Embracing Disruptive New Science? Biotelemetry Meets Co-Management in Canada's Fraser River

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Evidence-based management of fisheries means being continually open to new sources of scientific findings and data, but this is difficult when there is uncertainty or disagreement about their value and utility. We submit that this is the case for rapidly advancing animal tracking research, or biotelemetry. While biotelemetry science has been broadly accepted in fisheries and aquatic research communities, its incorporation into fisheries policy and management has been limited. To gain insight into this disjuncture, we conducted an exploratory study of perspectives on biotelemetry among government employees and nongovernmental stakeholders involved in co-managing salmon fisheries in Canada's Fraser River. Using a knowledge mobilization theoretical framework, we examine how respondents perceived biotelemetry research across three dimensions: its epistemic value (its capacity to generate useful and valid new knowledge), its practical value (relative to real-world considerations such as cost), and its degree of fit or discord with existing policy and management practices. We find a wide range of views between both groups, which may explain the hesitant uptake of biotelemetry into policy and management in this case. We conclude by advancing several research questions as a guide for future study of the integration of new sources of knowledge into evidence-based management.

INTRODUCTION

This article presents a case study of biotelemetry research in Canada's Fraser River salmon fisheries, and the challenges involved in incorporating findings and data from this research into evidence-based management. Evidence-based management of natural resources is promoted as a means of ensuring that advances in scientific knowledge are continually incorporated into policy and management decision making (Sutherland et al. 2004; Dicks et al. 2014; Cooke et al. 2017). However, a growing multidisciplinary literature suggests that moving scientific evidence and data from the research community to user communities that might apply them is more complex and difficult than is generally assumed (Roux et al. 2006; Nguyen et al. 2017). This heterogeneous literature uses several terms to conceptualize the process of incorporating new evidence and data into decision-making practices, including knowledge mobilization (KM) and knowledge exchange (KE; Young et al. 2016a).

Research on KM and KE has shown that a wide range of factors influence how knowledge is accessed, interpreted, and applied (or not) by various user communities. We summarize key findings from this literature in Table 1 and distinguish among three types of factors or challenges involved in mobilizing knowledge for decision making: social-organizational, individual-level, and evaluative. Social-organizational challenges refer to the influence of social structures and practices on a user community's receptiveness to new evidence and data in a general sense. Individual-level challenges refer to the capacities and preferences of key individuals with respect to particular types of evidence or data. Evaluative challenges refer to perceptions of the strengths and weaknesses of the evidence or data themselves, including practical considerations of whether it is worth the effort and cost to generate or apply a given type of evidence.

We used an exploratory research design, based on interviews containing a mix of closed- and open-ended questions, to elicit the views of government employees and

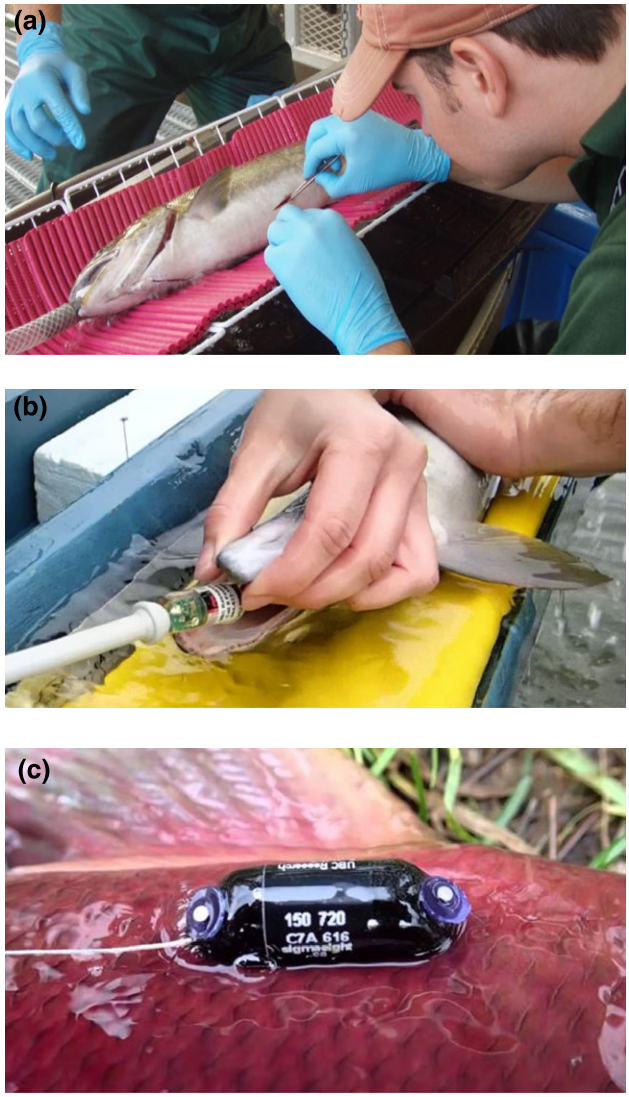
Table 1. Major challenges involved in mobilizing new knowledge into policy and management decision making (organizational, individual, and evaluative).

