., limitations) and their effect(s) on management capacity. We use the term "management" in its broadest sense, and include activities that some may consider separate (e.g., research, monitoring, stock assessment). The term "practitioner" refers to frontline individuals (e.g., managers, assessment biologists) who were the focus of our survey. Paying close attention to the abovementioned challenges, we high-

light opportunities (and areas of limited opportunity) to increase management capacity in freshwater fisheries. Though it is beyond this paper to propose solutions to each persistent and innate challenge, our work provides foundational information and guidance for pursuing such solutions.

1.1. The case

Administering and managing freshwater fisheries involves three primary considerations in fish, habitat, and people (Pearse 1988; Welcomme 2001; Arlinghaus et al. 2016). In Canada, freshwater fish are managed primarily by provinces and territories via monitoring, regulation, and enforcement. For some regions and (or) jurisdictions, activities such as stocking are also central to fish management. The authority to manage freshwater fish is delegated to provinces and territories via the Fisheries Act (Government of Canada 2022*a*), with exceptions in some jurisdictions (e.g., Newfoundland and Labrador, Nunavut) and for some anadromous species and populations managed in collaboration with, or entirely by the federal Department of Fisheries and Oceans (DFO). Freshwater fisheries are federally regulated, although some provinces and territories (e.g., British Columbia, Ontario, Yukon) can modify regulations with variation orders (Government of Canada 2022*a*). Variation orders expedite the often multiyear process of changing a regulation, but are unavailable to practitioners in some jurisdictions.

Unlike fish management, habitat management in Canadian freshwaters is primarily the responsibility of federal government: the responsibility for deleterious substances and water quality (e.g., contaminants, nutrient pollution) rests with Environment and Climate Change Canada, and DFO manages all other aquatic activities (e.g., culvert installation, dam construction) affecting freshwater fish habitat in accordance with the Fisheries Act (Government of Canada 2022*a*). Recently, habitat provisions in the Fisheries Act have varied from relatively strong to relatively weak under different federal governments (Fisheries and Oceans Canada 2021), and drawn much criticism (Quigley and Harper 2006; Hutchings and Post 2013). Terrestrial activities are also critical determinants of freshwater habitat quality. Land use is managed primarily by provincial agencies (e.g., Ministry of Agriculture, Forestry and Rural Economic Development [Alberta]) focusing on activities such as agriculture, forestry, and housing, in accordance with provincial legislation (e.g., Forest and Range Practices Act [British Columbia]). In most cases, managers of freshwater fish do not manage, and can only influence, aquatic and terrestrial impacts on freshwater habitat.

As with fish, fishery users in Canadian freshwaters are primarily the responsibility of provinces, except for relatively few jurisdictions wherein DFO is the primary authority. Typically, fishery use is managed with a combination of licensing, regulation, and enforcement. Specific measures include controls on fishing effort and outcomes (i.e., input and output controls; Hoggarth et al. 2006). People management is increasingly informed by human dimensions research (i.e., research involving human thoughts and actions in relation to fish; Hunt et al. 2013). The exact role of human dimensions research is still being determined, but the Survey of Recreational Fishing in Canada (see Brownscombe et al. 2014) is a prime example of social science informing management. Consultation and outreach are additional pieces which take various forms, ranging from mandatory consultation with Indigenous rights holders (Government of Canada 2022*b*) to casual liaising with recreational anglers. These activities ensure due process and are important complements to such critical pieces as regulation. These summaries of fish, habitat, and people management in Canadian freshwater fisheries provide a mere snapshot of this complex and varied landscape.

2. Methods

We developed our interview guide (Appendix A) and questionnaire (Appendix B) using information from academic and grey literature, as well as personal experience. Our questionnaire contained basic queries (e.g., What percentage of your time is devoted to monitoring?), while our interview guide contained questions requiring more detail and elaboration (e.g., To what extent are fisheries in your jurisdiction managed using an ecosystem approach?). A research ethics application (project # 112864) was submitted to the Carleton University Research Ethics Board on 4 May, and approved on 17 June 2020. To ensure respondent anonymity, directly identifying information is omitted from our results. Surveying began in the summer of 2020 and ended in the summer of 2021. Three pilot interviews were conducted and prompted no revisions of the interview guide and questionnaire. All three respondents were included in the survey. We sought current and recent members of provincial and federal government agencies tasked with managing freshwater fisheries, as well as members from the aforementioned supporting cast where government(s) provided an incomplete picture (e.g., provinces with substantial NGO contributions).

We identified and recruited respondents using online government directories, and then used peer referral to increase and optimize coverage (e.g., to identify key supporting cast members). In all cases, we selected individuals who we identified, who other respondents identified, or who self-identified as key informants (i.e., individuals possessing extensive knowledge on freshwater fisheries in a given jurisdiction and participating in their management). Key informant and chain-referral sampling are common methods when interviewing in conservation social science (Young et al. 2018), and our survey purposefully combined both to achieve relatively even and full coverage (Table 1). Following recommendations by Kirchherr and Charles (2018), we sent multiple invitations and follow-ups in all jurisdictions, and sampled in multiple waves over a calendar year. While samples like ours may be ill-suited for population-level inferences (Szolnoki and Hoffman 2013; Langer 2018), we do not attempt estimates of population parameters, and instead focus on the experiential knowledge of key informants. Obtained and analyzed in this way, our data are advantageous for their richness (Guest et al. 2013), insight on hard-to-reach groups (Penrod et al. 2003), and description of complex phenomena and processes (Drury et al. 2011; St.John et al. 2014). Other advantages of our approach include time-effectiveness (Schreuder et al. 2001), novel opportunities and questions (Lamm and

Table 1. Current or most recent positions and jurisdictions reported by survey respondents.

Position	*n*	Jurisdiction	*n*
Senior Biologist/Fisheries Biologist	11	Province of Ontario	6
Regional/Sectional Director	9	Great Lakes/Ontario/Prairies/Northern Region	4
Biologist/Fisheries Biologist	8	Province of Alberta	4
Fisheries/Regional/Sectional Manager	8	Province of Manitoba	3
Research/Fisheries Scientist	3	Province of Nova Scotia	2
Lake Manager	2	Province of Manitoba	2
Policy and Planning Biologist/Advisor	2	Province of British Columbia	2
Aboriginal Affairs Advisor	1	British Columbia Pacific Region/Fraser Basin	2
Provincial Allocation/Use Specialist	1	St. Lawrence River Basin	2
Migratory Fish Division Head	1	Province of Newfoundland and Labrador	2
Provincial Environmental Flow Specialist	1	British Columbia Kamloops Region	2
Fisheries Population Specialist	1	Great Lakes Basin	1
Vice President of Science and Outreach	1	Province of Prince Edward Island	1
President/CEO	1	Province of New Brunswick	1
		British Columbia South Coast	1
		Northern Saskatchewan	1
		Lake Erie	1
		Slave Lake Watershed/Region	1
		British Columbia West Coast Region	1
		British Columbia Cariboo Region	1
		Territory of Nunavut	1
		Québec Outaouais Region	1
		Yukon Territory	1
		Lake Ontario	1
		Québec Endangered Species	1
		Southern Alberta	1
		Province of Québec	1
		Québec Atlantic Salmon Fisheries	1
		Atlantic Gulf Region	1
		Northwest Territories	1

Note: Similar titles (e.g., Senior Fisheries Biologist and Senior Biologist) have been grouped.

Lamm 2019), and documenting niche, emergent, or understudied phenomena (Lehdonvirta et al. 2021).

Interview recordings were transcribed manually and analyzed by inductive thematic coding as in Thomas (2006). A working list of themes was created using journal entries recorded during surveying and transcription, and then refined during the first reading of all transcripts. This was then organized into a working code book, and segments of raw textual data organized into primary and secondary codes. A second round of coding was conducted for secondary codes containing large amounts of text and multiple subthemes, which were broken down and organized into tertiary codes. Coded interview segments were then compared to quantitative data from the questionnaire and interviews to assess their consistency, and to identify segments that pertained to broad themes. Following recommendations in Maxwell (2012) and Thomas (2006), as well as Young et al. (2018), we conducted member checks with nine (18%) of our respondents: five respondents made no suggestions, and we worked with the remaining four respondents to incorporate constructive feedback. Respondents who were quoted directly were allowed to review, and if necessary, revise quotations. Following recommendations by Young et al. (2018), we reflect critically on and report both the advantages and disadvantages of our methodology, along with other relevant information.