Challenge	Select literature
Social-organizational challenges	
Organizational (in)flexibility. Government bureaucracies are typically organized hierarchically. Procedures are heavily codified, and deviations require multiple levels of approval. Limits on employee discretion create a disincentive to risk-taking. Bureaucratic deliberations on the validity of new knowledge and evidence are often slow and hidden from public view.	Leiss (2000), Amayah (2013), Terry (2015)
Absorptive capacity. Refers to the ability of organizations to seek out and integrate new knowledge. Organizations that have a culture of learning (including appropriate allocations of time and rewards), open channels of communication (horizontally and vertically), and high levels of diversity in skills, education, and background are typically more open to new knowledge and evidence than those that are homogeneous and closed.	Zahra and George (2002), Belkhoja et al. (2007)
Political considerations. Political conflict or controversy can discourage experimentation, as authorities seek to avoid upsetting key stakeholders and/or an existing balance of interests. Considerations such as fairness and aversion to setting precedents can discourage experimentation, context-specific decision making, and/or small-scale piloting of new practices.	Irwin et al. (2012), Young et al. (2013)
Communicative limitations. Evaluation of scientific tools, findings, and evidence can be helped or hindered by communication choices and strategies. Knowledge generators often fail to adequately communicate potential applications to user groups.	Hulme (2015), Van Stigt et al. (2015)
Individual-level challenges	
Skills, education, familiarity. Key individuals may lack the capacity to access, interpret, and apply findings and evidence that may be unfamiliar.	Cvitanovic et al. (2014)
Experiences and preferences. The prior experiences and/or preferences of key individuals may encourage or discourage engagement with new forms of evidence.	Cook et al. (2010)
Evaluative challenges	
Epistemological value. Individuals, organizations, communities of practice may view the scientific, technological, and/or evidence basis of new knowledge as limited, flawed, or not relevant, thus restricting its value. Alternatively, novel information that is seen as credible can have high value.	Gieryn (1999)
Practical value. Considerations such as cost, time lags, limited spatial coverage, and/or access to data or findings can affect how potential users view scientific findings and evidence.	McGowan et al. (2016)
Perceived fit or departure from current practices. Knowledge or evidence that is perceived as consistent with current practices is often more easy to accept and/or integrate than evidence whose relationship to or consequences for decision-making practices are unclear.	Cash et al. (2003)

nongovernmental stakeholder groups on biotelemetry research and its potential applications to salmon management in the Fraser River. Because we are investigating perceptions of a specific type of evidence, this article focuses on evaluative challenges. Broader discussions of the social-organizational and individual-level challenges associated with this case can be found in Young et al. (2016a, 2016b).

BIOTELEMETRY AND FRASER RIVER SALMON FISHERIES

Biotelemetry involves the electronic tagging and remote tracking of animals within their environments (Cooke et al. 2004) and has become an important research tool in recent decades as the suite of available technologies has expanded and the cost of tags has decreased (Hussey et al. 2015). A variety of biotelemetry platforms exist, including radio, acoustic, passive integrated transponder (PIT), and satellite, each with their distinct benefits and limitations (summarized in Cooke et al. 2012). Biotelemetry has opened a portal for understanding the heretofore hidden lives of fish (including behavior, survival rates, environmental relations, and migration corridors) in habitats ranging from small streams to entire ocean basins. Large numbers of fisheries and aquatic scientists now use biotelemetry (Hussey et al. 2015), and biotelemetry research networks exist in the United States, Europe, Canada, and Australia. Despite this, there are still relatively few examples of biotelemetry findings and data being directly integrated into evidence-based fisheries management (Crossin et al. 2017; McGowan et al. 2017).



Pacific salmon in the Fraser River are tagged in a variety of ways to allow them to be tracked with telemetry including (a) surgical implantation, (b) gastric insertion, and (c) external tagging. Photo credits: Steven Cooke (top), Steven Cooke (middle), Melissa Dick (bottom).