2.1. Limitations and critical evaluation

Random sampling was not possible or practical, given our need for key informants and non-existent sampling frame. As such, the representativeness of our sample is uncertain. We acknowledge this, and instead prioritize detailed insights on complex phenomena. Though non-probabilistic, our sample was generated with the combined input of numerous key informants from our study population. We are confident that this strategy revealed patterns and noteworthy phenomena in Canadian freshwater fisheries. Investigator and respondent biases are a second limitation, given their potential influence on survey content and responses. We reduced these biases by diversifying the individuals and literature that determined survey content, as well as survey respondents. Insights from our qualitative analysis are cross-referenced with quantitative data (i.e., triangulated) and show no signs of inconsistency. This—as well as our member checks—suggests

that our results were not biased or otherwise affected by misinterpretations during qualitative analysis.

Our mixed approach proved versatile and flexible as described in Young et al. (2014). Structured interviews facilitated comparisons and the identification of patterns, yet remained flexible (i.e., allowed respondents to partially dictate content) due to our inclusion of open-ended questions in both the interview and questionnaire. Interviewing not only highlighted key phenomena, but allowed us to describe and explore them in detail. Basic quantitative data provided answers to more categorical questions, which both guided and helped validate our qualitative analyses. A potential disadvantage of our approach is its time costs (e.g., lengthy recruitment, transcription, and analysis), which we believe are justified by the rich data and insights herein.

3. Results

We conducted 50 remote (i.e., phone and Zoom) interviews with a mean duration of ~59.5 min, and obtained 44 completed questionnaires from practitioners spanning all Canadian provinces and territories. The mean age of survey respondents who provided information ($n = 42$) was 47.4 years, with a range of 31–67. Respondents who reported gender were predominantly male ($n = 33$) and the remainder were female ($n = 10$). Most respondents who reported their level of education held graduate degrees (Master's, $n = 19$; Doctorate, $n = 9$), while the remainder held undergraduate degrees ($n = 16$). In general, respondents were in advanced positions (e.g., Senior Biologist, Regional Director) and (or) specialized roles (e.g., Aboriginal Affairs Advisor, Provincial Environmental Flow Specialist), which distinguished them as key informants on freshwater fisheries management (Table 1). On average, respondents reported spending 6.2 years (SD = 5.4) in their current or most recent professional role. Most of the respondents who submitted a questionnaire ($n = 44$) held three or more positions in freshwater fisheries (1 position, $n = 3$; 2 positions, $n = 11$; 3 positions, $n = 13$; $\geq$4 positions, $n = 17$) during their career, and the mean total years spent in various positions was 19.4 (SD = 9.6). The number of positions held and years spent in various positions were probably underestimated, as our questionnaire allowed respondents to list no more than three previous positions. Respondent job titles varied widely (e.g., Provincial Environmental Flow Specialist, Senior Fisheries Policy Advisor, Fisheries Population Specialist), and major similarities and differences were noted among similar titles (e.g., Fisheries Biologist) within and across jurisdictions. These inconsistencies are due to semantic differences, as well as differing organizational structure, capacity, and mandate. Participating organizations included DFO, numerous provincial government agencies, one binational commission, and one NGO, collectively spanning all of Canada (Table 1). Direct quotations are not attributable to whole provinces, territories, agencies, or other organizations, and reflect only the views of individual respondents.

3.1. Persistent challenges

Canada's freshwater fisheries face persistent and innate challenges which often defy conventional problem solving and limit management capacity. Our analysis produced a list of challenges—some overlapping and (or) related—which we discuss here. Opportunities to address these challenges, which we discuss at length in Section 4., are summarized in Table 3. Other challenges which received less attention from respondents (i.e., were mentioned infrequently) included inertia (e.g., adhering to outdated policies, individual resistance to change), maintaining the simplicity of regulations, standardization, establishing targets, data poverty, and lacking expertise in government.

3.1.1. Bureaucratic sprawl

Bureaucratic sprawl refers to the numerous components, degrees of freedom (i.e., moving parts, determining factors), and inefficiencies that characterize large and sophisticated governance structures (i.e., bureaucracies):

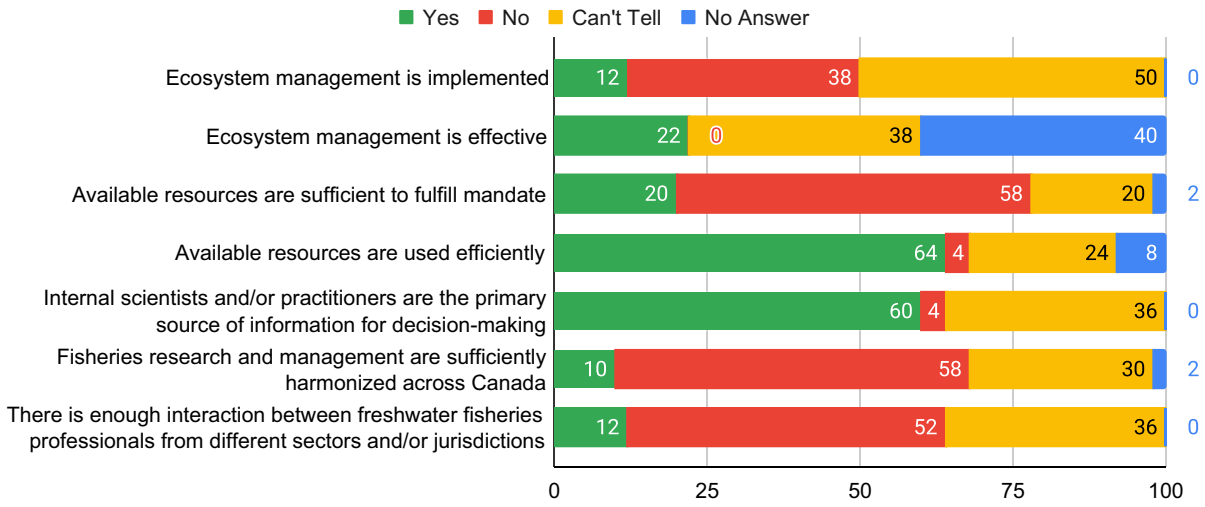
> Most of it is just this vortex of internal decision-making that doesn't go anywhere… not to say that it's not useful, and that government workers aren't diligent, hard-working, ethical, smart… but the machine is so clunky and cumbersome. (territorial level)
>
> I call it bureaucratic sprawl, it's a part of the gap, the knowledge-action gap… I think that's still very much a problem. (provincial level)

A total of 192 segments (i.e., individual statements) from 48 cases (i.e., 48 individual interviews) were associated with bureaucratic sprawl. Symptoms include a lack of agility (e.g., long turnaround on regulation changes), decision-making by non-experts, fragmented management (e.g., managing fish and habitat in isolation), siloing (e.g., lack of sharing and professional development), redundancy (e.g., reinventing the wheel, hitting one bird with two stones), restrictions on networking and spending, inharmonious management of shared waters, unclear divisions of responsibility, and the appearance of data deficiency (e.g., due to poor communication , data mismanagement). Questionnaire data suggest that interaction across sectoral and jurisdictional lines is lacking (Fig. 1)—a problem that results partially from bureaucratic sprawl.

Bureaucratic sprawl is a massive topic—summarized here as a lack of nimbleness in the management system. This rigidity is observable in the lag between societal and (or) environmental changes and corresponding adjustments in management. With each additional degree of freedom in the governance structure around freshwater fisheries comes the potential for new frictions and (or) gaps to emerge (e.g., inflexibility, unclear or unfulfilled responsibilities). Eliminating unnecessary degrees of freedom is desirable, but where and how to do this is a tremendous question. For example, high-level decision-making processes that appear lengthy and inefficient may ensure consistent applications of policy and (or) minimize risk in high-stakes decisions. Still, practitioners urge that freshwater fisheries governance leaves much to be desired:

> …the governance structure could be much improved, you have various levels of government… with First Nations de-

Fig. 1. Responses to pre-questionnaire and closed interview questions (%) in the context of each individual's jurisdiction.



veloping councils and agencies, management is just getting very complicated. It was complicated to begin with. (provincial level)

Because of the complexities of a two-tier system of governance in fisheries, it can be difficult to make decisions quickly. For example, even a simple change like boundaries on a fish sanctuary can take a long time—between 18 and 36 months depending on the federal policy cycle. (provincial level)

… Canada's motto is peace, order, and good government, and good government relies often, if not exclusively, on good governance… I think we need more conversations about governance. It's kind of dry, but it helps… the hiccups we face are when there is a failure to understand roles and responsibilities. (provincial level)

3.1.2. Lack of priority

Freshwater fisheries suffer from a lack of priority (Arlinghaus et al. 2002; Cooke et al. 2016), which constrains such fundamental activities as stock assessment (Lorenzen et al. 2016). Lacking priority was associated with 109 segments (39 cases) and typically manifests in disproportionately small amounts of funding and personnel:

The forestry branch and the parks branch, their budgets were maintained, their staffing levels were maintained, where we saw a 45% reduction over two years in our budget, and we lost about 30% of our positions that were vacant and were then cut… (provincial level)

In my region it's a 300 million dollar annual return to the economy. I don't think that's reflected in staff, and I don't think we are making investments in those fisheries… (provincial level)

Most respondents (58%) described available resources as insufficient to fulfill their mandate. Respondents who expressed uncertainty (20%) or described their resources as sufficient (20%) were fewer (Fig. 1). Most respondents (64%) felt that available resources were used efficiently (Fig. 1), sometimes noting that high efficiency was the result of prolonged scarcity.

Lacking priority can also mean limited abilities to collaborate and interact beyond one's sector or jurisdiction:

… there is very little ability for provincial biologists to interact—other than through your own social network—outside of the province, largely due to, I think, financial restrictions… (provincial level)

Additional symptoms include frequent cuts (e.g., lost funding, cancelled programs), a lack of executive-level fisheries staff, misuse of staff, failure to enforce regulations, reliance on outside help (e.g., private funds, borrowing from other departments), data deficiency, reactive management, and marginalization of freshwater fisheries in governance. In some cases, freshwater fisheries may receive a "fair share" of very limited resources (e.g., funding), in which case lacking priority may be an inconvenient truth. Some respondents recognized, and were understanding of this, as we discuss in Section 3.1.4.

3.1.3. Scope

Management scope was mentioned directly or indirectly in 108 segments (43 cases). The need to extend considerations beyond single species (i.e., to aquatic habitat, land use, human behaviour) has been highlighted (Nguyen et al. 2016) and was acknowledged by numerous respondents. However, doing so is more difficult (e.g., logistically challenging, costly) than recommendations for more holistic management often imply:

There are some attempts at that but really, like anywhere, "ecosystem approach" is mainly a buzzword… [it] isn't effectively implemented just because it's so enormous as it's written. (territorial level)

… it's complicated because it necessarily pushes you outside your jurisdiction. The ecosystem for some restoration species

> of interest, the barriers to success for those programs, are outside my jurisdiction. (provincial level)

> … while [ecosystem management] has now been mandated in the Fisheries Act… we haven't gotten the momentum yet. (federal level)

Only 12% of respondents described ecosystem-level approaches in their jurisdiction (Fig. 1). Others reported no such activities (38%), or expressed uncertainty about what ecosystem management might look like in practice (50%). Respondents were also uncertain about the effectiveness of ecosystem management in freshwater fisheries (38%), citing data poverty and their limited authority as barriers to implementation. The separation of fish and habitat management was also discussed frequently:

> DFO has responsibilities, and they're ramping up for it, but they're not in a position to deliver… quite frankly, we are on the ground… our conservation officers are out there, [and] sure, they can lay paper on someone if they see a habitat issue, but it's not necessarily their priority. (provincial level)

> DFO has jurisdiction over fish habitat which, between you and me, is silly… for me to manage a fish stock without talking about fish habitat… it doesn't make any sense. (provincial level)

Here, we see how degrees of freedom in governance can cause critical components of freshwater fisheries to "slip through the cracks." Management scope is not determined by what is ideal (e.g., ecosystem management), but what is practical given the structure and capacity of management systems, which are shaped by federal legislation (see Section 1.1.). Managers look beyond single species when and where possible, but are constrained by their limited sphere of influence and capacity to manage whole ecosystems.

3.1.4. Competing interests

Competing interests were associated with 101 segments (37 cases) and relate closely to lack of priority. Most notably, competing interests affect decisions about resource allocation (e.g., how funds are distributed) and policy (e.g., relative prioritization of environmental, economic, and social interests) that we discuss here. Often, competing interest scenarios do not favour freshwater fisheries:

> … the lion's share of money goes to healthcare, education, and justice, as it well should… we shouldn't really be surprised or upset that [municipality] needs a new MRI… are we really going to say [we] need a biologist versus a medical instrument that is going to help save lives? (provincial level)

Essential services were referenced somewhat infrequently (four segments, four cases), but it is reasonable to expect that certain essentials (e.g., healthcare) will always take precedence over freshwater fisheries. Far more numerous and widespread were references to political decision-making (47 segments, 25 cases), wherein science is just one of several considerations:

> … we then take that biology, but also then have to combine economics, sociology, and some politics of course, and render a management decision based on all of those things. They are always based in science, but they are modified by the latter components of a government. (provincial level)

> … we often get grilled for this, that decisions aren't being made on the best available science… it's really easy for a science report to say that this fishery or this issue is occurring, it's another one to sit there on the other side of the table and tell an entire group, say First Nations, that they can no longer fish for sustenance… (provincial level)

Political decisions are the product of many conflicting interests, such as those between user demands, commerce, and conservation. Recommendations for change or criticisms of management may fall on deaf ears, or even breed resentment if they are made without sufficient consideration of this. Less numerous and widespread, yet noteworthy, were competing interests within management and conservation (e.g., restricting AIS versus improving fish passage), which respondents also mentioned (two segments, two cases).

3.1.5. Political inconstancy

Political inconstancy was associated with 71 segments (29 cases), and refers to regular changes in government which affect freshwater fisheries (e.g., elections, budget cuts, restructuring, staff turnover). Though fundamental to democratic processes, inconstancy (in excess) creates discontinuity, which can hinder freshwater fisheries:

> … DFO is so susceptible to dramatic change resulting from a political shift. (provincial level)

> … we're actually working with government right now to address our funding model… every time we get really close we hit an interregnum period or change in government, or some issue like that. (non-governmental organization)

> … there's a lot of movement in and out [of] positions… you lose that consistency, and you kind of have to reinvent the wheel more often… (provincial level)

Most segments associated with political inconstancy involved a loss of general capacity and resources ($n = 32$). For example, multiple respondents referred to programs that received startup funds, but were deprived of funds needed to sustain them. Others referred to loss of expertise and (or) corporate memory ($n = 12$), as well as bureaucratic sprawl, shifting priorities, lack of political will, and loss of long-term data ($n < 10$). Changes to the Fisheries Act (see Section 1.1.) are a prime example: as one respondent noted, "the Fisheries act went one way under [Prime Minister] Harper, and then it came all the way back the other way… DFO appeared to get gutted, now they're rebuilding" (provincial level). Disruptive as it may be, political inconstancy is far beyond the purview of freshwater fisheries practitioners:

> … there are capacity challenges that slow us down. It's nobody's fault, it's just the way governments work. (federal level)

3.1.6. Socio-ecological complexity

Socio-ecological complexity was associated with 54 interview segments (24 cases), and refers to the numerous social and ecological complexities which are unavoidable in freshwater fisheries:

> … the range of the bioregion, from almost the Arctic, to the semi-Arctic, to something more temperate, with all kinds of different species and numerous river systems and lakes… it's very remote… trying to maximize recreational opportunity for the most people that you can, maximizing the season… the complexity of the regulatory regime… (federal level)

> … there's nothing worse in fisheries management than thinking you're doing the right thing, and then putting it out for public consultation and being broadsided… (provincial level)

> Fisheries ecology is difficult to predict. Cycles in population abundance that appear to be present can change. For example, just when you think there's kind of this up and down, opposite cycle for perch and walleye… suddenly there isn't. (provincial level)

The relatively immature human dimensions, and somewhat more mature ecological dimensions of freshwater fisheries, are each fraught with uncertainty. The innate complexities of ecosystems and society, however, are not the only sources of socio-ecological complexity. Mismatched ecological, regulatory, and socio-cultural boundaries are beyond the purview of freshwater fisheries practitioners, and complicate sustainable management even further (Barnard and Elliot 2015).