The Fraser River is one of Canada's most intensely fished rivers and has a history of conflict among user groups (Nguyen et al. 2016). Three fishing sectors targeting adult migrating Pacific salmon *Oncorhynchus* spp. occur in or near the Fraser River: commercial, recreational, and First Nation (indigenous), all with different catch allocations and restrictions. Regulation of these fisheries is complex, involving the Canadian Department of Fisheries and Oceans (DFO), the Canada–U.S. Binational Pacific Salmon Commission (PSC), and co-management arrangements with First Nation communities in the Fraser watershed. Other stakeholder groups such as commercial fisheries, recreational fisheries, and conservation groups are involved in co-management via advisory board committees that meet regularly with DFO to discuss planning and forecasts, escapement goals, and allocation of harvest (Cohen 2012). Both DFO and PSC are explicitly committed to evidence-based management of salmon fisheries (Cooke et al. 2016).

While the number of adult salmon returning to the Fraser River varies each year, recent fluctuations in Sockeye Salmon *Oncorhynchus nerka* have been extreme, including poor returns to spawning groups associated with very low production. This has raised concern among stakeholders and the general public, and in 2009, the Government of Canada convened a judicial inquiry presided by retired British Columbia Supreme Court Justice Bruce Cohen to investigate. The Cohen Commission heard from 179 witnesses, including government managers and scientists, academics, First Nations people, commercial and recreational fishers, conservation groups, and landholders. While no smoking gun was found to explain the fluctuations, the inquiry's final report highlighted the need for further research to better understand the challenges facing salmon populations in an era of environmental change.

At first glance, biotelemetry appears well suited for addressing this knowledge gap. Canada's southern Pacific coastal region has seen one of the most extensive deployments of biotelemetry research and infrastructure in the world (Hussey et al. 2015). Radio, acoustic, and PIT studies have been conducted nearly annually for the past 20 years on Sockeye Salmon, along with occasional studies on other salmon species (Welch et al. 2002; Ma et al. 2012). Acoustic and radio receivers (listening lines) have been deployed at numerous locales throughout the Fraser River watershed, as well as several acoustic receiver lines (each comprised of multiple receivers) situated coastally in the Pacific Ocean from southern Vancouver Island to northern Vancouver Island (see Figure 1). Passive integrated transponder telemetry stations have been placed strategically on key sites (e.g., within the Seton subwatershed) within tributaries where constrictions (e.g., fishways, spawning channels) allow deployment of PIT arrays. Additionally, biotelemetry researchers affiliated with several Canadian universities have held an annual knowledge exchange workshop since 2004 with the aim of communicating results to government regulators and stakeholders and

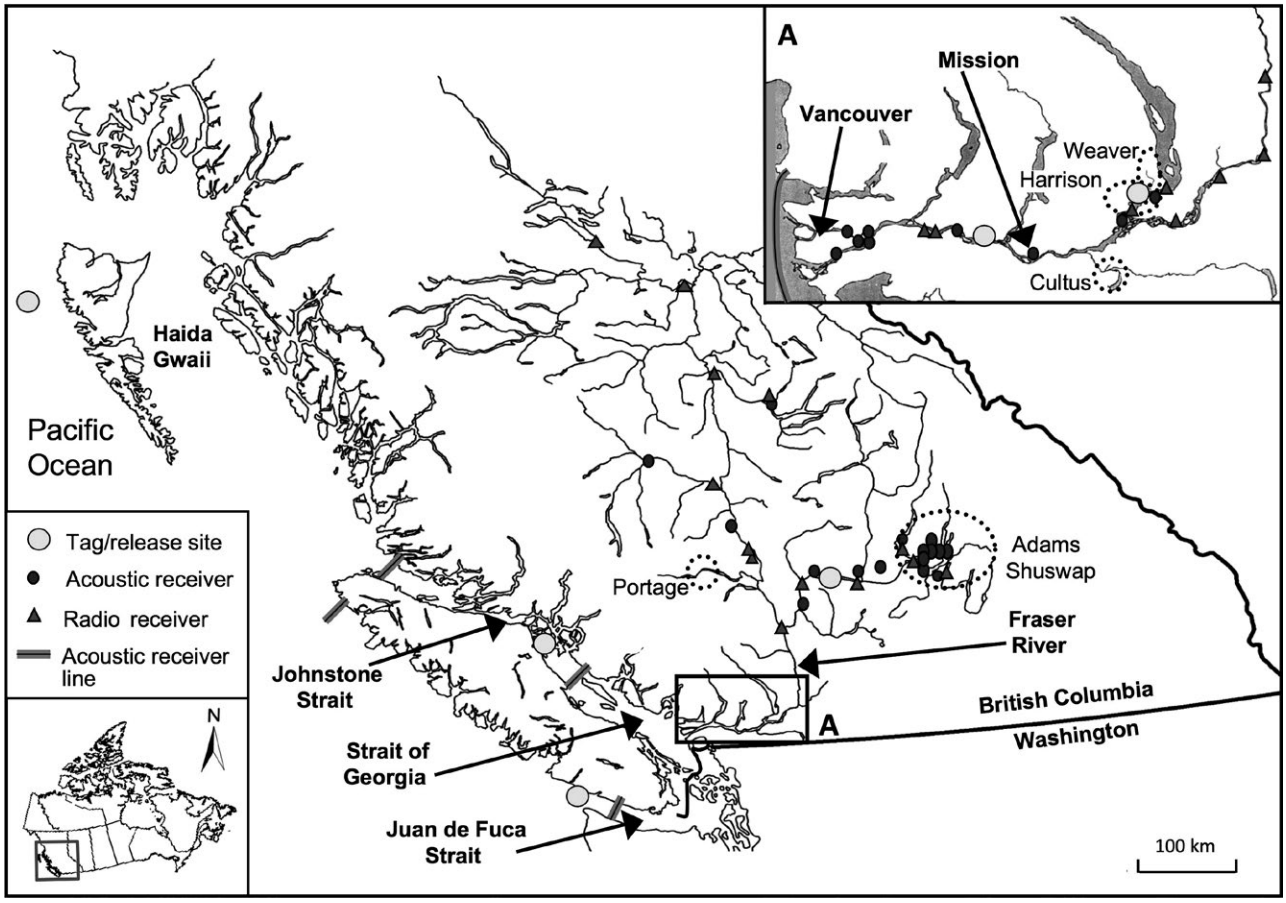


Figure 1. Map of the case region (passive integrated transponder receiver sites are not indicated). Modified from Hinch et al. (2012).

receiving feedback to guide future studies (e.g., Hinch and Gardner 2009). This workshop highlights biotelemetry findings, potential applications, and intersections with other physiological and ecological research.

METHODS

This research was exploratory, aimed at generating research questions rather than testing hypotheses. It was conducted in two stages as part of a larger project entitled "Mobilizing New Knowledge for Fisheries Management in the Fraser River" (see Young et al. 2016a, 2016b). The first stage involved 67 interviews conducted in person between November 2013 and September 2014, 33 with government employees and 34 with representatives of stakeholder groups involved in co-management (see Table 2). The sample population for the stage-one interviews was determined in consultation with DFO, the main regulating body. It includes a large number of people in fisheries management, as these are the employees most directly involved in daily decision making (see Table 2). The sample also includes employees in DFO Science who were identified as working closely with fisheries managers and stakeholder groups. Several senior managers were also interviewed, as well as members of PSC. As for the nongovernmental stakeholder population, we interviewed participants in co-management arrangements from a variety of backgrounds, including commercial marine fisheries, recreational freshwater fisheries, and First Nation fisheries. Our population also includes leaders of conservation groups and environmental consultants employed by stakeholder groups. A number of respondents had previously attended at least one session of the annual knowledge exchange workshop described in the previous section (see Table 2). It is possible that prior attendance

Table 2. Affiliations of respondents in two stages of the research.

	Stage 1	Stage 2
Government employees		
Fisheries management branch (Department of Fisheries and Oceans [DFO])	18	8
Science branch (DFO)	4	3
Senior management (DFO)	3	2
Pacific Salmon Commission	6	2
Other	2	1
Stakeholders		
Commercial fishery	4	1
Recreational fishery	8	2
First Nation fishery	5	5
Environmental nongovernmental organization	8	5
Environmental consultants	4	4
Other	5	2
Total number of respondents	67	35
Percentage of respondents who are female	24%	20%
Estimated response rate	64%	75%
Percentage of respondents who attended at least one biotelemetry workshop	31%	60%

at these events may have influenced respondents' views on biotelemetry, positively or negatively. For clarity, we indicate whether the participant had previously attended a workshop with each of the quotations discussed below.

The stage-one interviews addressed how respondents seek out, evaluate, and use different types of knowledge in their opinion formation and decision making about Fraser River salmon fisheries. The stage-one interviews also contained one open-ended question specific to biotelemetry (see Table 3). Stage-two interviews focused predominantly on biotelemetry and were conducted between December 2015 and May 2016 with a subsample of 20 respondents who self-identified as having high familiarity of biotelemetry during the stage-one interview (in response to question 1Qa). In addition, 15 new respondents were recruited, 11 from the original population and 4 new persons identified by DFO who had recently assumed positions or appointments.[1] A total of 82 individuals were interviewed: 47 participated in the stage-one interview only, 15 were stage-two only, and 20 were interviewed twice.