Established frameworks and scientific methods for dealing with socio-ecological complexity are often lacking, necessitating the use of what one respondent called the "art and science of fisheries management" (provincial level). Nonetheless, practitioners spend significant time on social activities like stakeholder engagement (Table 2). As some respondents noted, stakeholder engagement looks very different across jurisdictions in Canada, making it difficult for many such individuals to compare notes. In addition to numerous and diverse considerations, much uncertainty results from constant change in the environment and society:

> … all regulations are successful on some group of assumptions… if the situation and the environment changes, and now violates those assumptions, the success or failure of management approaches will change. (provincial level)

Table 2. Average percentage of time spent by respondents ($n = 44$) on various tasks.

	$\bar{x}$	SD
Fisheries management	34.0	27.4
Monitoring	14.4	13.7
Stakeholder engagement	13.0	10.6
Research	10.3	13.5
General management	6.3	14.4
Administration (financial and other)	5.2	11.1
Other natural resource management	4.9	13.5
Enforcement and compliance	3.3	5.5
Partnerships and related work	1.4	5.5
Miscellaneous or other	1.2	5.0
Procuring funds	0.7	3.3
Supervision and (or) advisory	0.7	3.8
Program and (or) policy development	0.7	4.5
Unforeseen issues and work	0.6	3.8
Technical advice	0.6	3.8
Hatchery work	0.5	3.0
Human resources and (or) health and safety	0.5	2.1
Rights-holder consultation and (or) engagement	0.3	2.3
Educational outreach	0.3	2.3
Staffing	0.3	2.3
Treaty work	0.2	1.5
Training and (or) professional development	0.2	1.1
Authorship (scientific papers and reports)	0.2	1.5
Addressing fish kills	0.1	0.8
Information technology	0.1	0.8
Other field work	0.04	0.3

3.1.7. Limited tools

Limited tools (e.g., regulatory options, legal authorities) were associated with 52 interview segments (29 cases), many of which were synonymous with limited influence and (or) authority. As mentioned previously, practitioners lack many of the tools needed to, for example, protect freshwater habitat:

> … the trends that we're observing in commercial and recreational fisheries, or collapses that we observe, sometimes are clearly related to a problem of habitat… we have the ability to manage the quota… to put a minimum length limit on a yellow perch fishery… it's really more difficult to change the laws about agriculture around the water bodies… (provincial level)

> We don't have a direct lever… we have to find other ways… we can't always tell other ministries that they aren't doing the things they should. They have their own agendas, and wildlife are often of least concern. (provincial level)

A lack of legal authority in activities directly impacting freshwater habitat is limiting, though a reality for fishery practitioners in Canada and beyond. Management tools and scope are also limited by divisions within natural resource management (e.g., forestry, agriculture, fish, wildlife), which somewhat simplify this daunting task. However, if these divisions become so solid as to create silos, resources such as fresh water and fisheries will deteriorate (Mitchell 2005). Simple, seemingly inconsequential changes in governance structure can cause breakdowns of this kind:

> The government structure in [province] has changed from that more team-focused and integrated approach around fish and wildlife, habitat, and ecosystems… now it's what's called an area-based model, [which] has taken the few resources that remain and kind of sequestered them in a geographically re-

Table 3. Opportunities for growth and corresponding challenges discussed in Section 4.1.

Opportunities	Challenges
Create and (or) extend bureaucratic efficiencies (e.g., variation orders); eliminate gaps and (or) redundancies hindering key activities	Bureaucratic Sprawl, Limited Tools
Aim for (i.e., support, promote) low political inconstancy; account for potential political shifts in short- and long-term strategies	Political Inconstancy, Reactivity
Quantify and communicate freshwater fishery value; advocate for fisheries not receiving a "fair share"	Lack of Priority, Competing Interests
Invest strategically and purposefully in social capital; strengthen links between divisions of natural resource management	Intersectoral Frictions, Limited Tools
Account for social and ecological unknowns in short- and long-term strategies; strengthen links between planners and managers; increase scientific rigour in "people management"	Reactivity, Socio-Ecological Complexity
Develop novel technologies to "boost" key activities (e.g., monitoring); develop practical guidelines for novel technologies, data, other innovations; invest in data management systems to keep pace with data collection	Geographies and Scale, Socio-Ecological Complexity, Scope
Optimize limited resources via strategic shifts and (or) innovations	Geographies and Scale

> stricted area that prohibits teamwork, sharing, coordination… (provincial level)

Other major tools which are frequently unavailable to practitioners include certain input and output controls (e.g., gear restrictions, authority to close seasons) and the ability to quickly modify regulations (e.g., variation orders). There is also uncertainty around the effectiveness of management tools: (Cormier et al. 2022) noted that scientific research on the effectiveness of technical measures in marine resource management is lacking—an observation that extends to freshwater fisheries. While the jurisdiction of freshwater fisheries practitioners is necessarily finite, results from our survey suggest that certain tools—some of them fundamental to sustainability, such as the authority to manage or co-manage terrestrial activities with significant effects on critical aquatic habitat—are missing.

3.1.8. Geographies and scale

Vast physical and human geographies are fundamental challenges faced by freshwater fisheries practitioners in Canada, 19 of whom referred directly or indirectly to this (35 segments):

> … you think of the scope of the country geographically and ecologically, as well as socially, there's a big rural-urban divide, there's a great demographic distribution or dissimilarity, lots of different ecosystems, lots of different fisheries, and the only thing that seems to be common is the continued expectation that no matter what we want we should get it. (provincial level)

> … we cover a large geographic area and we have four biologists, so we are fairly understaffed… (provincial level)

These statements capture a routine scenario for many practitioners, wherein such significant events as a fishery collapse can fall through the cracks (Post et al. 2002). In some cases, this has prompted the re-thinking of entire programs (e.g., transition to broad-scale monitoring in Ontario; Lester et al. 2003, 2021). Next to fisheries management, monitoring and stakeholder engagement were the most time-consuming activities for respondents (Table 2)—a testament to the vast human and physical geographies mentioned above.

3.1.9. Reactivity

A tendency toward and (or) legacy of reactive management in freshwater fisheries was associated with 29 interview segments (20 cases):

> … we have a completely reactionary management system. Before we change any form of regulations, the general policy here has been to wait until the fishery is collapsed or on the verge… (provincial level)

Some of the reasons for this lack of proactivity are justifiable (e.g., uncertainty of human behaviour), and others less so (e.g., not modelling uncertainty). As one respondent explained, AIS invasions are sometimes impossible to foresee, and can provoke rapid shifts in attention and resources. As discussed in Section 3.1.1., adjusting policies, plans, and even regulations can take a very long time, making rapid responses difficult or even impossible. Greater proactivity may be achieved with attention to select areas, which we discuss in Section 4.

3.1.10. Intersectoral frictions

Intersectoral frictions (i.e., inefficiencies, gaps, conflicting interests between sectors) were associated with 31 segments (18 cases). Conflicts and conflicting interests (e.g., conservation and economic growth) represent typical points of friction, while the notorious knowledge–action gap (Nguyen et al. 2017; Nguyen et al. 2018) represents a rift between sectors (e.g., government and academia). Both are barriers to synergy in freshwater fisheries:

> … they are not working together necessarily… there are all kinds of people, in academia as well, all kinds of people doing all kinds of fabulous work, but it's not all going into a master strategy for freshwater fisheries… (provincial level)

> … there needs to be more harmony… between DFO and the provinces, but [also] First Nations governments that are emerging, and different stakeholders that want to play a role… it needs to be less antagonistic… (non-governmental organization)

Most respondents to our questionnaire felt that fisheries management and science were insufficiently harmonized across Canada (58%), and that there was insufficient interaction between professionals from different sectors and jurisdictions (52%). Most remaining opinions were uncertain (Fig. 1), highlighting again the suboptimal connectivity between sectors. Intersectoral frictions are a reality in any public policy scenario, and some perceived gaps between knowledge and action may be inconvenient truths insofar as policies and regulations are not science-determined, but science-informed.

3.2. Management capacity

The abovementioned challenges are what limit management capacity in Canadian freshwater fisheries. Capacity can be measured by the sum of all resources possessed by and (or) available to institutions, as well as the efficiency with which they are used, minus the aforementioned limitations. In this section, we briefly discuss the tangible (i.e., material) and intangible (i.e., immaterial) resources, which partially determine capacity, and how Canada's freshwater fisheries operate given this balance of resources and limitations.