Given the exploratory nature of this research, both interview schedules employed a mixed-methods approach including closed- and open-ended questions (Axinn and Pearce 2006). The closed-ended question (2Qa) involved a series of Likert-style opinion statements for which respondents were asked to indicate their level of agreement on a five-point scale (strongly agree, agree, neither agree nor disagree, disagree, and strongly disagree), with the option of answering "I don't know." Open-ended questions (1Qa, 2Qb–d) allowed respondents to explain their positions and opinions freely (Seidman 2013). Two distinct coding methods were used for the open-ended responses: inductive and directed (Hsieh and Shannon 2005). Inductive coding was applied to stage-one interviews (as these were conducted with a more general population) and followed a three-step procedure (Thomas 2006). First, responses to each question 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. Directed coding was employed for the stage-two research (a more specialist population of more knowledgeable respondents) and followed a two-step process. First, responses were read to identify and highlight text associated with any of the three evaluative dimensions outlined in Table 1 (epistemic value, practical value, and fit). Second, highlighted text was reread to classify responses into one of the three categories for each dimension: high/good (clear statement of praise or endorsement without qualifiers), mixed/uncertain (multiple viewpoints, some positive and some critical), or low/poor (clear statement of criticism or negative evaluation, without qualifiers). Nonmentions were also catalogued. All coding was performed by the first author.

RESULTS

Stage-One Interviews

Findings from the open-ended question 1Qa are given in Table 4, which outlines the prevalence of positive or supportive comments about biotelemetry research, and Table 5, which does the same for critical or negative responses. The tables include the ratio of respondents who indicated that they were not familiar enough with biotelemetry to answer (~20% of respondents). Looking at Table 4, we see that respondents were most supportive of biotelemetry's generation of original data (mentioned by 23% respondents) and its illumination of the speed and/or timing of animal movements (19%). The fact that biotelemetry collects data on real individuals and behaviors was also seen as a strength by some (13%), as was information generated on migration routes and processes (13%) and information on animal mortality (13%). Most positive themes were expressed by both government employees and stakeholders, with a few exceptions. For example, stakeholders did not mention the generation of information on specific stocks as a strength, nor the use of biotelemetry to conduct exploratory research. We also note that most of the positive commentary refers to epistemic criteria, with "cost-effective" being the only practical criterion evoked.

In contrast, the critical comments about biotelemetry research are a mix of epistemic and practical considerations. The most commonly cited practical criticism is the high cost of research (mentioned by 28% respondents); the other practical criticisms were infrastructure maintenance, battery limitations, and time delay in getting data (each mentioned by one respondent). Important epistemic criticisms include suspicion that the insertion or presence of a transmitter may affect fish behavior (22%) or that the tag itself may cause mortality (16%). Concerns were also expressed about small sample sizes (8%) and the degree of interpretation required to analyze biotelemetry data (8%). Overall, government employees expressed a greater range of concerns than did nongovernmental stakeholders.

Stage-Two Interviews

Table 6 presents findings from the eight opinion statements that were read to respondents during the stage-two interviews (2Qa). For visual clarity, we have collapsed the five-point Likert scale to a three-point scale (agree/neither/disagree). The statements were designed to have mixed connotations to prompt a range of replies. Because the stage-two interviews involved a limited nonrandom sample, we did not perform inferential statistical analyses on the results. Nevertheless, Table 6 shows some patterns. First, respondents saw biotelemetry as

Table 3. Interview questions analyzed in this article.

Question	Type	Reference #
Stage-one interview		
Are you familiar with fisheries research using biotelemetry? [If yes] What do you think of this research?	Open-ended	1Qa
Stage-two interview		
Eight opinion statements on biotelemetry research	Closed-ended, Likert style	2Qa
Do you think biotelemetry research has a role to play in managing salmon fisheries in the Fraser River?	Open-ended	2Qb
In your opinion, what are the strengths and weaknesses of biotelemetry research?	Open-ended	2Qc
Can you imagine any scenario(s) in which biotelemetry would or could concretely help in the management of salmon fisheries in the Fraser River?	Open-ended	2Qd

Table 4. Positive or supportive comments about biotelemetry research in response to 1Qa (ratio of respondents mentioning).

	Government employees	Stakeholders	Total
Original data and/or information	0.27	0.19	0.23
Speed and/or timing of movements	0.21	0.16	0.19
Tracks real individuals/real behaviors	0.09	0.16	0.13
Migration routes and processes (information about)	0.15	0.10	0.13
Measuring mortality	0.15	0.10	0.13
Population dynamics of specific stocks	0.18	–	0.09
Exploratory research/question generation	0.12	–	0.06
Interesting (unspecified)	0.03	0.10	0.06
Environmental stressors (information about)	0.06	0.06	0.06
Valuable (unspecified)	0.03	0.06	0.05
Geospatial understanding of habitat and/or ecosystem	0.06	0.03	0.05
Cost-effective	–	0.10	0.05
None mentioned	0.03	0.03	0.03
Helps with selective fishing/targeting stronger stocks	–	0.06	0.03
Identifying anomalies and/or unknowns	0.06	–	0.03
Record of who catches what (anti-poaching)	–	0.03	0.02
High volumes of data	0.03	–	0.02
Not familiar enough with biotelemetry to answer	0.18	0.23	0.20

providing highly original data (#5) but were not unanimous in their assessment of its reliability (#1–3). Second, fewer respondents expressed concern about the cost-effectiveness of biotelemetry research (#4) than indicated in the stage-one findings. Third, there appeared to be a strong desire for biotelemetry to play a more central role in salmon management (#6), a sentiment that was most acute among government employees. Finally, opinion was divided on whether use of biotelemetry research by managers should await a formal review process (#8). For example, DFO uses a process termed a "CSAS (Canadian Science Advice Secretariat) review" for evaluating the current state of research and evidence on a topic of concern to fisheries managers. A CSAS review draws on both internal and external expertise, including academic

Table 5. Negative or critical comments about biotelemetry research in response to 1Qa (ratio of respondents mentioning).

	Government employees	Stakeholders	Total
Cost is too high	0.21	0.35	0.28
Tag may affect fish behavior	0.27	0.16	0.22
None mentioned	0.15	0.19	0.17
Tag burden may kill fish	0.15	0.16	0.16
Small sample sizes	0.12	0.03	0.08
Too much interpretation is required	0.12	0.03	0.08
Generalizability problems	0.15	–	0.06
Reliability is uncertain	0.12	–	0.06
Defection rate errors	0.06	–	0.03
Insufficient data on small stocks	0.06	–	0.03
Limitations of the technology in saltwater	0.03	0.03	0.03
Focus on individuals rather than populations is unhelpful	0.03	0.03	0.03
Infrastructure requires continuous maintenance	0.03	–	0.02
Fishers cannot be trusted with data/overexploitation danger	0.03	–	0.02
Receivers in wrong locations	0.03	–	0.02
Too much hype	0.03	–	0.02
Distance of detection is too great	0.03	–	0.02
Cannot tag small fish	0.03	–	0.02
Battery limitations	0.03	–	0.02
Time delay in getting data	–	0.03	0.02
Not familiar enough with biotelemetry to answer	0.21	0.23	0.22

Table 6. Responses to Likert-style opinion statements (2Qa), ratios.

	Agree	Neither agree nor disagree	Disagree	Don't know
1. Biotelemetry provides reliable information about salmon behaviors in the Fraser River				
Government	0.65	0.17	0.12	0
Stakeholder	0.79	0.05	0	0.11
2. Biotelemetry provides reliable information about ecosystems in the Fraser River				
Government	0.27	0.33	0.07	0.33
Stakeholder	0.33	0.33	0.17	0.17
3. The handling involved with inserting or attaching telemetry transmitters onto fish make the data generated by biotelemetry unreliable				
Government	0.14	0.79	0.07	0
Stakeholder	0.06	0.18	0.65	0.12
4. Biotelemetry research is cost-effective				
Government	0.38	0.31	0.06	0.25
Stakeholder	0.40	0.30	0.10	0.20
5. Biotelemetry provides us with information we wouldn't otherwise have from other sources or studies				
Government	1.00	0	0	0
Stakeholder	0.95	0	0	0.05
6. Biotelemetry should play a more central role in salmon management than it currently does				
Government	0.72	0.20	0.08	0
Stakeholder	0.58	0.32	0	0.11
7. The benefits of biotelemetry for salmon management are overstated				
Government	0	0.25	0.56	0.19
Stakeholder	0	0.22	0.61	0.17
8. Biotelemetry data and findings should only be used by managers after being subject to a review process by the Department of Fisheries and Oceans, such as the Canadian Science Advice Secretariat				
Government	0.53	0.18	0.29	0
Stakeholder	0.41	0.12	0.47	0

scientists and stakeholders, and is seen as an important process for institutionally validating or approving the use of new knowledge (Young et al. 2016b). While some respondents viewed this as a necessary step, others did not.