3.2.1. Tangible resources

Of the 203 interview segments associated with tangible resources, an overwhelming majority ($n = 184$) referred to funding and staff. As multiple respondents pointed out, these necessarily "go hand-in-hand" (provincial level). Human resources are a limiting factor in countless activities (e.g., monitoring, consultation) and are themselves limited by funding:

> My ministry suffers from a lack of resources and a lack of funding, which just limits our ability to staff correctly… (provincial level)

> … 25 years ago we probably would have had 12 staff, and we are down to four. (provincial level)

> … I have one technician that I have to share with two other people, because they don't have permanent technicians. (federal level)

Short-staffing was reported by 27 respondents spanning the northern territories and all but one southern province, five of whom referred specifically to a lack of entry-level and (or) technical staff. Further losses in staff to turnover and (or) burnout exacerbate this. One specific consequence of this is suboptimal equipment maintenance (e.g., few or no technical staff to repair nets, service vehicles), and while equipment and tools were associated with just 21 interview segments (16 cases), statements about lacking funds are synonymous with a lack of purchasing power. Some of the above statements imply serious deficiencies in tangible resources, while others describe more modest needs:

> … I have a staff of five to manage the sport fishery in the province. I probably don't need 10, but I need 8 to do it really effectively. (provincial level)

Laws and regulations may also be considered tangible resources in freshwater fisheries management, though allusions to these—in responses to explicit questions about management resources—were few and far between.

3.2.2. Intangible resources

Most respondents described their resources as insufficient (Fig. 1), but—as several individuals explained—tangible resources are not the only determinants of management capacity:

> I don't really know how much money, if at all, could be used to achieve the objective of totally understanding something like… the full range of impacts of climate change… (federal level)

As a subject, intangible resources are more complex and diverse than tangibles. Social capital, for example, is a category of intangibles which includes items like compliance and conservation initiative, both of which involve the complexities of human behaviour. Information is perhaps the most fundamental intangible in freshwater fisheries (e.g., long-term data) and is linked inextricably to the abovementioned tangibles:

> … to the extent that our resources or personnel are reduced, I think the issue becomes managing with maybe less information… either managing with more uncertainty or managing more conservatively… (provincial level)

> … the recreational fishery is a billion-dollar annual industry, and because of that we get to have the science and research branch… (provincial level)

> The biggest resource that is missing is information… (territorial level)

Insofar as they struggle with a lack of funding and staff, practitioners also struggle with a lack of information. Virtually all activities, from relatively simple (e.g., regulation setting) to more complex (e.g., ecosystem management), are impractical without certain prerequisite information. Without this, practitioners must adopt a precautionary approach that is itself very limited (Peterson 2006). The informedness of freshwater fisheries practitioners, however, also depends on peer and (or) social networks—an intangible referenced by all 50 respondents (e.g., when asked about their approach to answering questions):

> … the network of people you work with is very important… it's very difficult to think that you can structure this, because tomorrow a paper or a report that is not worded in any way like your search criteria, and you don't even know that it's

relevant to what you are doing, you wouldn't see that even if you [were] looking for it. The other aspect… you could sit there and read a paper and have no freaking clue what it is talking about because it's not your field… (federal level)

… we don't have infinite resources… the way we deal with that lack of capacity is those over-the-cubicle conversations, in the hallway, water cooler, pick up the phone, video call… (federal level)

… the minute you start talking to one person, you're connected to the next person. (federal level)

Peer and (or) social networks contain numerous key informants who aggregate, organize, and make readily accessible the most up-to-date information on freshwater fisheries. Most respondents (60%) identified peers as primary sources of information (Fig. 1). As the above statements suggest, the utility and mobility of much information depends on network quality.

Just as peer and (or) social networks interact with information, organizational and intellectual capital interact with such fundamental resources as funding and staff. Together, organizational and intellectual capital refer to intangible assets (e.g., individual experience, structured processes), which partially determine an organization's capacity. In freshwater fisheries, this translates to how much can be achieved with what is available:

… you need a certain amount of resources, but beyond that what you need is a really smart way to decide where you're going to invest, because you're always limited… (provincial level)

… part of that is financial, to hire the people, but the other part is that the intellectual capacity isn't necessarily there… a lot of people are new to the research and new to the management… there has been a real loss of that kind of intellectual capital… (federal level)

Often, organizational and intellectual capital are lost to political inconstancy (e.g., turnover, downsizing, restructuring). One respondent (federal level) referred specifically to downsizing in government as the cause for lost intellectual capital. Another respondent noted that a lack of technical staff also eliminates opportunities for intellectual capital to accumulate over the course of a long, multipositional career.

Like organizational and intellectual capital, social capital partially determines what can be accomplished in freshwater fisheries:

When I started here, the conversation was "the only solution to a better fishery is stock more fish," but now people are actually lobbying us to stock less… Why? because they are understanding the predator-prey issue… they seem to be much more science-literate and willing to engage in a meaningful, deep conversation… it puts it in the realm of reality… you need to cultivate that kind of culture… it opens up a lot more possibility of getting things done. (provincial level)

… if the government acts like we know best, most people believe that we don't. Working collaboratively with our stakeholders really helps. We may not always agree, but when we do, they are our strongest advocates… (provincial level)

Investments in social capital can pay dividends, as the above statements suggest. Inviting various groups and individuals into existing peer and (or) social networks creates buy-in in various forms (e.g., compliance with regulations), allowing limited resources (e.g., enforcement staff) to stretch further than they otherwise might. Other activities, like influencing land-use decisions, also become more productive when social capital is high.

The above discussion contains what is likely a non-exhaustive list of intangible resources. Social capital, for example, is a very broad category containing many items (e.g., trust). Legislature and public policy are major intangibles not captured in the above discussion, or most literature on freshwater fisheries (e.g., relative to political science). Freedom from constraints (e.g., deadlines, jurisdictional boundaries, time) was arguably a fifth category of intangible resources identified in interviews, yet not discussed at length. Most notably, intangibles have a profound influence on the effectiveness of various activities and the efficiency with which tangible resources are used. Many intangibles are also less physically limited: for example, the amount of social capital in a fishery does not subtract from the amount of social capital afforded to industry or essential services. Intangibles like social capital may, however, be limited in less obvious ways (e.g., finite mental energy of people).

3.2.3. Chronic incapacity

All of the preceding discussion points to, and paints a picture of chronic incapacity. Chronic incapacity does not describe the achievements of freshwater fisheries practitioners or the result(s) of their efforts, but rather the main challenge faced by so many. Key to this phenomenon are the interactions between individual challenges, such as competing interests and lacking priority: as a government service, freshwater fisheries management must compete with many other services (e.g., healthcare), making the priority (i.e., resources) afforded to fisheries inevitably low. Data deficiencies stemming from a lack of priority also lead to intersectoral frictions when high-priority activities such as monitoring are delayed, causing other activities (e.g., conferencing) to be curtailed. Political inconstancy frequently disrupts programs, creating gaps in long-term data and perpetuating reactivity (e.g., late detection of fishery declines). Socio-ecological complexity creates a problem of scope, wherein lacking data on fishery users and whole ecosystems render ecosystem management impractical. Political inconstancy often underlies bureaucratic sprawl due to the scattering and deprioritization of various activities that may occur during a political shift. This disruption may then create a problem of limited tools, as activities with major implications for freshwater fisheries (e.g., shoreline development) are relocated farther outside the practitioner's purview. Each unique interaction creates at least one unique problem or "symptom" of chronic incapacity.

3.2.4. Triage management

Together, the symptoms of chronic incapacity create a syndrome that can be described as triage management:

> … where we end up spending quite a bit of our time is a triage approach… trying to kind of parachute in and think about the places that are in acute situations, or most at risk… (provincial level)

> … now it's reactive, and capacity is so diminished. I think peoples' knowledge base is far lower than it used to be, and people are just reacting to crisis, to crisis, to crisis… not actually trying to manage the landscape, they are just reacting to issues. (non-governmental organization)

In medicine, triage describes an approach to unforeseen and (or) urgent situations, wherein lacking resources necessitate the rationing of care according to perceived urgency. While most freshwater fisheries are not threatened with immediate collapse, approaches to management and conservation lack proactivity in ways comparable to medical triage situations. Triage situations in fisheries entail getting stuck in a "reactivity cycle." This leaves little time and few resources to "do more," or envision ways to "do differently," and opportunities (e.g., to increase management scope) are lost. Troubleshooting this is a massive undertaking, which must begin with a full and detailed understanding of the problem.