Next, we turn to findings from the stage-two open-ended questions (2Qb–d). Here, we focus on how respondents discussed the evaluative challenges involved in using biotelemetry evidence and data in policy and management, as outlined in Table 1. Specifically, we examine how respondents assessed the epistemological value, practical value, and perceived fit of biotelemetry data with current management practices. Table 7 provides a summary of the ratios of structured codes that emerged in the interviews with government employees and nongovernmental stakeholders, including nonmentions of these codes. This table shows that stakeholders tended to be more polarized in their views—more willing to voice unqualified positive or negative positions on epistemic value, practical value, and fit than government employees, who tended to voice mixed opinions. Both groups focused their commentary on epistemic issues (mentioned by 86% of government employees and 95% of stakeholders), and epistemic value scored higher than the other dimensions (with stakeholders being particularly enthusiastic). The two quotations below illustrate the "high epistemic value" assessment, the first from a government employee and the second from a nongovernmental stakeholder:

> So most salmon, 97%–99% of the young salmon that leave the river, die. And we don't know when they die or where they die or how they die. But we know that the mortality rate is very, very high. So effectively it is more normal to die than it is to live. But the mechanisms are the great unknown. [Biotelemetry] helps us understand about things like adapting to change and how fisheries might affect population characteristics. Not all fish are the same. That's what we're learning. [Biotelemetry] operates on the individual fish level, and up to now, most of our science has been on population or even species level. So it gives you the complexity of behaviour that these fish express, and that's really powerful. (Interview #13; male; fisheries management; response to 2Qb; did not attend workshop).

Table 7. Assessments of epistemic value, practical value, and fit (ratios).

	High/ good	Mixed/ uncertain	Low/ poor	Not mentioned
Government employees				
Epistemic value	0.29	0.57	0.00	0.14
Practical value	0.07	0.50	0.07	0.36
Fit	0.14	0.43	0.07	0.36
Stakeholders				
Epistemic value	0.58	0.21	0.16	0.05
Practical value	0.16	0.21	0.32	0.37
Fit	0.05	0.05	0.53	0.37

> What we need to understand is how each fishery is impacting a [specific] stock of fish. One of the problems we have right now with DFO's management, at least for sockeye, and perhaps chum and pink, are [that] the models they use are based on escapement goals and catch. But they're not based on who catches the fish and where and when. And that's where [bio]telemetry can make fishing fairer, by knowing when that fish enters a fishery's fishing area and when it exits and how long it's been exposed to [a particular] fishery. (Interview #21; male; indigenous fishery; 2Qc; did not attend workshop).

The comments received on biotelemetry's practical value were generally more skeptical, particularly among stakeholders. As with the stage-one interviews, most criticisms focused on cost, as we see in this example:

> [Biotelemetry is a] tremendously expensive way to do something that can be done with just really good catch monitoring and escapement monitoring that you should be doing anyway. So biotelemetry would be an expensive way of doing something when there's another way that is better and more important to have implemented. (Interview #63; male; environmental nongovernmental organization (ENGO) affiliation; 2Qb; did attend workshop).

With respect to fit, we again see a high degree of skepticism among stakeholders, with 53% making unqualified statements about the poor fit between biotelemetry research and current policy and management practices. While government employees are less overtly critical, only 14% gave an unqualified statement that biotelemetry fits well with existing practices. Additionally, we observed a potentially important thematic difference in how government employees and stakeholders talked about fit. One the one hand, some government employees described biotelemetry research as a kind of academic curiosity—a field of research that might be interesting but does not connect well with management priorities. For example,

> The biggest issue in fisheries is measuring abundance. [Biotelemetry] simply doesn't help to estimate total abundance of a population. This really limits its usefulness, in my mind. Stock assessment is our main job, and this doesn't help us. (Interview #50; male; fisheries management; 2Qd; did attend workshop)

> At this stage of the game I think that [bio]telemetry's more of a research tool than a management tool. Some people have suggested that it could be useful for test fisheries, but I think we're a long ways from being able to do that. … I guess I think of it more from the perspective [of] what's the problem we're trying to solve versus how can we use the technology? What are the best tools for solving this problem? How can we best get at this? And I think that [bio]telemetry should probably be on a list of possible tools in many different cases—but it's not now. (Interview #54; female; senior management; 2Qb; did attend workshop)

These comments are consistent with Cash et al.'s (2003) seminal argument that government managers judge new knowledge based in large part on its salience to known problems. In contrast, stakeholders remarked that poor fit has more to do with management failings. According to this logic, biotelemetry research is potentially disruptive—providing evidence that ought to prompt a rethink in policy and management. It is precisely this potential for disruption that prompts authorities to ignore or underplay biotelemetry findings and data. For example,

> Our current management of fisheries is like a supertanker. You've got really detailed and very specific program strategies that are laid out there. And to change that requires a huge amount of effort. Using biotelemetry to its full potential would mean abandoning a lot of those tools and rewriting the strategies that we rely on for fisheries management. That is very unlikely to happen with all of the different interests in play, and with governments that are frankly gun-shy when it comes to innovations. I can't imagine the effort it would take to change direction in this way. (Interview #57; male; ENGO; 2Qd; did attend workshop)