4. Discussion

Opportunities to build capacity and resilience in freshwater fisheries range from very limited, to more practical and potentially fruitful. By paying close attention to the abovementioned resources and limitations, it is possible to distinguish true opportunities for growth (e.g., using modern technology and strategy to enhance monitoring) from areas of more limited opportunity (e.g., requesting greater shares of very limited and widespread funds).

4.1. Emerging opportunities

Many of the challenges in Section 3.1. are beyond the purview of freshwater fisheries practitioners. Political inconstancy, for example, is a basic fact and positive aspect of democracy. Many of the inefficiencies underlying bureaucratic sprawl are also basic facts of large-scale democratic governance (i.e., checks and balances). In these examples, opportunities are limited by a lack of clear solutions and (or) desirable alternatives, as well as the need for action at much higher levels of government. Practitioners and supporting cast members looking to build capacity and resilience in freshwater fisheries may, therefore, wish to focus elsewhere.

Persistent as the above challenges are, grains of opportunity still exist. Political inconstancy, for example, may be mitigated by taking a longer-term view of issues such as Fisheries Act habitat protections, to avoid drastic fluctuations in the strength of these protections (see Section 1.1.): policies should be reformed with careful consideration of the social and economic interests that compete with freshwater habitat. Prioritizing freshwater habitat must not deprioritize social and economic interests so severely to incentivize an equal, opposite deprioritization of freshwater habitat in future reforms. The specifics of this should be decided by experts in public policy. What we wish to highlight here are the roles of incremental improvement and compromise in long-term success. Achieving greater stability here, and in other areas, would mean fewer precious resources wasted retooling in the wake of political shifts (see Section 3.1.5.). Support for this long-term perspective was expressed by some respondents:

> … in terms of, let's say, habitat management, it was getting pretty powerful… [and] almost absurdly restrictive, so I do understand some of the cuts, even though they were appalling… it's like "oh we just need to [turn] it back to the way it was…" [but] it's not like it was perfect. Reform it, but reform it properly. Don't swing the pendulum all the way over. (territorial level)

The consequences of political inconstancy may be reduced by striving for "low" inconstancy, as opposed to "no inconstancy." In any case, freshwater fisheries practitioners and supporting cast members should operate as if drastic changes in governance are possible, if not likely. In relation to bureaucratic sprawl, grains of opportunity exist wherever new efficiencies can be found. These opportunities are largely beyond the scope of this paper, but two potential starting points are (1) the rift—or perceived rift—between some provincial governments and DFO on the issue of freshwater habitat, and (2) the inability of some provincial authorities to use variation orders (see Section 1.1.).

There are also grains of opportunity related to the challenge of lacking priority: there is evidence that many freshwater fisheries receive less than their "fair share" of attention and resources in management and conservation (Cooke et al. 2016; Lynch et al. 2016). Here, advocacy is both appropriate and necessary, but discrepancies in priority must be quantified precisely and "spelled out" clearly for this to be effective. Though complex and difficult, accurate valuation of freshwater fisheries is a critical task. As discussed in Section 3.1., competing interests and lacking priority may be inconvenient truths for some freshwater fisheries (i.e., fisheries receiving proportionate shares of very limited resources). Researchers should acknowledge and work within this reality, and look to build capacity via ingenuity. Failing to do this may cause research and recommendations to fall on deaf ears, or even undermine relationships and trust.

There are opportunities for capacity building in relation to limited tools, as well as intersectoral frictions: due to existing divisions in natural resource management, landscape-level approaches are only as effective as the relationships between participants (e.g., land-use agencies, fisheries practitioners, NGOs). The quality of these networks—and collaboration(s) within them—are variable:

> … a sustainable fishery has to have good policy and management of fish habitat, as well as water quality… it's difficult when it's not in your jurisdiction. Right now it's working out okay, but in the past it hasn't been as good a relationship. (provincial level)

> … it really depends on the level of coordination and collaboration. We have everything from antagonistic and antithetical approaches, to ones that should be collaborative and aren't. (provincial level)

Social capital is key in all activities that require collaboration. Grafton (2005) identified social capital as a key determinant of user behaviour(s) and cooperation in fisheries—an observation that likely extends to practitioners and their supporting cast. Since divisions in natural resource management will likely persist, increasing management scope will also require strong links and greater harmony between participants. This will require high social capital, as well as governance structures that do not create silos within natural resource management. Social capital is one of several intangibles that may increase management capacity despite tangible resource limitations. Strategic investments in social capital are beyond the scope of this paper, but our results provide a rationale for paying greater attention to intangible resources as a whole. Such investments may be considered worthwhile if their anticipated benefits (e.g., increases in compliance) outweigh potential costs (e.g., mental burnout).

The problem of reactivity relates to virtually all other persistent and innate challenges, but there are opportunities to reduce and (or) avoid reactivity by ensuring that management plans are flexible enough to accommodate "unknown unknowns." For many practitioners, the importance of flexibility is obvious, but their supporting cast may also benefit from operating as though changes in environment and society (e.g., economic recessions, ecological regime shifts) are possible, if not likely. Also key to reducing reactivity are the (sometimes weak) links between planners (i.e., policy makers) and managers (i.e., regulators) in freshwater fisheries. Robust links between these individuals and processes are requisites for proactive management and key to sustainability in all types of fisheries (Gee et al. 2017). Managers and researchers in freshwater fisheries may look to marine fisheries literature (e.g., Gee et al. 2017) in addressing this specific challenge.

There are major opportunities to improve our grasp on freshwater fisheries socio-ecology by incorporating scientifically robust methods and human dimensions research where they are lacking (e.g., where management is informed by non-probabilistic and [or] non-standardized data):

> … when it comes to the human elements of work, I do trust my knowledge and gut a fair amount… (federal level)

> … it might be more prone to the personal bias of the manager because it's so much more social. (provincial level)

As they are currently conducted, activities such as consultation may provide decision-makers with misleading information (Hunt et al. 2010). Increasing the scientific rigour of "people management" could involve leveraging the national Survey of Recreational Fishing, or drawing on human dimensions research (e.g., angler heterogeneity and spatial dynamics [Beardmore 2013; Dabrowska et al. 2017], aquatic stewardship [Bruskotter and Fulton 2008; Landon et al. 2018], and user preferences [Poudyal 2021]) in creative, new ways. Human dimensions research (e.g., forecasting fishing patterns) can facilitate proactive management in ways similar to ecological forecasting (Hunt et al. 2021) and is a necessary complement given the intertwinedness of people and ecosystems in fisheries.

Opportunities to better grasp ecological complexity also exist in the creation—and prospective incorporation—of new technologies and methods for monitoring and researching fisheries. As a whole, modern technologies can facilitate more responsive freshwater fisheries management (Cooke et al. 2022). Environmental DNA (eDNA) and genomics, for example, can provide data on fish populations (e.g., abundance, structure, sublethal stress) and whole ecosystems (e.g., prevalence of specific stressors) not currently collected, or collected less efficiently with current methods (Lacoursière-Roussel et al. 2016; Connon et al. 2018; Yates et al. 2019, 2021; Semeniuk et al. 2022). The potential benefits of this are numerous (e.g., more time- and cost-effective monitoring, rapid AIS detection, steps toward ecosystem management), as some practitioners are already aware:

> As soon as eDNA breaks through… which I think is really close, then our monitoring costs go way down. (provincial level)