> The problem is that they have no incentive to embrace [biotelemetry research]. There is a lack of desire on the part of many stakeholders and the department [DFO] to get to clear answers from tagging studies, because it may not be advantageous to them. [This] is a cynical view I know—I see it: a fear of too much knowledge could lead to less access for the [commercial fishing] industry and more problems for the department [DFO]. They just don't want to go there. (Interview #40; male; environmental consultant; did attend workshop)

DISCUSSION

Evidence-based management has been lauded as a way of enhancing the role of scientific findings and data in decision making about fisheries (Dicks et al. 2014). However, as demonstrated by the burgeoning literature on KM and KE, the user communities that are involved in decision making employ different criteria for evaluating the value and utility of scientific findings and data than do scientists themselves (Hulme 2015). This observation is not pejorative but reflects the fact that governance involves fundamentally different norms and processes than scientific research (Young et al. 2013). The research reported in this article is an exploratory attempt to map how key participants in co-managing Fraser River Salmon fisheries interpret the value and utility of biotelemetry research findings and data for fisheries management. In this section, we draw on our findings to advance a series of research questions to guide future study on this topic—in this case and others in which new or rapidly evolving sources and types of evidence vie for the attention of decision makers.

Are there associations between demographic variables (gender, age, educational background, career history) and perspectives on the value and utility of biotelemetry? The extended literatures on KM, KE, and KT contain contradictory evidence on the potential role of demographics in how people interpret new types of evidence. Some studies suggest that gender and educational background in particular have an impact on access to knowledge and information, while others find no impact (e.g., Herschel et al. 2001; Durbin 2011). We collected demographic data in our interviews, but the limitations of our sampling in this case preclude direct analysis. Anecdotally, we did not observe demographic patterns in our data. Further hypothesis-driven inquiry is required.

Is there a tipping point in assessments of epistemic and practical value? Is there a point at which epistemic value is deemed high enough to mitigate concerns about practical value (where the epistemic benefits outweigh practical concerns)? Alternatively, is there a point at which practical concerns become severe enough to negate a positive epistemic assessment? Knowledge about such thresholds or tipping points could help the research community and research technology developers identify key strengths and weaknesses in the practical applications of their work.

What explains respondents' generally positive views of biotelemetry in closed-ended questioning and more critical views in open-ended questioning? It is likely that the closed-ended questioning elicited global or generalized views of biotelemetry, which were mostly positive, while the open-ended questioning allowed respondents to articulate the complexities of their views and experiences, which often involved particular critiques. The dynamic between positive associations at the general level and more complex associations when freely discussing specific applications is likely significant for explaining the hesitant uptake of biotelemetry in this and other cases.

Why are stakeholders more polarized in their views of biotelemetry than government employees? Stakeholders expressed more unqualified opinions on biotelemetry—positive and critical—than did government employees. The reasons for this polarization are unclear, but it may have significant consequences for future efforts to integrate biotelemetry in decision making, particularly under co-management arrangements such as this one, where nongovernmental stakeholders actively participate in these processes.

Do government employees and stakeholders have consistently different views of the fit between biotelemetry research and management and the consequences of poor fit? Government employees who saw poor fit as an issue conceptualized it as an external problem of salience—that biotelemetry research does not match up well with management needs. Stakeholders who discussed poor fit, however, saw it as a problem internal to government—that key authorities were unwilling to initiate changes based on findings and data from biotelemetry research. If these different views are consistently held, it suggests a profound disagreement over the potential role that biotelemetry research might play in the future, as either a support to or a disruptor of current decision-making practices.

CONCLUSION

This exploratory study was intended to map the perspectives of government employees and nongovernmental stakeholder on biotelemetry research and its applicability to co-managed Pacific salmon fisheries in Canada's Fraser River. It was also intended as a case study of the difficulties involved in enacting evidence-based management, particularly when there is uncertainty or disagreement about the value and utility of new or rapidly evolving sources of evidence. We have used a KM/KE framework focused on evaluative challenges to frame our investigation and used our findings to advance research questions to anchor future studies. Our findings indicate that biotelemetry findings and evidence are generally viewed favorably in epistemic terms but that concerns about practical value and fit may be hindering timely integration into policy and management. Getting to the bottom of these disagreements is a critical step in understanding the potential and limitations of biotelemetry research for fisheries management.

NOTE

[1]The 11 new respondents from the existing population had declined to participate in the stage-one research but agreed to participate in stage two (eight government employees and three stakeholders). This may have been related to the results of a federal election held in October 2015, which precipitated a change of government in Canada. The previous, Conservative Party of Canada government had placed restrictions on the abilities of certain federal civil servants to speak with researchers, and these restrictions were lifted by the incoming, Liberal Party of Canada government immediately prior to the launch of the stage-two research.

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