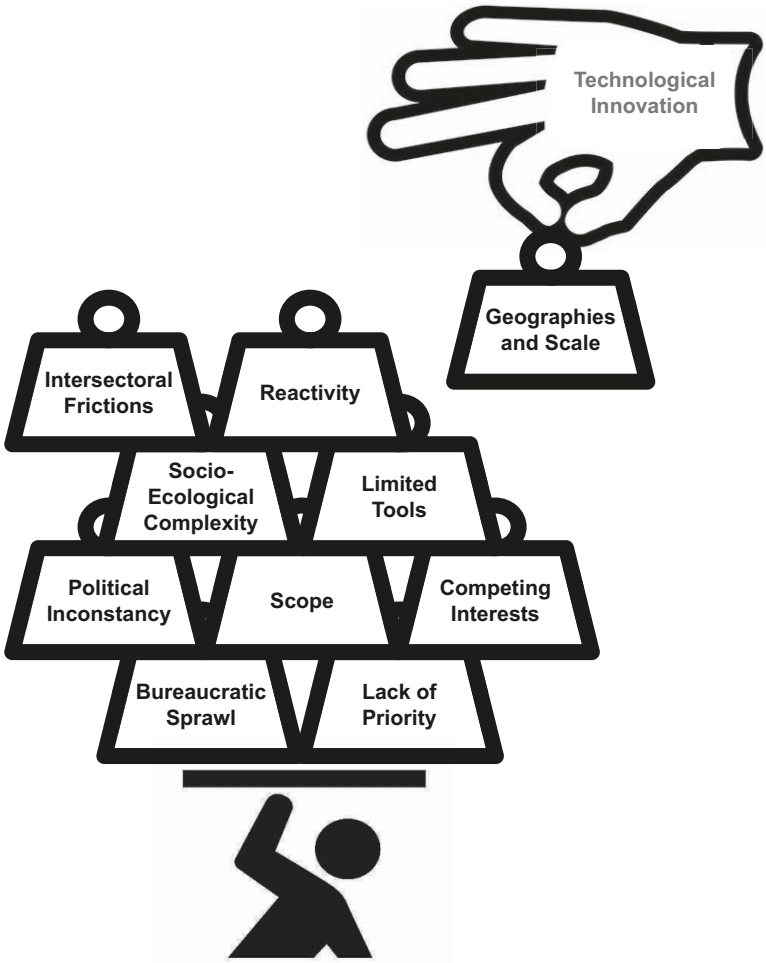
Developers of novel technology and technique should carefully consider where and how products can "boost" management. Enhancing routine, albeit resource-intensive activities like monitoring, is a major opportunity to increase capacity despite harsh limitations. Enhancements of this type can reduce the challenge of geographies and scale, as well as increase and (or) optimize management scope by allowing vast freshwater fisheries to be monitored more comprehensively at an equal, or even reduced cost. In other cases, vast landscapes have been made more manageable by strategic shifts (e.g., transition to broad-scale monitoring in Ontario; Lester et al. 2003), which also provide opportunities to address this challenge.

Novel technologies can provide novel data, but their utility will be minimized if data management lags behind: mismanagement and inaccessibility currently prevent large quantities of high-resolution data from being used to various ends (Blair et al. 2020; Nicholson et al. 2020). Until this problem is solved, opportunities related to novel technology and data (e.g., moves toward ecosystem management) will be lost. As mentioned in our discussion of bureaucratic sprawl, data may simply appear deficient if they are mismanaged or poorly communicated—moves toward open data and investments in data management capacity are necessary for these reasons. A second major barrier to novel technology and data use is the lack of practical guidelines accompanying some innovations and suggestions (e.g., data on sublethal stress and ecosystem management). So long as freshwater fisheries practitioners are in "triage" mode, the costs of adopting new tools and methods must be near zero. The aforementioned supporting cast must, therefore, play the role of facilitator, and innovate in ways that provide a long-term boost with little or no short-term drag.

5. Conclusion

Managers in Canadian freshwater fisheries face persistent challenges (e.g., bureaucratic sprawl) which defy conven-

Fig. 2. The limiting effect(s) of persistent and innate challenges on freshwater fisheries management. Due to connections and interactions between challenges (e.g., bureaucratic sprawl and limited tools), alleviating strain in one area will reduce cumulative strain, creating new opportunities for growth. For example, technological innovations that lead to more efficient monitoring may reduce the challenge of Canada's physical geography, giving practitioners more freedom to address issues such as intersectoral frictions.



tional problem solving (e.g., basic science, advocacy). The need for creative solutions in this area is acknowledged—at least implicitly—in calls and (or) recommendations for more impactful fisheries science (Rothschild and Beamish 2009; Nguyen et al. 2018). Capacity in freshwater fisheries is limited for many reasons—some of them satisfactory (e.g., precedence of essential services) and others less so (e.g., undervaluation of freshwater fisheries). The consequences of this are chronic incapacity and triage management in many fisheries. Limited resources must be maximized, and emerging opportunities seized, to provide the best chance of sustainability.

Practitioners and their supporting cast must work within the realities of bureaucracy and politics, seeking new efficiencies and supporting and (or) striving for low political inconstancy within their spheres of influence. Where freshwater fisheries receive less than their fair share of resources, practitioners and their supporting cast must advocate coherently for the elimination of this disparity (i.e., quantify precisely and communicate clearly the value of freshwater fisheries to decision-makers and their constituencies). Strong links and high social capital should become primary goals in all activities requiring collaboration across sectors and levels of government, the primary example of this being habitat management. These activities will also require governance structures that do not create silos within natural resource management. As a whole, intangibles like social and organizational capital must not be ignored, particularly where these can increase management capacity despite tangible resource limitations. In the interest of more proactive management, flexibility should be optimized in all management plans, and stronger links sought between planners and managers. Monitoring and management of the human dimension in freshwater fisheries must become more scientifically robust and be considered alongside ecological and biological information to understand and anticipate human impacts amidst societal and environmental change. Strategic innovations, such as broad-scale monitoring, have made vast freshwater fisheries more manageable despite persistent limitations, and represent a broad and diverse category of opportunities for capacity building. Modern technologies and methods

provide unprecedented insight on the ecology and biology of freshwater fish, and—like strategic innovations—can dramatically enhance such routine activities as monitoring, as well as provide novel data on species and whole ecosystems. However, data management and accessibility are lagging behind, preventing much novel data from translating to novel insight.

Canada's vast physical and human geographies present arguably the most persistent challenge discussed in Section 3.1. and tell a story of freshwater fisheries management more broadly. Both of the opportunities that we identified in relation to this challenge (i.e., technological and strategic innovation) increase what can be accomplished with limited resources, and are similar in that they result from ingenuity. Solutions like this are desirable, and in fact necessary to confront wicked problems (Homer-Dixon 2010). Because limitations in freshwater fisheries management (see Section 3.1.) interact and overlap, and because practitioners may wear multiple hats, the provision of support in one area will reduce strain in adjacent areas and create new opportunities (Fig. 2). Increasing the efficiency of monitoring, for example, might provide the necessary freedom to form new collaborations across jurisdictions and sectors, or look beyond single species to whole ecosystems. Transcending triage management, therefore, will require supportive contributions beyond what currently exist, as well as readiness to seize the opportunities that arise from this.

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To ensure confidentiality, and per our agreement with the Carleton University Research Ethics Board (project # 112864), data for this project are not publicly available.

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Appendix A. Interview guide as administered in survey

Freshwater Fisheries Management Practitioner Interview Guide

Participant: _____
Date: _____
Interviewer: _____
Oral Consent (Y/N): _____

Introduction: *First, I want to thank you for agreeing to participate in this interview. You may already be aware, but I'm interested in the management of Canada's freshwater fisheries and how that varies across different jurisdictions. My first question is about your jurisdiction and personal responsibilities.*

1. What is the jurisdiction that you're responsible for?

a. What are your specific responsibilities? *(e.g., management, assessment, research? Just fish, or other natural resources?)*

Regulations and Activities: *The next few questions cover some fundamentals of freshwater fisheries management in your jurisdiction (e.g., regulations, management activities).*

2. In your jurisdiction, what techniques are used most commonly to… (Prompt [if asked for examples]: Implementing/modifying regulations, conducting stock assessments, implementing education and outreach programs…)

a. Manage fish stocks?
b. Manage habitat?
c. Managing fishery users (i.e., anglers, commercial fishers)?

3. Can you describe how fishing regulations are created in your jurisdiction?

a. Do you use formal processes to make decisions and/or reach consensus on management actions or strategies (e.g., assessing stocks, restoration, modifying regulations)?
b. [if "yes" to 4a] Can you describe what these processes are?
c. Who is involved, and how do they contribute?
d. [if "no" to 4a] How do you make decisions about regulations?

4. To what extent are fisheries in your jurisdiction managed using an ecosystem approach?

a. [if applicable] Can you describe how this approach is implemented?
b. [if applicable] In your opinion, is this approach effective?

Collaboration: *This series of questions will involve the collaborations that take place in your management jurisdiction. I'll ask about the advice you receive, stakeholder relationships, and collaborative management.*

5. Are stakeholders formally engaged in fisheries management (in your jurisdiction)?

a. [if "yes" to 5] Can you describe in what ways stakeholders are formally engaged?
b. [if "no" to 5] Why aren't stakeholders engaged formally?
c. [if "no" to 5] Are stakeholders engaged informally?
d. [if "yes" to 5c] Can you describe in what ways stakeholders are informally engaged?

6. Do other organizations, agencies, or groups play a role in the management of fisheries within your jurisdiction?

a. [if "yes" to 6] Which organizations, agencies, or groups play a role?
b. [if "yes" to 6] Can you explain their role?

7. [if applicable] Do you feel that non-governmental individuals/institutions help your organization manage fisheries?

a. [if "yes" to 7] Where do non-governmental individuals and/or institutions make the biggest impact?
b. [if "no" to 7] What changes are needed for non-governmental "individuals" or "institutions" to have a more positive impact?

In the next few questions, I'll ask further about the roles of non-governmental institutions and individuals in fisheries management. I define non-governmental institutions as any groups, organizations, and/or associations that are not part of the government, such as angling clubs and watershed groups.

8. [if applicable] In the previous decade, did your organization transfer any management responsibilities to non-governmental institutions/individuals, or other external groups?

a. [if "yes" to 8] What responsibilities were transferred, and to whom?
b. [if "yes" to 8] Why were responsibilities transferred?

9. *(Prompt: In the pre-questionnaire, you reported [see pre-questionnaire Question 4] interactions with managers outside of your jurisdiction)* In your opinion, is there enough interaction between fisheries professionals from different jurisdictions (e.g., non-governmental, other governments)?

a. What type of interactions occur most frequently across jurisdictional boundaries?
b. What type(s) of interactions do you wish occurred more? Why?

Communication and Knowledge Exchange: *This next series of questions will involve the flow of information, and the use of science by your organization and throughout your jurisdiction.*

10. What would you do if you had a question about… *(Prompt [if asked for examples]: Implementing/modifying regulations, conducting stock assessments, implementing education and outreach programs)*

a. Managing fish populations?
b. (Prompt [if applicable]: if not already answered fully…) Managing aquatic habitats?
c. (Prompt [if applicable]: if not already answered fully…) Managing fishery users?

11. Can you describe how external fisheries science reaches you and/or your organization?

a. In your jurisdiction, who would you say is responsible for the communication of information between management groups?

b. What percentage of your communication with other individuals and/or groups is "informal" or "casual"? *(Prompt [if asked to explain]: by this, I mean casual or friendly exchanges that take place outside of your official work environment)*

12. How can you tell if information is reliable for decision-making purposes?

a. Is new information formally vetted via an institutional process? *(Prompt [if asked to clarify/explain]: for example, CSAS reviews scientific information for provision to DFO)*
b. [if "yes" to 14a] What happens to new information after formal vetting?

13. Do you think fisheries science translates effectively to action?

a. [if "yes" to 16] Why? *(Prompt: Can you remember a good example of this?)*
b. [if "no" to 16] Why not? *(Prompt: Can you remember a good example of this?)*
c. Do you have any say in what research is conducted "externally" or "non-governmentally," and how?

Resources: *This series of questions is about the resources that your organization uses to manage fisheries. I'll ask about the use of management resources (e.g., money, data, labour, expertise), where resources are lacking, and how specific types of resources affect your management of fisheries.*

14. Do you believe your organization has enough resources to manage fisheries effectively?

a. [if "no" to 17] What resources are lacking, and why?
b. [if "no" to 17] How are resource shortages combatted?

15. What management activities require the most resources?

a. What do you think makes them so resource-intensive?
b. In your opinion, are resources used efficiently?

Trends and Effectiveness: *This series of questions is about past trends that you've witnessed, and anticipated future trends. I'll ask about your observations, and the lessons, improvements, bright spots, barriers, and potential solutions that you've identified through experience.*

16. Is fisheries management in your jurisdiction more, less, or equally effective as it was ten years ago? Why/why not?

a. In the past decade, were there any major management breakthroughs?
b. [if "yes" to 19a] Can you describe these breakthroughs?
c. [if "yes" to 19a] What impact(s) did this/these have?
d. [if "yes" to 19a] What led to these breakthroughs?

17. What developments (e.g., in management, use) make you excited about the future of freshwater fisheries?

a. What areas of the management system in your jurisdiction have the greatest opportunity to improve?

18. What would you consider the single biggest threat to Canada's freshwater fisheries?

19. If you could make one change in how we manage freshwater fisheries in Canada, what would it be?

20. Do you think there is a need for a more harmonized approach and/or more collaboration in fisheries management and science across Canada?

COVID-19 Questions: *The next two questions are about the COVID-19 pandemic, and its effect on fisheries management, health, and use.*

21. What management challenges did your organization face when dealing with the COVID-19 pandemic?

22. Do you think the COVID-19 pandemic has influenced fish populations and/or fishing patterns significantly in your jurisdiction? *(Prompt [if in need of examples]: for example, due to increases, decreases, or other changes in fishing pressure and anthropogenic disturbance)*

a. [if "yes" to 25] What do you think caused these changes?
b. [if "yes" to 25] In your opinion, how positive/negative are these changes?

c. [if "yes" to 25] Do you think these changes will be short-lived (i.e., <5 years), or extend to the long-term (i.e., >5 years)?

Closing Questions: *My three final questions will conclude this session, identify additional interview candidates, and set the stage for a future/follow-up study.*

23. How similar do you think your experience is, relative to that of other members of your organization?

a. How similar is fisheries management in your province/region to other provinces/regions?

Given the topic of our study, we would appreciate your help in identifying other individuals that we could talk to.

24. Who, in your organization, would you consider an expert authority on fisheries management in your jurisdiction that we could also contact? *(Prompt: option to follow up* via *email)*

We hope that you enjoyed this discussion, and would like to invite you to participate in a follow up study. This could involve an interview, questionnaire, or focus group about more specific scientific developments in the fisheries management toolbox.

25. Would you be open to a follow-up?

Appendix B. Questionnaire as administered in survey.

Pre-Interview Questionnaire

Participant Name: _____ Age: _____ Gender: _____
Education/Training (highest degree attained): _____
Organization: _____
Current Position: _____ Duration (years): _____
Previous Position(s) (fisheries management):

Organization	Position	Duration
_____	_____	_____
_____	_____	_____
_____	_____	_____

1. What percentage of your time is devoted to the following activities…

Fisheries management (e.g., policy development, implementing regulations)? _____ %
Management of other natural resources (e.g., wildlife, forestry)? _____ %
Enforcement/compliance? _____ %
Monitoring? _____ %
Research? _____ %
Stakeholder engagement? _____ %
Other? (include all that apply)
_____ _____ %
_____ _____ %
_____ _____ %
_____ _____ %
_____ _____ %

2. How frequently do you consult… (highlight/circle the most appropriate option)

Colleagues and internal scientists?	daily	weekly	monthly	quarterly	yearly	never
Non-governmental scientists?	daily	weekly	monthly	quarterly	yearly	never
Recreational fishers?	daily	weekly	monthly	quarterly	yearly	never
Commercial fishers?	daily	weekly	monthly	quarterly	yearly	never
Indigenous groups?	daily	weekly	monthly	quarterly	yearly	never

Other? (Include all that apply)

_____	daily	weekly	monthly	quarterly	yearly	never
_____	daily	weekly	monthly	quarterly	yearly	never
_____	daily	weekly	monthly	quarterly	yearly	never
_____	daily	weekly	monthly	quarterly	yearly	never
_____	daily	weekly	monthly	quarterly	yearly	never

3. What percentage of fisheries management goals in your jurisdiction are fulfilled by non-governmental contributions? Estimate. _____ %

a. What percentage of management goals are aided by non-governmental institutions? Estimate. _____ %
b. What percentage of fisheries organizations in your jurisdiction are non-governmental? Estimate. _____ %

4. How frequently do you interact with managers outside of your jurisdiction? (highlight/circle the most appropriate option)

daily	weekly	monthly	quarterly	yearly	never

5. What were the most notable fisheries management issues in your jurisdiction during the previous decade? (rank according to significance)

1. _____
2. _____
3. _____
4. _____
5. _____

6. What fisheries management issues do you anticipate emerging/intensifying in the next decade? (rank according to significance)

1. _____
2. _____
3. _____
4. _____
5. _____